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The sediment stratigraphy of a flood event: An example from the Sabie River, South Africa

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ABSTRACT

The geomorphic effects of river floods in various climatic settings worldwide have been extensively described, but there is little information on sedimentary processes during and immediately following flood peaks. Here we reconstruct sedimentary processes and patterns of the 2012 flood on the Sabie River in Kruger National Park, South Africa, from the preserved geomorphic and sedimentary signature of this event. Based on a combination of geomorphic and sedimentary evidence, the maximal and waning flow stages of the flood event are identified, shown by cut and fill and fining up sequences within aggradational bars, and organic horizons, which may be buried, that correspond to the period of flood peak recession. The presence of organic horizons suggests a strongly seasonal flow regime typical of semi-arid South African rivers. It also provides an exemplar of a flood event stratigraphy that is usually poorly preserved in the geologic record.

1. Introduction

During flood events, the high sediment transport capacity and thus potential for geomorphic work means that river floods can result in clear and diagnostic morphological and sedimentary signatures of both erosion and deposition. The net effects of river flood events have been described in the literature, from different environmental, topographic and climatic settings worldwide, and on rivers of different sizes (e.g., Zawada and Smith, 1991; Smith, 1993; Hattingh and Zawada, 1996; Russell and Knudsen, 1999; Brock et al., 2008; Magilligan et al., 2008; Sheffer et al., 2008; Sambrook Smith et al., 2010; North and Davidson, 2012; Carling, 2013; Saitoh and Masuda, 2013; Schillereff et al., 2014; Kermode et al., 2015; Plink-Björklund, 2015). Despite this very large literature, the event stratigraphies of flood events on different rivers are poorly conceptualized in terms of both facies models and sequence stratigraphy (e.g., Miall, 2010), and in the systematic description of flood sediments from field evidence (e.g., Smith and Zawada, 1990; Hattingh and Zawada, 1996; Schillereff et al., 2014). An event stratigraphy is defined as the stratigraphic signature of a single forcing event, in which all stages of the event's life cycle are preserved through the proxy record of a sediment stratigraphy (see Kauffman, 1988). Facies models for river systems tend to focus on cyclic (seasonal, diurnal) patterns of discharge and the general behaviour of rivers under these types and relationships arising from single flood events (cf., Srivastava et al., 2006), although it is likely that rising and waning flow conditions result in different facies types and morphostratigraphic relationships. However, such flood event records should be well preserved in areas with strongly seasonal or episodic flow regimes, where a steep falling limb results in rapid sedimentation and the preservation (rather than reworking) of landforms and sediments that have been deposited during peak flow conditions (Pickup, 1991; Jansen and Brierley, 2004).

Southeastern Africa is a region characterized by a strongly seasonal precipitation patterns and with a record of significant annual flood events over recent years (e.g., Zawada, 1997; Rountree et al., 2000; Heritage et al., 2001b, 2003, 2004, 2015). Several studies have described the effects of flooding on the morphology of middle reaches of several rivers in this region, including the Sabie, Olifants and Klaserie (Zawada, 1997; Rountree et al., 2000; Heritage et al., 2001a, 2001b, 2003, 2004). However, very little is known of the fate of sediments that have been excavated during floods, or the patterns of sediment erosion and deposition in the lower river reaches as these sediments are usually removed from the landscape or buried over time. This paper presents field data at the termination of the Sabie River, where it exits into a reservoir at the border of South Africa and Mozambique, southeast Africa (Fig. 1). The location of the reservoir is important only in that it provides a sediment depocentre, preserving a snapshot of the flood stratigraphy and developed in sediments that would have previously been transported farther through the river system (e.g., Baade et al., 2012). As such, the area immediately upstream of the reservoir's entry point preserves the full spectrum of maximal flood and waning

