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Determination of denudation rates by the measurement of meteoric ^{10}Be in Guadiana river sediment samples (Spain) by low-energy AMS

S. Padilla[a,b,*], J.M. López-Gutiérrez[a,c], D.M.R. Sampath[d], T. Boski[d], J.M. Nieto[e], M. García-León[a,f]

[a] Centro Nacional de Aceleradores (Universidad de Sevilla, Consejo Superior de Investigaciones Científicas, Junta de Andalucía), Thomas Alva Edison 7, 41092 Seville, Spain
[b] Laboratorio Nacional de Espectrometría de Masas con Acelerador (LEMA), Dpto. Física Nuclear y Aplicaciones de la Radiación, Instituto de Física, Universidad Nacional Autónoma de México (UNAM), Apartado Postal 20-364, 01000 Ciudad de México, Mexico
[c] Dpto. de Física Aplicada I, Escuela Universitaria Politécnica, Universidad de Sevilla, Virgen de Africa 7, 41011 Seville, Spain
[d] CIMA, Centre for Marine and Environmental Research, University of Algarve, 8005-139 Faro, Portugal
[e] Dpto. Geología, Facultad de Ciencias Experimentales, Universidad de Huelva, Av. 3 de Marzo, S/N, 21071 Huelva, Spain
[f] Dpto. de Física Atómica Molecular y Nuclear, Universidad de Sevilla, Reina Mercedes s/n, 41012 Seville, Spain

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ABSTRACT

The concentration of meteoric ^{10}Be in estuarine sediment samples has been measured by Spanish Accelerator for Radionuclides Analysis (SARA) at CNA and subsequently used to assess the denudation rate in Guadiana river basin together with the sediment budget method, on both sides of the frontier between Spain and Portugal. The two methods yielded coincident results. The estimation by the ^{10}Be method gave the denudation rate of $(0.76 \pm 0.10) \times 10^{-2}$ cm/y. After correcting for an approximate 80% attenuation of the sediment discharge into the ocean, caused by the river dams, the sediment budget method yielded the rate of $(0.77 \pm 0.17) \times 10^{-2}$ cm/y.

1. Introduction

Erosion and sedimentation responses to the changes occurring in hydrographical basins or in fluvial channels are of broad scientific and practical interest in agriculture, forestry and territorial management in general. There is a need to predict how the land use would affect the erosion and sedimentation as well as the relative importance of the different sediment sources to prioritize measures of erosion control. It is necessary to anticipate the location of sediment deposition, the storage duration and their re-mobilisation, therefore, a precise estimation of denudation rate can be used to estimate the temporal variability of the sediment retention rate within the upstream of the estuary limits.

In the recent years, great progress in several areas was achieved thanks to the application of meteoric ^{10}Be in terms of the measurements of soil profile ages, denudation rates, production models in the atmosphere, the influence of the weather on its production or solar activity (Field et al., 2006; Heikkilä, 2007).^{10}Be is a radionuclide which may be found in water, soil and rocks in very low concentration such as 10^7 atm/g in sediments, 10^7 atm/m^3 in aerosol filters, 10^5 atm/L in rain waters or 10^4 atm/gin ice cores (von Blanckenburg, 2005; von Blanckenburg et al., 1996). It is produced by interaction of cosmic rays with atmospheric ^{16}O and ^{14}N (meteoric) and ^{16}O within mineral lattices at the Earth's surface (in situ) through spallation reactions (Fig. 1a). Meteoric ^{10}Be is primarily produced in the lower Stratosphere and upper Troposphere. The average residence time in the atmosphere ranges between two weeks and several years, depending on the origin layer (Troposphere or Stratosphere). The production, Stratosphere-Troposphere exchanges, as well as transport and tropospheric deposition, modulate the fluxes to the Earth surface, and influence the ^{10}Be concentrations at the surface (Graly et al., 2010). ^{10}Be attached to aerosols particles in the atmosphere is carried to the lower Troposphere and deposited at the Earth surface, either by rain, in soluble form or by dry deposition (Field et al., 2005). Once on the surface, the high reactivity of hydrolized ^{10}Be at most natural pH levels ensures that meteoric ^{10}Be is readily adsorbed to particles in the upper meters of soil profiles (von Blanckenburg et al., 2012), serving as a tracer of the path taken by soil particles. Sedimentary systems can record the long-term deposition of meteoric ^{10}Be even after complex pathways due to the chemical leaching, dissolution by rain, erosion or mixing in soils. Hence meteoric ^{10}Be has a great potential to be used as a geochemical tracer for denudation rate (Ebert et al., 2012; Masarik and Beer, 1999).

The denudation rate in a drainage basin is also very useful for the

* Corresponding author. Laboratorio Nacional de Espectrometría de Masas con Acelerador (LEMA), Dpto. Física Nuclear y Aplicaciones de la Radiación, Instituto de Física, Universidad Nacional Autónoma de México (UNAM), Apartado Postal 20-364, 01000 Ciudad de México, Mexico. Tel.: +5556225159; fax: +55 56225009.
E-mail address: spadilla@fisica.unam.mx (S. Padilla).

