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Review

A complete and easily accessible means of calculating surface exposure ages or erosion rates from ^{10}Be and ^{26}Al measurements

Greg Balco[a,*,1], John O. Stone[a], Nathaniel A. Lifton[b], Tibor J. Dunai[c]

[a]Quaternary Research Center and Department of Earth and Space Sciences, University of Washington, Mail Stop 351310, Seattle, WA 98195-1310, USA
[b]Geosciences Department, University of Arizona, Tucson, AZ 85721, USA
[c]University of Edinburgh, School of GeoSciences, Institute of Geography, Drummond Street, Edinburgh EH8 9XP, UK

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Abstract

We codify previously published means of calculating exposure ages and erosion rates from ^{10}Be and ^{26}Al concentrations in rock surfaces, and present a single complete and straightforward method that reflects currently accepted practices and is consistent with existing production rate calibration measurements. It is intended to enable geoscientists, who wish to use cosmogenic-nuclide exposure age or erosion rate measurements in their work to: (a) calculate exposure ages and erosion rates; (b) compare previously published exposure ages or erosion rate measurements on a common basis; (c) evaluate the sensitivity of their results to differences between published production rate scaling schemes. The method is available online at http://hess.ess.washington.edu.

Keywords: Cosmogenic-nuclide geochronology; Beryllium-10; Aluminum-26; Exposure dating; Erosion rate measurements

Contents

*Corresponding author. Tel.: 1 206 221 2579.
E-mail address: balcs@u.washington.edu (G. Balco).
[1]Present address: Berkeley Geochronology Center, 2455 Ridge Road, Berkeley, CA 94709, USA.

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1. Introduction

In this paper we describe a complete method for calculating surface exposure ages and erosion rates from measurements of the cosmic-ray-produced radionuclides ^{10}Be and ^{26}Al in surface rock samples. It is available online via any web browser at the following URL: http://hess.ess.washington.edu/.

This method codifies previously published procedures for carrying out the various parts of the calculation. The importance of this contribution is not that we present significant improvements over previous calculation schemes, but that we have combined them with all published production rate calibration measurements in an internally consistent fashion, and made the resulting method easily accessible via an online system. This system is intended to enable geoscientists who seek to use cosmogenic-nuclide exposure ages or erosion rate measurements in their work to: (a) calculate exposure ages and erosion rates; (b) compare previously published exposure ages or erosion rate measurements on a common basis; (c) evaluate the sensitivity of their results to differences between published production rate scaling schemes. This contribution is part of the CRONUS-Earth project, an initiative funded by the U.S. National Science Foundation whose goal is to improve Earth science applications of cosmogenic-nuclide geochemistry. It also reflects collaboration with the CRONUS-EU project, an initiative with similar goals funded by the European Union.

This project is motivated in the first place by the fact that the number of applications of cosmogenic-nuclide measurements, as well as the number of papers published on the subject, is growing rapidly. These studies are no longer being carried out exclusively by specialists in cosmogenic-nuclide geochemistry, but by Earth scientists who wish to apply cosmogenic-nuclide methods in a wide variety of studies. These methods are still in active development, so a variety of data-reduction procedures, reference nuclide production rates, and production rate scaling schemes exist in the literature. Many of these schemes are at least in part inconsistent with each other, and yield different results for the same measurements of nuclide concentrations. The effect of this has been that published exposure age and erosion rate data sets lack a common basis for comparison. For example, even without regard to the absolute accuracy of any of the exposure age calculation methods relative to the true calendar year time scale, the variety of inconsistent methods makes it difficult to directly compare the results of any two exposure-dating studies. This, in turn, is a serious obstacle for paleoclimate research or any other broader research task which relies on synthesizing the results of many studies. We seek to address this situation by providing an easily accessible means of comparing new and previously published exposure ages or erosion rates in a consistent fashion.

The primary goal of this system is to provide an internally consistent result that reflects commonly accepted practices. At present, it is impossible to evaluate whether or not it will always yield the 'right answer,' that is, for example, the correct calendar age for exposure-dating samples of all locations and ages. There are still many uncertainties in the present understanding of nuclide production rates and scaling factors, and there are certain to be future improvements in understanding the physics behind production rate calculations as well as in the quality and coverage of production rate calibration measurements. This means that the exposure age that we infer from a particular measurement of nuclide concentration, at a particular location, will change as production rate calculation methods improve. In nearly all cases, the exposure age calculated with this system from a published ^{10}Be or ^{26}Al measurement will differ from the age reported in the original paper. Future versions of this system that reflect improved understanding of nuclide production rates will, in turn, yield different results from the present version. Our goal is to ensure that, at any time, it will be possible to recalculate old and new measurements with a common method.

The second goal of this project is to standardize the entire array of published production rate scaling schemes to a common set of calibration measurements. Papers reporting cosmogenic-nuclide measurements commonly parameterize nuclide production rates by a reference production rate at sea level and high latitude. This hides the important fact that a stated reference production does