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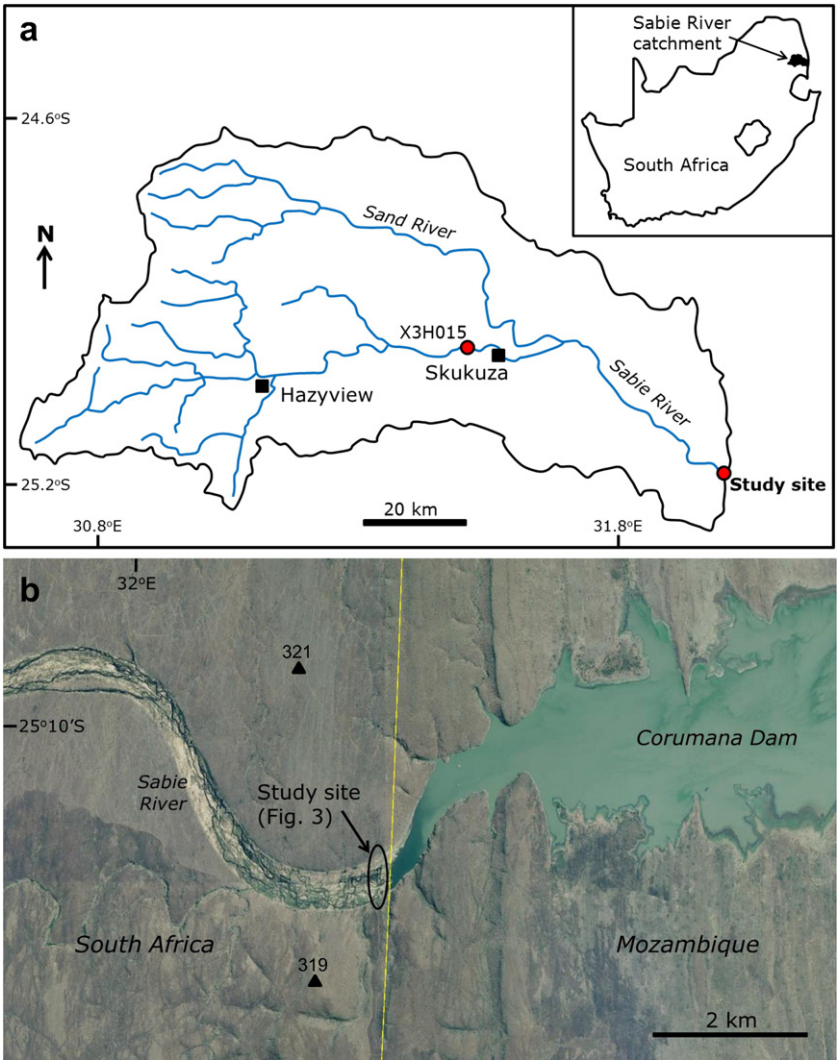

Fig. 1. (a) Location of the Sabie River basin in northeast South Africa, showing the study site and location of river hydrograph X3H015 (Fig. 2). (b) Google Earth image of the study site (date: 18 September 2013) at the confluence of the Sabie River with Corumana Dam. The yellow line represents the international border between South Africa and Mozambique. Selected hilltop elevations are shown (m asl).

flow stages that are not usually preserved if flood waters can transport sediments away from the site unimpeded. In detail, this paper (1) briefly outlines the climatic and geomorphic setting of the study area; (2) presents evidence for a flood 'life cycle', in particular during waning flow stages; and (3) proposes a sequence stratigraphic model that describes the sedimentary signatures of a flood event that may be typical of flashy river regimes in semi-arid environments.

2. Study area

The Sabie River (catchment of 6320 km^2) is a mixed bedrock–alluvial river that flows eastwards from the Eastern Escarpment of southern Africa, draining into the Incomati River and the Indian Ocean (Heritage and van Niekerk, 1995; van Niekerk et al., 1995; Heritage and Moon, 2000; Rountree et al., 2000; Heritage et al., 2001b). Significant differences in channel morphology have been noted between bedrock and sediment substrates along the river (van Niekerk et al., 1995; Broadhurst and Heritage, 1998; Rountree et al., 2000; Heritage et al., 2001b, 2003). The upper part of the catchment is mainly agricultural land and settlements; the lowermost part of the catchment falls within the Kruger National Park (KNP), and as such is dominated by semi-natural lowveld xeric grasslands. Annual precipitation values vary considerably across the catchment, from ~2000 mm a^{-1} in the headwaters to ~600 mm a^{-1} in lower river reaches. Precipitation is strongly seasonal and driven by austral summer cyclonic rainfall, resulting in a peak summer discharge (DJF) and winter low flow (JAS). Mean annual runoff of the Sabie is ~762 × 10^6 m^3. The record of recent discharge of the Sabie River is shown in Fig. 2. The morphodynamic behaviour of this river has been relatively well studied, mainly because of its role in influencing the ecology and management practices of KNP (Moon et al., 1997; van Coller et al., 1997; Heritage and Moon, 2000; Pollard et al., 2011). These studies find that flood events are significant geomorphic agents, in particular along middle reaches of the river where bedrock is intermittently exposed (Heritage et al., 2001a, 2001b, 2003, 2004). Flood events result in transformation of the river from a single to a multiple channel system, avulsion and flooding of the width of the river valley (a sedimentary floodplain is usually absent), sediment stripping from within bedrock channels, and very rapid and turbulent floodwaters carrying both sediments and ripped-up trees and other large vegetation matter (Heritage et al., 2001b, 2004). The Sabie River experienced an extreme flood event (~7000 m^3 s^{-1}) in January 2012 with the landfall of Cyclone Dando. Heritage et al. (2015) used LIDAR to map a 50 km reach of the Sabie before and after this event, noting net erosion of 920,348 m^3 along this reach (equivalent to 18 m^3 m^{-1}). Flood events are therefore geomorphically significant along the Sabie and adjacent rivers in southern Africa.