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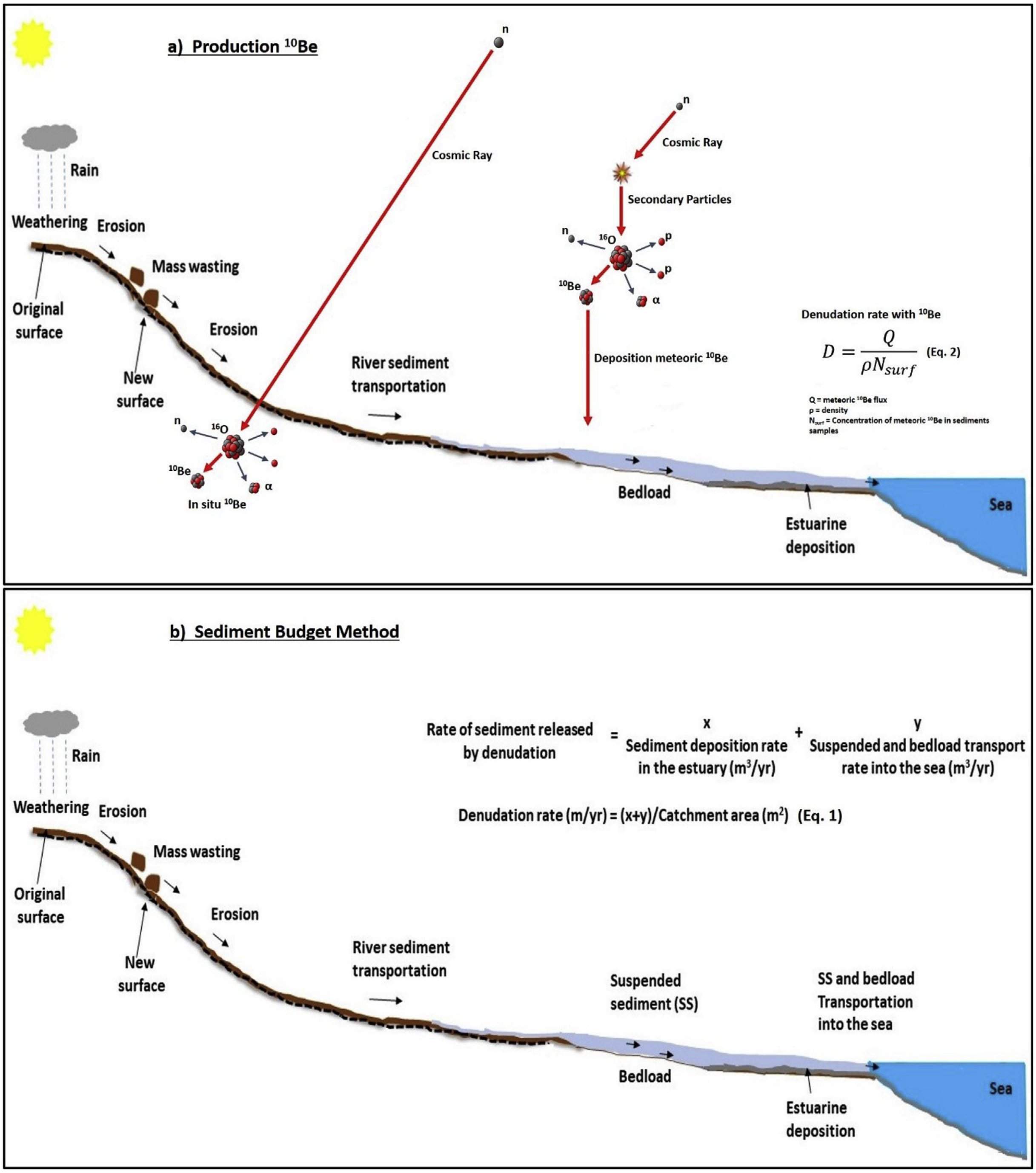

Fig. 1. a) Diagram of the production of both meteoric ^{10}Be in atmosphere and in situ ^{10}Be at the Earth's surface. The assessment of the denudation rate is calculated with the variables in Eq (2). **b)** Schematic diagram of a soil profile and definitions of variables for the assessment of the denudation rate by sediment budget method by Eq. (1).

study of the sediment filling models of estuarine systems. It refers to the total mass of solids removed from the shallow depth at Earth surface. It is the result of the combined effect of the physical (erosion) and chemical (weathering) processes. Since cosmogenic radionuclides collected into the material are continuously transferred to the ground surface, the total denudation rate (cm/y) can be measured. The estimations of the rate of the cosmogenic radionuclide transfer into soils reflect the denudation rate of fluvial geographical accidents, which are subject to geological processes such as weathering, mass movements and surface and fluvial flux. Those geological processes can be measured in time scales ranging from 10^3 to 10^7 years (von Blanckenburg, 2005; Willenbring and von Blanckenburg, 2010). The advantages of the meteroric ^{10}Be over the insitu-produced nuclides consists in the higher concentrations of the former, requiring smaller sample amounts, its applicability to quartz-free lithologies, and the possibility to determine denudation rate time series in fine-grained fluvial or estuarine sediments. The interference of ^{10}Be produced in situ in these depositional settings may be easily eliminated by chemical stripping from the grain surface (meteoric) and dissolution of the mineral (in situ produced) (Willenbring and von Blanckenburg, 2010).

The sediment budget method for a river catchment has to take into account all the sources and deposition of the sediment as well as its transportation from the origin to its evacuation from a drainage basin, usually called the yield (Wasson, 2003). In its complete form, the