Earth and Planetary Science Letters 425 (2015) 154–167

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Spatial variability of ^{10}Be-derived erosion rates across the southern Peninsular Indian escarpment: A key to landscape evolution across passive margins

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ARTICLE INFO

Article history:
Received 14 January 2015
Received in revised form 25 May 2015
Accepted 28 May 2015
Available online 11 June 2015
Editor: A. Yin

Keywords:
cosmogenic nuclides
catchment-averaged erosion rate
local erosion rate
relief
southern Peninsular India
escarpment

ABSTRACT

The persistence of significant topography in ancient, tectonically inactive orogenic belts remains one of the outstanding questions in geomorphology. In southern Peninsular India, the impressive topographic relief of the Western Ghat Mountains in tectonic quiescence since at least ca. 65 Ma has raised important questions concerning the long-term mechanism of topographic evolution. Quantifying the distribution of erosion in space and time is critical to understanding landscape evolution. Although the long-term erosion rates are reasonably well known, the short-term erosion rates and the relative importance of factors controlling erosion in southern Peninsular India are less well constrained. We present a new suite of catchment-averaged and local erosion rates using *in situ* produced ^{10}Be concentrations in river sediments and exposed bedrock samples in southern Peninsular India. Catchment-averaged erosion rates vary from 9.6 ± 0.8 m Ma^{-1} in the highlands to 114.3 ± 13.8 m Ma^{-1} on the escarpment side. Bedrock erosion rates range from 2.4 ± 0.2 m Ma^{-1} in the ridge-top to 143.4 ± 25.4 m Ma^{-1} in active channel beds of the highlands. Catchment-averaged erosion rates derived from the across-escarpment, westward-draining catchments are significantly higher than those derived from the eastward-draining, over highland catchments. The difference indicates that long-term down-wearing of the highland proceeds at lower rates than in the escarpment zones. Catchment-averaged erosion rates are moderately correlated with mean hillslope angles and local relief whereas they are strongly correlated with catchment-averaged channel steepness index. This suggests that topographic steepness is the major control on the spatial variability of erosion while strong rainfall gradient is of minor importance in this area. ^{10}Be-derived average erosion rates in highlands are consistent with previous long-term erosion rate estimated from thermochronometry. These results collectively point to large-scale steady-state topography, only decaying slowly with time. Steady state likely reflects the balance between erosion and isostatically driven uplift of the southern Peninsular India.

1. Introduction

The Earth's topography results from the competition between tectonic and erosive forces (e.g., Molnar and England, 1990; Avouac and Burov, 1996; Willett, 1999). Although tectonics and erosion act in opposing directions, there may be feedbacks that couple the two (Willett and Brandon, 2002). Despite progress in understanding tectonics–topography–erosion couplings, the persistence of elevated topography in many post-orogenic regions, such as passive continental margins remains a geologic paradox (Matmon et al., 2003b; Egholm et al., 2013; Scharf et al., 2013). Theoretical concepts suggest that mountain ranges should disappear within ∼100 Ma (e.g., Tucker and Slingerland, 1994; Beaumont et al., 2000). However, the long-term preservation of high mountains and relief results either from changes in the erosional regime of the landscape during the post-orogenic phase (Egholm et al., 2013), or because relief is sustained by erosion and isostasy for much longer periods than previously assumed (e.g., Matmon et al., 2003a; Braun et al., 2014).

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http://dx.doi.org/10.1016/j.epsl.2015.05.050

