Estimating Geologic Age from Cosmogenic Nuclides: An Update

We and others have used in situ–produced cosmogenic nuclides to estimate exposure ages of geomorphic surfaces such as moraines and alluvial fans (1). Every study published to date has calculated exposure ages using temporally averaged production rates commonly acknowledging but then disregarding variations in production rates caused by a variable geomagnetic field.

In order to improve the accuracy of exposure age estimates, we have recently developed a model which allows cosmogenic exposure ages to be calibrated for changing geomagnetic field strength (2). The model incorporates published paleomagnetic field strength records (3), field strength/rigidity relationships (4), and accepted altitude/latitude corrections (5) excluding the contribution of muons to $^{26}$Al and $^{10}$Be production (6). In calibrating, we assume that the current geographic latitude of a site represents its average geomagnetic latitude over the duration of cosmic-ray exposure. The model indicates that production rate response to changing field strength is a nonlinear function of altitude, latitude, and exposure duration. Geomagnetically modulated production rate changes and age inaccuracies are greatest at high altitudes and low latitudes.

Applying our model to existing data conciles three apparently disparate production rate estimates for $^{26}$Al and $^{10}$Be (4, 7), generally increases calculated exposure ages, and appears to confirm recently published data suggesting that a glacial advance in the Rocky Mountains may have occurred during Younger Dryas time (8). To demonstrate how the model changes exposure ages, we have recalculated recently published ages (1) for alluvial fan boulders (9).

Our model and relevant documentation are publicly available (10) and will be updated in the near future to include additional nuclides and paleomagnetic intensity records.

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9. Available from the authors at their e-mail address.
10. Compiled Macintosh code (COSMO-CALIBRATE) by anonymous ftp from beluga.uvm.edu.

Pliocene Extinction of Antarctic Pectinid Mollusks

The report by Edward J. Petuch (1) about a two-stage Pliocene-Pleistocene mass extinction that decreased the diversity of stenothermal molluscan genera in Florida raises the question of where the climatic cooling events propagated. It is accepted that the Northern Hemisphere ice sheets began developing at the end of the Pliocene (2), but their feedback and late Neogene connection with changes in the Antarctic ice sheets (3) have not been resolved. Southern Ocean molluscan extinctions, however, provide evidence that an environmental threshold was reached at the end of the Pliocene around Antarctica. Throughout most of the Cenozoic, pectinid bivalve genera (primarily Chlamys) inhabited coastal environments around the continent as indicated by extensive deposits from the Eocene (4), Oligocene (5), and Pliocene (6). These Paleogene-Neogene pectinids had large (>5 cm) thick shells, which indicate that calcium carbonate precipitation was enhanced for early Cenozoic bivalves as compared to that for subsequent cold-water pelecypods in the Southern Ocean, 70% of which are smaller than 1 cm today (7). Large thick-shelled pectinid bivalves became extinct in the Southern Ocean during the Pliocene, perhaps in conjunction with the spread and first appearance of cold-water Chlamys species in New Zealand (8). After the Pliocene, large wallichin–shelled Adamussium cocklebries emerged into coastal environments from the deep sea around Antarctica (9), where it originated during the Oligocene (10). This endemic meso-specific genus, with its circumpolar distribution (11), has been the only pectinid in Antarctic coastal areas during the Quaternary. The marked diversity decrease among Pectinidae in Antarctic coastal environ-

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