

## Exposure dating meets history: Precise $^{10}\text{Be}$ dating of very young surfaces

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Surface exposure dating (SED) of terrestrial surfaces of historical age has been difficult because short exposure times produce only very small amounts of terrestrial cosmogenic nuclides (TCN), which makes it difficult to determine nuclide concentrations with good accuracy. In addition, the low nuclide concentrations found in young samples are more susceptible to perturbation by geomorphic effects such as might be caused by inheritance from prior exposure. Here, we report extensive data from surfaces as young as a century old containing minute amounts of  $^{10}\text{Be}$ . These results imply that precise SED with  $^{10}\text{Be}$  is possible for historical surfaces and that disturbances caused by geomorphic processes can be much less important than previously thought. We present the requisite geochemical and analytical techniques used and elaborate the scientific impact of being able to date very young surfaces on disciplines such as climatology (e.g. dating of Holocene glaciations), tectonics (historical uplift events), geomorphology (frequencies of recent landslides), natural hazards (e.g. earthquake and tsunami dating) and on TCN methods (novel perspectives on production rate calibration).

## Calcite dissolution kinetics in saline waters

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The specific effect of ionic strength on the reaction kinetics of calcite dissolution in intermediate to high ionic strength ( $0.5 \leq I \leq 6.0$ ) solutions applicable to natural waters has been investigated using classical free-drift methods where all other parameters ( $m_{\text{Ca}^{2+}}$ ,  $P_{\text{CO}_2}$ , and  $T$ ) have been held constant. Phosphate-free solutions of both potassium chloride (KCl) and sodium chloride (NaCl), as the dominant ionic strength determining salt, were investigated. Calcium concentrations were held close to constant in all solutions at approximately  $10^{-2}$  molal. Reaction rates were found to vary significantly as a function of ionic strength of the reacting solution, beyond its influence on activity coefficients. This is probably due to the lowering of the activity of water with increasing ionic strength resulting in a decrease in the rate of cation hydration. When modeled with the general rate equation,  $R = k(1 - \Omega)^n$ , first-order kinetics ( $n=1$ ) are sufficient to fit the experimental data. Furthermore, the rate constant ( $k$ ) is directly proportional to the ionic strength of the reacting solution.

The influences of  $P_{\text{CO}_2}$  and  $T$  were also investigated. Dissolution rates increase with either an increase in  $P_{\text{CO}_2}$  or an increase in  $T$ . An Arrhenius plot yields an apparent activation energy for this reaction of approximately  $20 \text{ kJ mol}^{-1}$ . This value for the activation energy falls in the range of activation energies reported for calcite dissolution ( $\sim 8 - \sim 60 \text{ kJ mol}^{-1}$  see reviews in [1]) and agrees relatively well with other recent findings [2, 3].

These results provide a baseline for calcite dissolution in solutions of relatively simple composition from which the influences of other common constituents of natural waters may be evaluated in future studies. Results also have potential applications to the response of the ocean to acidification by fossil fuel  $\text{CO}_2$ , as well as  $\text{CO}_2$  sequestration in subsurface saline waters in calcium carbonate-hosted reservoirs.

[1] Morse & Arvidson (2002) *Earth Sci. Rev.* **58**, 51-84.

[2] Alkattan *et al.* (2002) *Chem. Geol.* **190**, 291-302.

[3] Gledhill & Morse (2006) *GCA* **70**, 5802-5813.