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Late Quaternary floodplain reworking and the preservation of alluvial sedimentary archives in unconfined and confined river valleys in the eastern interior of South Africa

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ABSTRACT

In this study, geomorphological, sedimentological, and geochronological work was conducted on unconfined and confined reaches of three rivers in the eastern interior of South Africa in order to quantify the relative rates of floodplain reworking and alluvial preservation along river courses with variable valley confinement and lithology. Using optically stimulated luminescence (OSL) dating techniques, new chronologies for the Schoonspruit and Mooi River were created and the existing Klip River chronology was expanded. The results suggest that floodplains in both unconfined and confined reaches preserve complex spatial and temporal patterns of alluviation, although differences in boundary conditions lead to variation in the processes and rates of floodplain construction and reworking. On the Klip and Mooi Rivers where local base levels are stable, channels in unconfined reaches rework floodplain sediments through slow lateral migration punctuated by local erosion during avulsion events. On the Schoonspruit where base level has lowered, the channel in the unconfined reach is incised, the floodplain is abandoned, and a large gully has formed. In the confined reaches of all three rivers, the narrow floodplains are reworked by scour and fill activity and limited lateral migration. The OSL results suggest that unconfined reaches preserve relatively continuous alluvial records that extend into the Pleistocene, while the floodplains in the confined reaches preserve relatively discontinuous alluvial records biased toward the late Holocene. The alluvial geochronologic records in these systems preserve signals of changes in local base level controlled by variation in lithology and incision rather than climate change. By defining the processes, rates, and patterns of floodplain reworking in reaches with different degrees of valley confinement and channel incision, the findings contribute to understanding how rivers build, modify, and preserve alluvial sedimentary archives.

1. Introduction

Floodplains are important sedimentary archives that can be used to investigate broader landscape changes in riverine landscapes. Although floodplain sedimentary processes and landforms have been widely investigated (e.g., Lewin, 1978; Nanson and Croke, 1992; Asselman and Middelkoop, 1995; Anderson et al., 1996; Bridge, 2003), most studies have focused on floodplains formed by alluvial rivers in unconfined valleys. Many conceptualizations of river systems depict systematic downstream progressions from confined valley source regions to partially confined or unconfined transfer and sink zones (e.g., Leopold and Maddock, 1953; Schumm, 1977; Church, 1996; Brierley and Fryirs, 2005). Nonetheless, many rivers flow through catchments with heterogeneous lithologies that have varying resistance to weathering and erosion and consequently exhibit variable valley confinement and incision. In combination with nonlinear downstream changes in gradient and unit stream power, channels commonly undergo abrupt variations in long profile, planform, and cross-sectional characteristics as they transition between confined, partly confined, and relatively unconfined valleys (Grams and Schmidt, 1999; McDowell, 2001; Tooth and McCarthy, 2004; Damm and Hagedorn, 2010). Valley confinement is known to be a key control on many aspects of floodplain and alluvial terrace development including sedimentation rates, erosion rates, and long-term preservation potential (e.g., Lewin and Brindle, 1977; Brakenridge, 1984; Nanson, 1986; Nanson and Croke, 1992; Lewin and Macklin, 2003; Cohen and Nanson, 2007, 2008; Jain et al., 2008; Fryirs and Brierley, 2010; Macklin et al., 2010). Less well known is how floodplains build, modify, and preserve alluvial sedimentary archives where local base level changes arise from temporal and spatial variation of incision into heterogeneous lithologies across catchments.

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Given that many rivers flow through valleys of variable width and heterogeneous lithology, it is reasonable to expect that floodplain development and alluvial preservation vary spatially and temporally along river courses, but this has yet to be demonstrated quantitatively in many river types worldwide.

Rivers in the semiarid to subhumid interior of eastern South Africa (Fig. 1) flow through valleys of variable width controlled by variation in lithology resulting in downstream alternations between unconfined and confined valleys (Tooth et al., 2002). Similar to Brierley et al. (2002) and Brierley and Fryirs (2005), the term 'unconfined' is used herein to refer to reaches in which less than 10% of the channel abuts the valley margin and 'confined' is used to refer to reaches in which a higher percentage of the channel, commonly more than 90%, abuts the valley margin. These reach types are similar to the alternating and 'parks' and 'canyons' terminology used by some other researchers (e.g. Grams and Schmidt, 1999). In the eastern interior of South Africa, these downstream alternations provide an opportunity to quantify and compare the rates and processes of floodplain construction and preservation in adjacent reaches with different degrees of confinement and incision. Channel beds in both unconfined and confined reaches are typically bedrock with discontinuous, thin covers of sediment. The unconfined valleys are up to 2 km wide and are developed in less resistant sandstone and mudstone, while the confined valleys are <200 m wide and are developed in more resistant dolerite (also termed diabase) sills and dykes (Fig. 2). Floodplains are typically present in both unconfined and confined reaches; but extensive floodplain wetlands, which are of considerable conservation, ecotourism, and water resource value, only occur in the unconfined reaches. A number of the floodplain wetlands are in a near-pristine state and have national or international protection. However, many are degrading—some in response to inappropriate land use practices (Tooth and McCarthy, 2007) but others in response to natural landscape dynamics. Remediation efforts for degrading wetlands are underway (Ellery et al., 2009; McCarthy et al., 2010), but in many instances are restricted by a lack of understanding of the controls, timing, and rates of late Quaternary and historical changes (Tooth et al., 2012).

