COSMOGENIC BURIAL DATING OF SHALLOW DEPOSITS – A PRELIMINARY STUDY

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Determining the burial time of quartz-bearing regolith materials using the relative decay of the terrestrial cosmogenic nuclides ^{26}Al and ^{10}Be has proven to be a useful method for dating deeply buried sediments. As will be demonstrated in this presentation, cosmogenic burial dating of shallow deposits is more problematic because post-burial nuclide production by cosmic ray muons cannot be ignored.

The ratio $^{26}Al/^{10}Be$ in quartz is dominated by the cosmogenic nuclide production rate ratio for all but the lowest (< 10 m/Ma) erosion rates where radioactive decay starts to become significant. Because ^{10}Be and ^{26}Al are produced at a constant ratio, independent of absolute production rates, the $^{26}Al/^{10}Be$ ratio in quartz is robust against temporal production rate variations. In a steadily eroding landscape, quartz grains within the soil and sediment contain ^{26}Al and ^{10}Be concentrations in this predictable ratio. If these quartz grains are subsequently buried, for example deep within a sedimentary deposit, and completely shielded from cosmic rays, inherited ^{26}Al and ^{10}Be concentrations diminish by radioactive decay. Because ^{26}Al (radioactive half-life = 0.701 ± 0.02 Ma) decays more rapidly than ^{10}Be (1.51 ± 0.03 Ma), the $^{26}Al/^{10}Be$ ratio decreases exponentially with time. By measuring the ^{10}Be and ^{26}Al concentrations using accelerator mass spectrometry, the current $^{26}Al/^{10}Be$ ratio in the sample can be determined, and the burial time and pre-burial steady-state erosion rate calculated. The method has a useful age range of 0.1 – 5 Ma.

However, in many geomorphological settings the interpretation of cosmogenic burial ages is problematic because of contributions to the post burial cosmogenic nuclide inventory due to insufficient shielding of the sample. ^{26}Al and ^{10}Be are produced in quartz as a result of nuclear interactions between ^{28}Si and ^{16}O, primarily by cosmic ray neucleons (neutrons and protons), but also by slow and fast muons. For quartz on the surface, the production rate due to nucleons dominates. However, muons penetrate much further than nucleons, so that at sufficient depth production by muons becomes dominant. For a clast buried at a depth of 10 m nuclide production due to nucleons has been reduced by a factor of 10^{-7} from its surface value, while production from muons is still about 15% of its surface value (Figure 1).

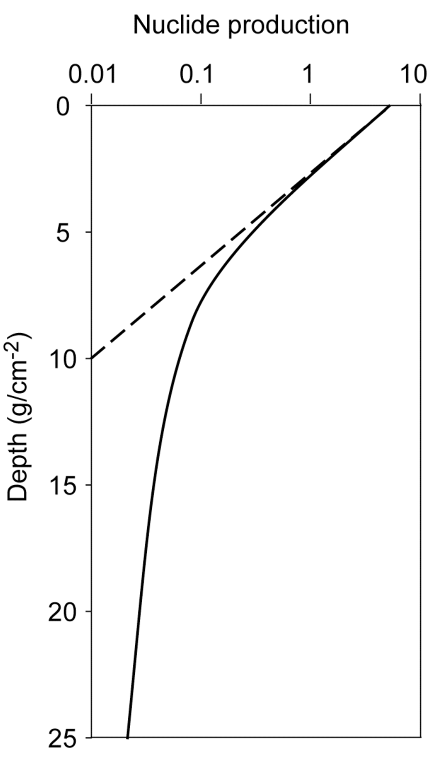

Figure 1: Plot of cosmogenic nuclide production versus depth. The dashed line shows production by nucleons only. The curve shows production with depth for nucleons and muons.

To almost completely shield a sample from cosmic rays it needs to be buried under at least 27 m of rock (density 2.7 gcm^{-3}), or 37 m of sediment (density 2 gcm^{-3}). Ignoring post burial production in situations where cosmic ray shielding is incomplete results in a naïve burial age that underestimates the true burial age (Figure 2).

Until recently, cosmogenic burial dating has only been applied to sediments in caves where the problem of insufficient shielding could be ignored. In this pilot study an attempt was made to determine the deposition age of a shallow (5 m thick) sedimentary unit in South Gippsland. The sediments overlie a sub-horizontal unconformity and are exposed in an actively degrading sea-cliff. Two samples were collected, one at the surface and one at 495 cm depth below the surface. Al and Be were extracted from the samples at the Research School of Earth Sciences. $^{10}Be/^{9}Be$ and $^{26}Al/^{27}Al$ were measured at ANSTO.

The naïve burial age of the sample at depth suggests the sediments were deposited about 860 ± 160 ka. Including post-burial production by muons increases this age to 1,870 ± 350 ka (Figure 2). The burial age calculations assume that the depth of the sample has not changed during its burial history. Hence the calculated burial age may still be an under estimate.

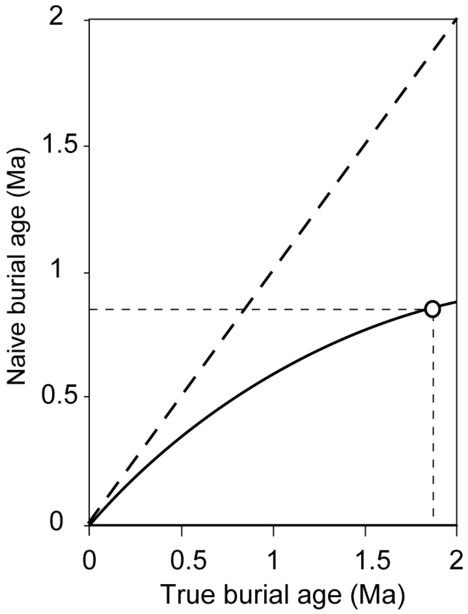

Figure 2: Plot of naïve versus true burial age. The true age includes post burial production by muons, while the naïve age ignores muons The circle represents the sample used in this study buried at 495 cm in overburden with a density of 2 g cm^{-3}. The heavy dashed line gives the line on which the naïve age equals the true age, i.e., the sample has been completely shielded from cosmic rays since burial.

To check if erosion has occurred a surface sample was analysed yielding a $^{26}Al/^{10}Be$ ratio consistent with a steady-state erosion rate of 0.6 ± 0.06 mm ka^{-1} and an exposure age of 2,170 ± 280 ka. As expected, this surface exposure age, although within error, is greater than the burial age, and shows the need to integrate post-burial erosion into the burial age calculations.

These preliminary results of applying the cosmogenic burial dating technique using ^{26}Al and ^{10}Be to samples that are not completely shielded are encouraging and work is continuing to refine the method.

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