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Threshold-dominated fluvial styles in an arid-zone mud-aggregate river: The uplands of Fowlers Creek, Australia

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Abstract

Fowlers Creek is a mud-aggregate fluvial system. Floodplain muds dominate the river's deposits and consist of silt, fine to very fine quartzose sand, and clay. Up to ~80% of the silts and clays are bound into sand- and silt-sized aggregates and comprise a substantial component (>42%) of the floodplain muds. Mud-aggregate sediments behave like sands during transport, and as a result, muds can be deposited under conditions of greater flow velocity than would otherwise be the case. Newly deposited floodplain muds are loose and easily entrained, but older floodplain muds are cohesive, and the distribution of modern and older floodplain muds influences erosion patterns across Fowlers Creek.

In the lower order streams of the Fowlers Creek uplands, alternate reaches of shallow rectangular channels and unchannelled floodplains collectively form discontinuous ephemeral streams. These landform sequences consist of gullies, coalescing downstream to arroyos, which terminate in distributary intermediate floodouts. At Fowlers Creek, floodouts are preferentially located at tributary junctions, reflecting their origin during very large floods. At floodouts, low slope and high vegetation density promote sheetflow infiltration and landform stability. Their efficiency in retaining runoff make floodouts drought refugia; they are an important ecological element in this arid area.

The higher order channel of the mid-uplands is a mobile, low-sinuosity, single-thread arroyo, incised into wide muddy unstable floodplains. Fluvial processes are dominated by episodic flood-driven channel avulsion, and variability in stream energy and boundary resistance contributes to a non-equilibrium fluvial style. Frequent reach-scale channel relocation is accompanied by the burial of the abandoned channel in floodplain muds and both erosion and aggradation in downstream floodplains.

Keywords: Arid environment; Arroyos; Ephemeral streams; Floodplains; Fluvial sedimentation

1. Introduction

Braided channels and single-thread, wide and shallow channels have been regarded as characteristic of desert environments, but dryland rivers encompass a much wider range of river types (Tooth, 2000; Nanson et al., 2002). They may contain arroyos, or unchannelled reaches (floodouts), or both, and may transport a mud-aggregate sediment load. In this study, a mud-aggregate river with both arroyos and floodouts is described, and the relationships between its fluvial processes and its mud-aggregate sediment load are explored. Firstly, mud-aggregate rivers and rivers containing arroyos and floodouts are briefly reviewed.

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1.1. Mud-aggregate rivers

Although aggregated grains of silt and clay are a fundamental component of soils (Marshall et al., 1996), such particles usually disintegrate during fluvial transport. The silts and clays thus liberated are then deposited by settling out from slow or still waters. Interpretation of mudstones preserved in the rock record usually reflects this expectation of low-energy depositional environments (Nanson and Croke, 1992; Makaske, 2001).

However, some more robust mud aggregates are able to survive fluvial transportation (Nanson et al., 1986; Maroulis and Nanson, 1996); behaving like sands, they can be deposited in bedforms (Rust and Nanson, 1989; Gierlowski-Kordesch, 1998; Gierlowski-Kordesch and Gibling, 2002; Müller et al., 2004). Such aggregates originate in vertisols or other soils containing swelling clays (Nanson et al., 1986; Rust and Nanson, 1989, 1991; Maroulis and Nanson, 1996; Gibling et al., 1998; Müller et al., 2004). Vertisols form where aridity exceeds moisture for at least part of the year, contain > 30% clay, usually including some smectites, and are often associated with deep large cracks and gilgai (Blokhuis, 1996; Mermut et al., 1996). Many vertisols are self-mulching (generate a surface of loose soil aggregates) but others can be massive, and this is sometimes associated with a lower clay content (Blokhuis, 1996).

After mud aggregates are deposited, the aggregate structure is commonly destroyed (Nanson et al., 1986; Rust and Nanson, 1989; Maroulis and Nanson, 1996; Gibling et al., 1998; Gierlowski-Kordesch and Gibling, 2002). In the rock record, mud aggregates are usually preserved only under favourable circumstances, e.g., rapid burial rate, early carbonate cementation, or protection by non-compressible clasts (Rust and Nanson, 1989; Gierlowski-Kordesch and Gibling, 2002; Müller et al., 2004).

Mud aggregates are being increasingly recognised in modern and ancient fluvial systems. Cooper Creek is the most comprehensively documented (Nanson et al., 1986; Maroulis and Nanson, 1996; Tooth and Nanson, 2000) and is the modern analogue most commonly applied to ancient mud-aggregate rivers (Rust and Nanson, 1989; Marriott and Wright, 1996; Gierlowski-Kordesch, 1998).

1.2. Discontinuous ephemeral streams, erosion cells, arroyos and floodouts

Described in a fluvial setting by Schumm (1977), scour-transport-fill (STF) landform sequences form *erosion cells* in non-fluvial as well as fluvial landscapes (Pickup, 1985; Tongway and Ludwig, 1990). In Australia, erosion cells are a common and an ecologically important landscape component (Pickup, 1985; Pickup, 1988; Bourke and Pickup, 1999). They consist of a sediment source (the scour zone), a transport zone, through which sediment is routed, and a fill zone, where sediment is deposited and plant growth is enhanced (Pickup, 1985). Erosion cells can form complex interlocking mosaics at different scales (Pickup, 1985; Pickup, 1988) (Fig. 1) and are likely where episodic short-lived rainfall promotes discrete transport events (Pickup, 1988). Scour-transport-fill events on a mega-flood scale can have long-lasting effects on fluvial geomorphology (Bourke and Pickup, 1999).

Alternating arroyos and unchannelled valley flats can be thought of as a linear series of erosion cells. Termed discontinuous ephemeral streams by Bull (1997), they represent STF sequences in which gullies and badlands

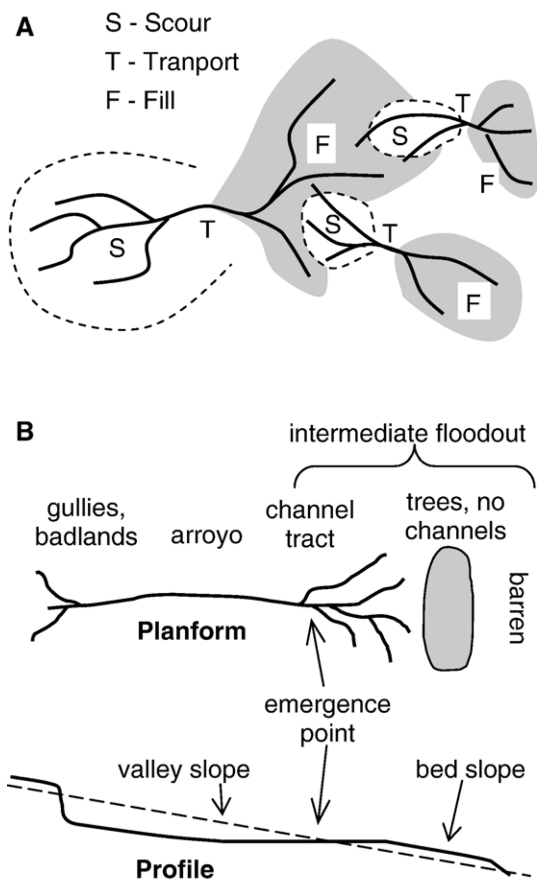

Fig. 1. (A) A mosaic of erosion cells (after Bourke and Pickup 1999). Flow is from left to right, grey areas indicate sediment deposition. (B) Planform and profile of a discontinuous ephemeral stream (after Bull, 1997).