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Debris flow dominated alluvial fans in the Australian high country indicate that landscape denudation through the Holocene has been dominated by post-bushfire runoff events

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Bushfires play a major role in shaping landscapes across the globe. Whilst the role of fire in shaping and changing vegetation assemblages is relatively well understood, there is still debate about the significance of fire in driving landscape denudation, relative to other processes, such as major rainfall and flood events and questions remain about the frequency of extreme fire events over longer timescales in response to climate forcing. Studies of post-fire landscape impact of recent bushfires in southeast Australia indicate that where storm events occur shortly after a major bushfire, hillslope erosion is enhanced, due to debris flows and erosion of both primary hillslope sediment and sediment stored in hillslope channel networks. In Australia, knowledge of long-term bushfire frequency is largely derived from pollen and micro-charcoal records in lake-sediment archives and is not directly relevant to resolving questions regarding fire impacts on landscape denudation and sediment transfer.

We excavated trenches in four alluvial fans at the base of hillslopes in the high country of northeast Victoria, Australia. This area was burnt by bushfires in 1939 and 2003, and regional climate and hydrology are strongly controlled by El Niño. The trenches were up to 3.5m deep, and in most cases intersected underlying floodplain sediment at the base of the trench, indicating that they provide a full record of sedimentation for that sector of the fan. Fan stratigraphy consisted of sub-horizontal (parallel to the fan surface) units 0.3–0.5m thick, with occasional units 1–1.2m thick, and cross-cutting channelized units. Debris flow deposits accounted for 70–80% of the observed sediments, with water-laid gravels and soil units forming the remainder. Most soil layers were burnt, and most (but not all) debris flow units contained charcoal. A typical stratigraphy consisted of 6–8 debris flow units per fan, with four units containing a fire signature or overlying a burnt soil layer. The basal floodplain unit had a burnt upper silts unit overlying unburnt floodplain silts. Radiocarbon ages were measured from charcoal samples taken from all burnt units or debris flows with a fire signature. Ages reveal fire signatures at 10 ka BP, 8 ka BP (the burnt floodplain), then a fire at 1 ka intervals up to 3 ka BP, and fires at approximately 300 yr. intervals from 3 ka onwards.

This archive of bushfire-triggered debris flows is distinctive in that it demonstrates a strong relationship between large bushfires, which vary in frequency according to regional climate changes during the Holocene, and enhanced landscape denudation, indicated by erosion of bedrock hillslope material. This enhanced erosion is coupled with transfer of sediment from hillslope to channel to alluvial fan and hence to the fluvial system. Sediment is primarily delivered directly to the river channel and transferred downstream during flood events, but there is also significant storage and remobilisation of bushfire-related sediment in the floodplain. This paper presents a model of hillslope response to bushfire in the context of sediment delivery to the fluvial system and Holocene climate changes.