Available online at www.sciencedirect.com

SCIENCE DIRECT®

Earth and Planetary Science Letters 230 (2005) 163–175

EPSL

www.elsevier.com/locate/epsl

Cosmogenic ^{3}He concentrations in ancient flood deposits from the Coombs Hills, northern Dry Valleys, East Antarctica: interpreting exposure ages and erosion rates

H.R. Margerison[a,b,*], W.M. Phillips[a], F.M. Stuart[b], D.E. Sugden[a]

[a]School of GeoSciences, University of Edinburgh, Edinburgh, EH8 9XP, UK
[b]Isotope Geosciences Unit, Scottish Universities Environmental Research Centre, East Kilbride, G75 0QF, UK

Received 18 August 2004; received in revised form 26 October 2004; accepted 11 November 2004
Available online 28 December 2004
Editor: K. Farley

Abstract

In situ produced cosmogenic ^{3}He analyses provide independent support for the model of a stable, hyper-arid polar climate persisting in East Antarctica since the mid-Miocene and provide quantitative constraints on long-term rates of erosion within the Dry Valleys. In the Coombs Hills area, a series of cobble-size boulders form mega-ripples with wavelengths of approximately 50 m. Their topographic position and association with features characteristic of scabland, such as stripped, corrugated bedrock surfaces, indicate the boulders were deposited by subglacial floodwaters. Such outburst flooding could only have occurred during overriding of the northern Dry Valleys by a greatly expanded East Antarctic ice sheet. Timing of the overriding episode has been previously assigned to 14.8 to 13.6 Ma by correlation with volcanic ash deposits dated by ^{40}Ar/^{39}Ar in the Asgard Range of the Dry Valleys. Cosmogenic ^{3}He concentrations in clinopyroxene from Ferrar dolerite boulders are consistent with 8.6 to 10.4 Ma exposure, calculated using scaling factors appropriate for Antarctica and assuming zero erosion. These are among the oldest surface exposure dates yet measured on Earth, but are not however consistent with the ^{40}Ar/^{39}Ar chronology used to define the age of the landscape due to unconstrained levels of erosion. Erosion rates of 0.03–0.06 m Ma^{-1} are necessary to have produced the measured boulder exposure age if they were deposited at 14.8 Ma. These are less than half the steady-state erosion rate derived from cosmogenic ^{3}He in the nearby bedrock surfaces (0.17 m Ma−1) and testify to the extreme stability of the landscape.
© 2004 Elsevier B.V. All rights reserved.

Keywords: stable cosmogenic isotopes ^{3}He; exposure age; erosion rates; paleoclimatology; landscape evolution; Dry Valleys

* Corresponding author. School of GeoSciences, University of Edinburgh, Edinburgh, EH8 9XP, UK. Tel.: +44 131 650 9172; fax: +44 131 650 2524.

E-mail address: hrm@geo.ed.ac.uk (H.R. Margerison).

0012-821X/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsl.2004.11.007

1. Introduction

The extensive ice-free areas of the Dry Valleys contain the longest terrestrial record of past glacial fluctuations on earth and provide the key to understanding climate change in East Antarctica (Fig. 1). The preservation of in situ, mid-Miocene volcanic ashes within glacial sediments suggests remarkable stability of the Dry Valleys landscape and limited slope evolution for millions of years [1,2]. Well-preserved glass shards with intact vesicles indicate that the ashes have been undisturbed and unweathered since deposition by airfall [3,4]. $^{40}Ar/^{39}Ar$ ages of ash preserved on steep valley slopes indicate minimal slope evolution in at least 11.3 Ma in the Quatermain Mountains and 13.6 Ma in the Asgard Range. The interpretation is that major landforms, such as rectilinear slopes and overlying colluvium, are relict features. This hypothesis is supported by additional evidence, such as the preservation of small Miocene cinder cones, which reinforces the view that remarkably low rates of denudation are in operation [5].

These findings form the basis of the hypothesis proposing the long-term existence of a cold, hyper-arid polar climate and the associated geomorphic stability of the area since the mid-Miocene. Many of the main landscape features of the Dry Valleys area are argued to have originated in a fluvial environment before or during the growth stages of the East Antarctic Ice Sheet [6]. Correlation with nearby offshore cores at Cape Roberts suggests that much of the landscape erosion occurred during the Oligocene and early Miocene [7]. At this time, the main valleys were initiated. This interpretation is consistent with microfossils and sediments from cores sampled by the Dry Valleys Drilling Project (DVDP) in Taylor and Wright Valley, which indicate that the major valleys had formed by the late Miocene [8,9]. However, some of the evidence used in support of this hypothesis is not widely accepted. For example, buried ice in Beacon Valley, thought to be over 8.1 Ma [10,11], and the fluvial origin of many geomorphic features are disputed [12].

The alternative view suggests that the landscape of the Dry Valleys was largely formed during the Pliocene and Pleistocene periods. Marine diatoms of Pliocene age are found within the high-altitude glacial deposit known as the Sirius Group [13]. The diatoms were believed to be in situ, leading to the theory that marine basins existed within Antarctica during the warmer Pliocene period. Subsequent ice sheet growth incorporated the diatoms into a glacial till which was later tectonically uplifted to the present high-altitude sites [13,14]. This scenario implies severe deglaciation of the East Antarctic ice sheet, followed by a post-Pliocene phase of mountain uplift and associated geomorphic activity. The suggestion that aeolian processes may have incorporated the diatoms into the high-altitude glacial deposit has cast doubt on the basis of this alternative hypothesis [15–18].

The current hyper-arid, polar climate of the Dry Valleys of East Antarctica favours slow rates of weathering and erosion [19] providing a favourable area in which to examine and develop the use of cosmogenic isotope dating techniques. If in situ cosmogenic isotope measurements are to contribute significantly to the understanding of the timing and rates of the geomorphic evolution of the Dry Valleys landscape, it is essential that the technique is robust. Here, we address the issues surrounding the accuracy that can be achieved when applying cosmogenic isotopes over time periods of millions of years. We use cosmogenic ^{3}He in pyroxene to examine the long-term exposure of a group of boulders interpreted as remnants of a glacial outburst flood [7]. Cosmogenic ^{3}He concentrations in nearby bedrock surfaces provide an estimate of the rate of erosion of Ferrar dolerite within the Dry Valleys. By placing limits on the rates of down-wearing, we emphasise the need to apply well-constrained erosion rate corrections to cosmogenic surface exposure estimates. Accurate long-term chronologies can then be established with cosmogenic isotope measurements providing a quantitative geomorphic tool with which to analyse the long-term climatic history of the Dry Valleys.

2. In situ cosmogenic isotope studies in the Dry Valleys

Within the Dry Valleys, cosmogenic isotope data have provided estimates of Quaternary ice fluctuations [20,21], identified some of the oldest surfaces on earth [22,23], provided erosion rate estimates [19,24–26], placed limits on the rates of surface uplift in the Transantarctic Mountains [25,27], and provided constraints on models of patterned ground formation [28].

Download English Version:

https://daneshyari.com/en/article/9522535

Download Persian Version:

https://daneshyari.com/article/9522535

Daneshyari.com