Using meteoric 10Be to track soil erosion and transport within a forested watershed, Susquehanna Shale Hills Critical Zone Observatory, PA

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Abstract

This study presents new meteoric 10Be data from 30 hillslope and bedrock core samples, data which allow for estimation of soil residence times and inferred rates of soil erosion in the Susquehanna Shale Hills Critical Zone Observatory (CZO). The Shale Hills CZO is located in the temperate climate of central Pennsylvania and comprises a first-order watershed developed on a Fe-rich, organic-poor, Silurian-aged shale. Two major perturbations to the landscape have occurred at the Shale Hills CZO in the geologically recent past, including significant periglacial activity until the retreat of the Laurentide ice sheet (~15 ka) and deforestation during early colonial land-use. Meteoric 10Be depth profiles were measured from bulk soil samples (n=16) collected at three locations along a planar hill-slope on the southern ridge of the catchment, representing the ridge top, mid- and foot-slope; samples were amalgamated over 10 cm depth intervals to the base of the soil (depth to hand auger refusal). Soil and rock chip samples (n=14) were also collected and analyzed along a 24 m deep core drilled into the northern ridge top. Meteoric 10Be was extracted from each sample using a total fusion method and analyzed at Lawrence Livermore National Laboratory. All meteoric 10Be concentration profiles show a declining trend with depth, with >50% of the 10Be held in the upper-most decimeters of the soil. Meteoric 10Be inventories are high at the mid- and foot-slope sites, at 3.71 ± 0.02 x 10^10 at/cm^2 and 3.69 ± 0.02 x 10^10 at/cm^2, respectively. The ridge top site has a lower inventory of 1.90 ± 0.01 x 10^10 at/cm^2, while the meteoric 10Be inventory for soil at the deep core site (also on a ridge top) is 4.09 ± 0.07 x 10^9 at/cm^2. Bedrock samples from the core contain at least an additional 1.07 x 10^10 at/cm^2 10Be. If we assume that soils sampled at the Shale Hills CZO formed in place, and that 10Be delivery has been constant over time (1.8 x 10^6 atoms/cm^2 x y) and balanced by removal via erosional processes, then the 10Be inventories reflect soil residence times of ≥10,600 years for the southern ridge top, ≥20,600 years for the mid- and foot-slope sites, and ≥2,280 years for the

northern ridge. Low 10Be inventories in soils on the north ridge could reflect recent soil loss or 10Be penetration to bedrock via fracture-flow pathways. We suggest that soils along the ridge tops have largely developed since the last glacial maximum, while soils at lower elevations may include material present during periglacial activity. Discrepancies exist between residence times presented here (duration of 10Be inventory accumulation in the soil profile) and those calculated using uranium series disequilibrium (time since initiation of chemical weathering), suggesting non-steady state conditions. This study, in concert with those aimed at determining rates of bedrock weathering and regolith production in our watershed, contributes preliminary data toward understanding whether the landscape at the Shale Hills CZO is currently at steady-state, or if it is still responding to the recent perturbations of periglacial influence and deforestation.

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