

## Precise $^{10}\text{Be}$ production rate calibration in New Zealand's Southern Alps for the Holocene and Last Glacial Maximum periods

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Recent progress in sample preparation techniques and isotope analysis has greatly enhanced the precision of terrestrial cosmogenic nuclide (TCN) methods, but the application to millennial-scale problems remains hampered by systematic uncertainties associated with the rate at which cosmogenic nuclides accumulate in a rock surface as a function of latitude, altitude, and time.

We present the first high-precision  $^{10}\text{Be}$  production rate for the southern hemisphere derived from an early Holocene debris flow deposit in the central New Zealand Southern Alps. An *in situ* fossil shrubland, crushed by the deposition event, underlies the deposit. Ten radiocarbon dates yield a deposition age of  $9,630 \pm 50$  calendar years B.P.  $^{10}\text{Be}$  concentration data from seven large surface boulders embedded in the surface sediments of the debris flow demonstrate high internal consistency.

$^{10}\text{Be}$  surface-exposure ages from a set of Last Glacial Maximum moraines, that are radiocarbon-dated to be  $\sim 18$  ka old, are most consistent when calculated using the local production rate, indicating that TCN production rates did not change significantly from Last Glacial Maximum to Holocene time in New Zealand. The derived production rate values range from 4.2-4.7 atoms  $\text{g}^{-1} \text{a}^{-1}$  (if scaled to sealevel and high latitude using standard scaling methods). These numbers are in agreement with a recent production-rate calibration study from New England, USA, but are about 11% lower than previous values.

## Reaction-induced fracturing during replacement reactions

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Replacement reactions occur whenever minerals are in contact with fluids with which they are out of equilibrium. The mechanism for such reactions is coupled dissolution of the parent phase and reprecipitation of the product phase(s). A sharp reaction interface moves from the original surface through the parent crystal resulting in a pseudomorphic replacement. The generation of porosity and hence permeability in the product phase is a necessary pre-condition for the reaction to proceed, allowing the fluid to maintain contact with the reaction interface. Recent experimental results on replacement mechanisms in a wide range of mineral systems show that the reaction interfaces are generally sharp, even on a nanoscale. However, in some cases fractures are generated ahead of the reaction interface, allowing fluid infiltration ahead of the advancing planar front. These fractures become sites for new lateral spreading of the reaction. In some experimental systems characteristic fracture patterns are very well developed. Large changes in molar volume of the solid reactants are more likely to initiate fractures. Examples will be given from the pseudomorphic replacement of ilmenite by rutile in which there is a large molar volume decrease, and from the replacement of leucite by analcime in which there is a molar volume increase. In the case of ilmenite – rutile the generation of fractures is shown to be dependent on the fluid composition. Factors such as the differences in crystal structure and molar volume, the amount of porosity generated by the reaction, as well as the relative solubilities of the parent and the product phases in the relevant fluid are likely to play a role in fragmentation.