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New constraints on the late Cenozoic incision history of the New River, Virginia

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Abstract

The New River crosses three physiogeologic provinces of the ancient, tectonically quiescent Appalachian orogen and is ideally situated to record variability in fluvial erosion rates over the late Cenozoic. Active erosion features on resistant bedrock that floors the river at prominent knickpoints demonstrate that the river is currently incising toward base level. However, thick sequences of alluvial fill and fluvial terraces cut into this fill record an incision history for the river that includes several periods of stalled downcutting and aggradation. We used cosmogenic ^{10}Be exposure dating, aided by mapping and sedimentological examination of terrace deposits, to constrain the timing of events in this history. ^{10}Be concentration depth profiles were used to help account for variables such as cosmogenic inheritance and terrace bioturbation. Fill-cut and strath terraces at elevations 10, 20, and 50 m above the modern river yield model cosmogenic exposure ages of 130, ~600, and 600–950 ka, respectively, but uncertainties on these ages are not well constrained. These results provide the first direct constraint on the history of alluvial aggradation and incision events recorded by New River terrace deposits. The exposure ages yield a long-term average incision rate of 43 m/my, which is comparable to rates measured elsewhere in the Appalachians. During specific intervals over the last 1 Ma, however, the New River's incision rate reached ~100 m/my. Modern erosion rates on bedrock at a prominent knickpoint are between ~28 and ~87 m/my, in good agreement with rates calculated between terrace abandonment events and significantly faster than ~2 m/my rates of surface erosion from ancient terrace remnants. Fluctuations between aggradation and rapid incision operate on timescales of 10^4– 10^5 year, similar to those of late Cenozoic climate variations, though uncertainties in model ages preclude direct correlation of these fluctuations to specific climate change events. These second-order fluctuations appear within a longer-term signal of dominant aggradation (until ~2 Ma) followed by dominant incision. A similar signal is observed on other Appalachian rivers and may be the result of sediment supply fluctuations driven by the increased frequency of climate changes in the late Cenozoic.

Keywords: Appalachians; Fluvial terraces; Cosmogenic dating; Landscape evolution

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1. Introduction

Even after more than a century of geomorphic study, the spatial and temporal patterns of erosion and exhumation in the Appalachian Mountains are not known in detail. Many studies suggest that erosion from this tectonically inactive landscape averages 20–40 m/my over million-year timescales (Hack, 1965; Pavich et al., 1985; Pavich, 1989; Roden, 1991; Boettcher and Milliken, 1994; Pazzaglia and Gardner, 1994; Matmon et al., 2003; Spotila et al., 2004). However, the shorter-term variability of erosion rates is less well documented. The ubiquity of fluvial terraces throughout the central Appalachians demonstrates variability in the erosional efficacy of river networks through time (Houser, 1980; Colman, 1983; Bartholomew and Mills, 1991; Howard et al., 1995; Mills, 2000; Granger et al., 2001). Since major rivers are the only outlets for sediment removed from the tectonically quiescent landscape, the erosional efficacy of these rivers applies a dominant control over rates of relief production and erosion from the rest of the landscape (e.g., Hack, 1960; Montgomery et al., 2001).

The capacity for erosion and sediment transport of a major river is affected by complex interactions between a large number of external influences, such as climate, bedrock lithology and structure, tectonic activity, sediment supply as determined by rates of hillslope erosion, global base level change, and regional drainage reorganization (e.g., Bull, 1979; Blum and Törnqvist, 2000). Climate variability is a likely driver of many of these forcing factors that affect the behavior of fluvial systems through time (e.g., Zhang et al., 2001). Abundant fluvial deposits throughout the Appalachians provide a record of river downcutting that can be compared to records of climate variability if the duration and detail of the downcutting record can be quantified. For example, thick alluvial deposits abandoned high above modern river levels imply a period of fluvial aggradation followed by subsequent incision (e.g., Granger et al., 2001), but the timing of deposition of this alluvium is not well constrained. Thus, it is unknown whether changes in fluvial regime between aggradation and incision are related to climate change events such as the most recent onset of glacial cyclicity ca. 2–4 Ma (e.g., Shackleton et al., 1984; Maslin et al., 1996).

Many workers have attempted to assign ages to Appalachian river deposits based on relative age indicators, such as degrees of soil development and fluvial terrace morphology (e.g., Colman, 1983; Mills and Wagner, 1985). However, until the past decade, no absolute age data were available by which to calibrate these relative indicators, as most deposits are well beyond the age range of radiocarbon dating techniques. Recent advances in cosmogenic radionuclide (CRN) dating, especially ^{10}Be and ^{26}Al exposure dating, allow ages to be assigned to formerly undatable river deposits such as ancient alluvial terraces (e.g., Hancock et al., 1999; Perg et al., 2001). Even with these newer techniques, exposure dating of old surfaces is challenging. In the humid temperate climate of the Appalachians, numerous weathering and erosion mechanisms degrade potentially datable surfaces, affecting their apparent exposure history (e.g., Mills and Wagner, 1985; Phillips et al., 1998; Hancock et al., 1999; Granger and Smith, 2000). This study applied these cosmogenic techniques, supported by detailed geomorphic observations, to date well-characterized terraces of the New River in SW Virginia.

2. Terraces of the New River in the Virginia Valley and Ridge

The New River is the only major river that drains to the Gulf of Mexico while cutting through the Blue Ridge, Valley and Ridge, and Cumberland (Allegheny) Plateau physiogeologic provinces of the Appalachian Mountains (Fig. 1). Its headwaters lie in the crystalline rocks of the North Carolina Blue Ridge, and it drains ~19,500 km^2 and drops 1360 m in elevation as it passes from North Carolina through Virginia and West Virginia before joining the Ohio River. In the Valley and Ridge province, the river meanders across wide valleys floored with Cambrian and Ordovician carbonate rocks before crossing more tightly folded and uptilted Cambrian through Mississippian sandstones, shales, and carbonate rocks (Fig. 1A). Here, the New River is typically ~2 m deep and floored by mud. The New River's longitudinal profile reflects the drastic changes in lithology that the river crosses, with riffle zones and knickpoints (such as Big Falls) where it crosses the most resistant units (such as