Dating marine sediments by strontium isotope stratigraphy

John W. Farrell*, Steven C. Clemens, and L. Peter Gromet, Department of Geological Sciences, Brown University
*now at Joint Oceanographic Institutions

The concept of time is central to geology. Determining the age of rocks and sediments and creating a time scale allows geologists to sequentially order events in Earth history, according to both relative and absolute age. By knowing age, geologists can also estimate the rates of planetary processes, whether they be nearly instantaneous events, such as catastrophic meteorite impacts, or protracted changes, such as evolution and continental weathering. One way to determine the age of marine deposits, and to correlate them globally, is based on variations in the ratio of two isotopes of strontium, $^{87}Sr/^{86}Sr$. The ratio in seawater, at any point in time, is faithfully preserved in sediments (e.g., microfossils) that form penecontemporaneously. Over the last 40 million years, the seawater ratio has increased because riverine input of the heavier isotope ^{87}Sr has exceeded the contribution of 86Sr from mid-ocean ridges. This observation is based on mass spectrometer measurements of the $^{87}Sr/^{86}Sr$ in independently-dated (e.g., by magnetostratigraphy) marine sedimentary sequences. We constructed a reference curve of seawater $^{87}Sr/^{86}Sr$ variation through the past 7 m.y. based on planktonic foraminifer samples from ODP Site 758 in the Indian Ocean [*Clemens et al.,* 1993; *Farrell et al.,* 1995] (see figure), and calibrated it to numeric age based on the site's magnetostratigraphy. This curve provides a way to date strontium-bearing marine deposits (often carbonates) when other means are untenable. For example, scientists trying to unravel the history of global sea level change by studying mid-ocean atolls and continental margin sediments use this curve for chronostratigraphy. Paleoclimatologists studying rapid climate change recorded by geochemical variations in the annual bands in corals heads that grew in short, specific intervals in the Pliocene, use the curve to anchor these floating chronologies in that epoch. Others, studying climate evolution in the Antarctic use the curve to unravel complex stratigraphic relationships. In short, if you've got the $^{87}Sr/^{86}Sr$, you've got the time.

References:
Clemens, S.C., J.W. Farrell, and L.P. Gromet, Synchronous changes in seawater strontium isotope composition and global climate, *Nature, 363,* 607-610, 1993.
Farrell, J.W., S. Clemens, L.P. Gromet. Improved chronostratigraphic reference curve of Late Neogene seawater $^{87}Sr/^{86}Sr$, *Geology, 23,* 403-406, 1995.

Plot of $^{87}Sr/^{86}Sr$ vs. age at Site 758. Line segments connect mean values of individual analyses from each sample. Upper and lower confidence intervals (±19 x 10-6) on the fifth-order polynomial curve enclose 97% of data. Polynomial equation can be solved iteratively to estimate age from $^{87}Sr/^{86}Sr$. Factors for polynomial terms (e.g., M0, M1, M2) are provided for the Shackleton et al. [1995] time scale used here. Normal events in magnetochronology from Site 758 are labeled above. Strontium isotope ratios are reported relative to a $^{87}Sr/^{86}Sr$ value for SRM-987 of 0.710257. See Farrell et al. [1995] for details and references cited.