The conceptual model for cyclic floodplain wetland development in the eastern interior of South Africa presented by Tooth et al. (2004) is largely built on observations from the Klip River and is supported by limited work in other floodplains in the region (Tooth and McCarthy, 2007; Grenfell et al., 2008). The model suggests that variation in lithology controls floodplain wetland cycles (Tooth et al., 2004). In this region, surficial geology is dominated by Permian sandstones and mudstones of the Karoo Supergroup that were extensively intruded by dolerite sills and dykes at the breakup of Gondwana. Because the dolerite sills and dykes are of higher resistance to erosion than the surrounding lithologies, they form local base levels where exposed in river long profiles (Tooth et al., 2004). Upstream of dolerite reaches, channels formed in sandstone and mudstone lithologies adjust by meandering and avulsing over 1–2 km-wide belts, forming dynamic floodplain wetlands that could potentially preserve paleoclimate signals (Fig. 2). As the rivers incise the dolerite reaches, the channels are locally steepened. The dolerite reaches eventually become deeply incised or incised through exposing the underlying, less resistant sandstones and mudstones in the channel beds. Consequently, incision increases and local base levels are lowered; river incision progresses upstream through the floodplain wetlands, resulting in channel–floodplain decoupling, wetland desiccation, and terrace and gully formation. Eventually, another dolerite sill or dyke may be exhumed in the channel long profile, restarting the cycle. Outside of the Klip River valley, little geochronologic work has been done to define the timescales of floodplain wetland development in the region.

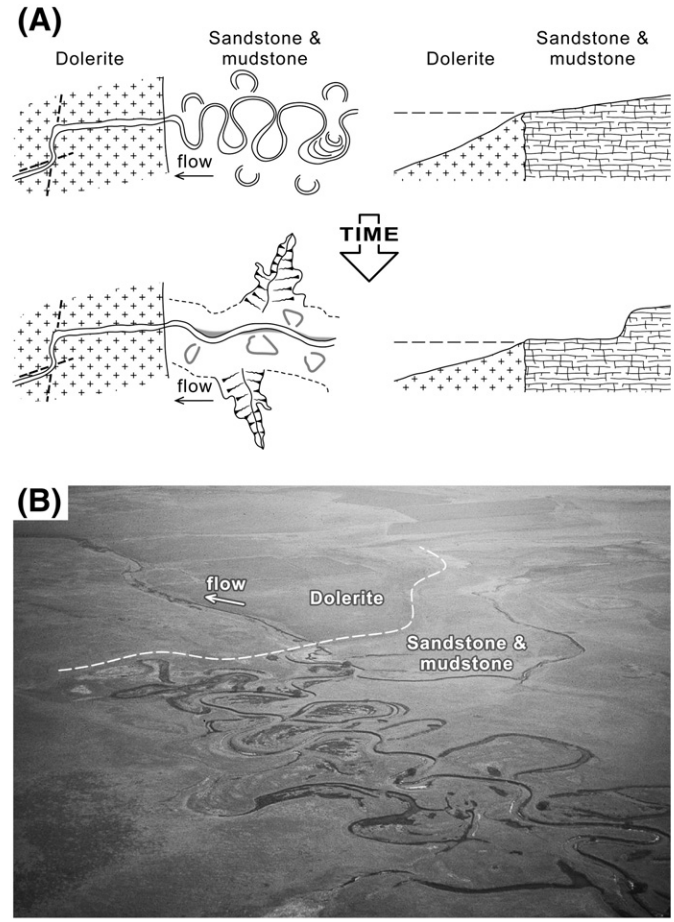

Fig. 2. Floodplain wetland development and the typical configuration of unconfined and confined reaches in the study rivers. (A) The formation of floodplain wetlands in unconfined reaches upstream of dolerite sills and dykes and the changes that result from incision over time is illustrated (modified from Tooth et al., 2004). See Section 1, paragraph 3 in the text for a detailed description of cyclic floodplain wetland development. (B) The oblique aerial photo of the Klip River shows the abrupt downstream transition from the unconfined to confined reach. The floodplain wetland upstream is characterized by a highly sinuous channel that transitions to a straighter channel with a small narrow floodplain downstream.

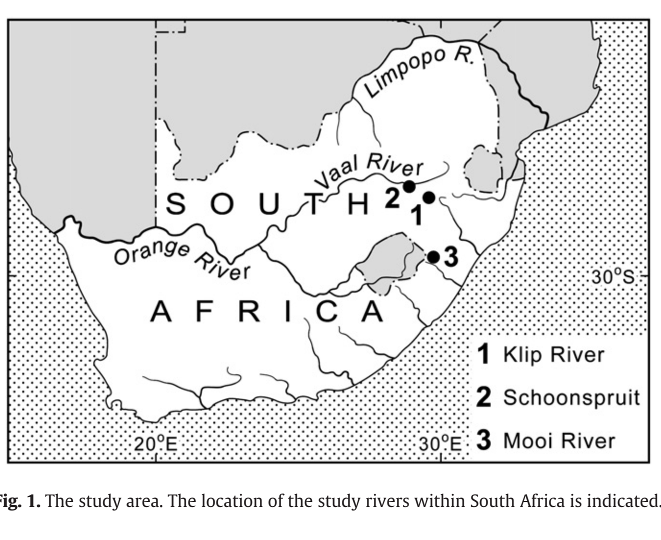

Fig. 1. The study area. The location of the study rivers within South Africa is indicated.

As a contribution to improving understanding of the operative timescales of cyclic floodplain wetland development across South Africa's eastern interior, geomorphological, sedimentological, and geochronological work was undertaken along unconfined and confined reaches of three rivers in the region. The rivers represent different stages in the conceptual model for floodplain wetland development; the Klip and Mooi Rivers have near-pristine floodplain wetlands and the Schoonspruit has an abandoned, degraded wetland. Using optically