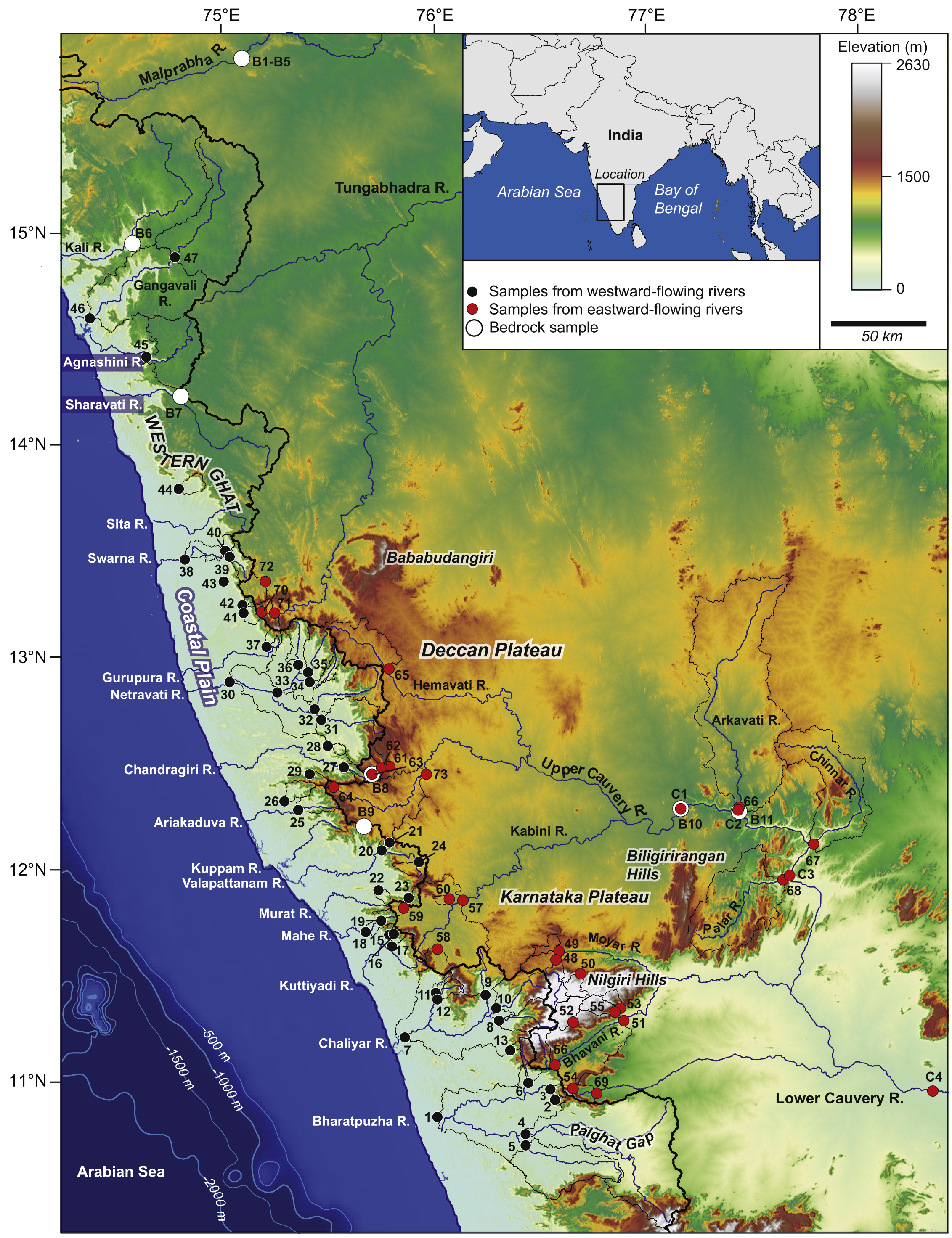

Fig. 1. SRTM 90-m digital elevation model (Jarvis et al., 2008) showing the topographic overview and river catchments across southern Peninsular Indian escarpment (location in inset). Bathymetric contours based on ETOPO1 digital elevation model (http://www.ngdc.noaa.gov/). Blue lines = main river channels. Black polygons = sampled catchments. Thick black line = major water divide. Sampling locations shown with circles, color-coded for sample type: white = bedrock; black = river sediment from westward-flowing (across the escarpment) catchment; red = river sediment from eastward-flowing (over the upland plateau) catchment. Numbers and letter–number combinations refer to sample ID used in the main text (Table S1 and Table S2).

The western seaboard of Peninsular India has been a passive continental margin for ∼65 Ma (Chatterjee et al., 2013); yet the Western Ghat Mountains (WGM) retains a high relief, with the highest elevation reaching over ∼2600 m a.s.l. (Fig. 1). Like for other passive margins, the history and persistence of this topography is a matter of debate (Gunnell and Radhakrishna, 2001 and references therein), as to whether the high topography is in a state of quasi-equilibrium, maintained isostatically by slow decay over geological time, or whether it has been rejuvenated during the Neogene (Bonnet et al., 2014). The discovery of buckle folds in the Indian Ocean lithosphere (Bull and Scrutton, 1990, 1992; Beekman et al., 1996) has also led to hypothesize that large-scale buckling of the Indian continental lithosphere may be a consequence of India–Eurasia collision (Müller et al., 2014), with high topography