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Regional and local controls on the spatial distribution of bedrock reaches in the Upper Guadalupe River, Texas

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ABSTRACT

While studies on gravel mantled and mixed alluvial bedrock rivers have increased in recent decades, few field studies have focused on spatial distributions of bedrock and alluvial reaches and differences between reach types. The objective of this work is to identify the spatial distribution of alluvial and bedrock reaches in the Upper Guadalupe River. We compare reach length, channel and floodplain width, sinuosity, bar length and spacing, bar surface grain size, and slope in alluvial and bedrock reaches to identify whether major differences exist between channel reach types. We find that local disturbances, interaction of the channel and valley sides, variation in lithology, and regional structural control contribute to the distribution of bedrock reaches in the largely alluvial channel. Alluvial and bedrock channel reaches in the Upper Guadalupe River are similar, particularly with respect to the distribution of gravel bars, surface grain size distributions of bars, and channel slope and width. Our observations suggest that the fluvial system has adjusted to changes in base level associated with the Balcones Escarpment Fault Zone by phased incision into alluvial sediment and the underlying bedrock, essentially shifting from a fully alluvial river to a mixed alluvial bedrock river.

1. Introduction

Because of the recognition of the importance of fluvial bedrock incision on continental landscape evolution, many studies of bedrock incision have been undertaken in recent decades (e.g. Howard, 1980, 1998; Seidl and Dietrich, 1992; Howard et al., 1994; Sklar and Dietrich, 1998, 2001; Whipple and Tucker, 2002; Sklar and Dietrich, 2004; Bishop et al., 2005; Jansen, 2006; Montgomery and Stolar, 2006; Sklar and Dietrich, 2006; Turowski et al., 2007; Chatanantavet and Parker, 2008). Understanding the role of coarse bed material in bedrock incision processes is essential to understanding bedrock incision mechanics (Sklar and Dietrich, 1998, 2004, 2006) and has led to an increased interest in gravel mantled and mixed alluvial bedrock streams. Studies of mixed alluvial bedrock channels are generally focused on long profile development and are based on a model that attributes the occurrence of bedrock or alluvial channel type to spatial variations in the balance of sediment transport capacity and sediment supply that dates back to Gilbert's (1877) work on the Henry Mountains. While some field studies approach mixed alluvial bedrock streams as unusual fluvial forms and focus on geomorphologic descriptions (Kale et al., 1996; Gupta et al., 1999; Heritage et al., 1999; Tooth and McCarthy, 2004), few field studies have focused on spatial distributions of bedrock and alluvial reaches and differences between reach types (Brakenridge, 1985; Ashley et al., 1988; Montgomery et al., 1996; Montgomery and Buffington, 1997; Heritage et al., 2001; Massong and Montgomery, 2000).

In North America, field studies of mixed alluvial bedrock streams and reference reaches used for testing bedrock incision models have been conducted in humid regions in active tectonic settings (Brakenridge, 1985; Ashley et al., 1988; Seidl and Dietrich, 1992; Montgomery et al., 1996; Montgomery and Buffington, 1997; Howard, 1998; Sklar and Dietrich, 2004; Lancaster and Grant, 2006; Sklar and Dietrich, 2006) and focus on local and reach scale controls on the distribution of bedrock reaches (Seidl and Dietrich, 1992; Montgomery et al., 1996; Montgomery and Buffington, 1997; Howard, 1998; Sklar and Dietrich, 2004; Lancaster and Grant, 2006; Sklar and Dietrich, 2006). In order to improve the understanding of mixed bedrock–alluvial rivers, field investigations across a range of climates and tectonic settings are necessary. The Upper Guadalupe River in central Texas is a mixed alluvial bedrock river in a sub-humid, post-orgenic setting that provides an opportunity to investigate controls on the spatial distribution of alluvial and bedrock reaches in a setting that is often neglected in scientific research in fluvial geomorphology.

The objective of this work is to identify the spatial distribution of alluvial and bedrock reaches in the Upper Guadalupe River. We compare reach length, channel and floodplain width, sinuosity, bar length and spacing, bar surface grain size, and slope in alluvial and bedrock reaches to identify whether major differences exist between channel reach types. To determine whether local or regional processes dominate the

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distribution of channel reach type in the Upper Guadalupe River, we examine local conditions at channel transitions from alluvial to bedrock (or vice versa) as well as regional scale patterns of structure and lithology that may influence the spatial pattern of channel type.

2. Regional setting

In central Texas, the Upper Guadalupe River flows from headwaters in the Edwards Plateau region of the Great Plains province at ~600 m above mean sea level. The study reach begins at Flat Rock Dam near the city of Kerrville and extends downstream for 140 km, ending just upstream of Canyon Lake Reservoir (Fig. 1). The drainage area of the study reach is 3405 km^2. The catchment geology is predominately Cretaceous limestone with some thinly bedded layers of shale and sandstone cropping out in the channel banks and valley sides (Brown et al., 1974; Ashworth, 1983). Average rainfall on the Edwards Plateau is 66 cm/year (Carr, 1967) and potential evapotranspiration is 114 cm/year (Clark, 1983). Precipitation is very seasonal and the region is prone to periods of drought and flood. The combination of low infiltration capacity of upland soils, a steep highly-dissected watershed, and dryland vegetation result in conditions for rapid runoff. Flooding and its effects on geomorphology in central Texas are well documented (Baker, 1975, 1977; Patton and Baker, 1977).

The Upper Guadalupe River channel type alternates from fully alluvial to fully bedrock reaches. Alluvial reaches have fully alluvial beds and banks. Bedrock reaches vary from bedrock floored reaches with alluvial banks to reaches with the cross-section composed entirely of bedrock. Many incised reaches appear incised into bedrock and overlying alluvium such that the bed and lower channel walls are composed of bedrock and the upper channel walls and banks are composed of alluvium (Fig. 2). Ground water sapping is evident in bedrock channel walls and on contacts between bedrock and overlying alluvium. Erosional features such as longitudinal grooves, knickpoints, and abrasion or quarrying scars are present in planar bedrock floored reaches (Fig. 3).

In a small nearby Texas watershed, Tinkler (1971) noted a channel morphology with two channels in cross-section, a small channel on the outside of the bend at a lower elevation and a larger one on the inside of the bend at a higher elevation. In cross-section, both of these channels are inset within a larger flood channel. Although the pattern is discontinuous, this morphology is common on the Upper Guadalupe River. This channel-within-channel morphology has been observed in rivers that have two dominant channel-forming flow regimes or are subject to high-magnitude floods (Tinkler, 1971; Rhodes, 1990; Gupta, 1995; Gupta et al., 1999) and has been observed in bedrock channels (Shepherd and Schumm, 1974; Baker, 1988; Wohl, 1992; Tinkler and Wohl, 1998; Richardson and Carling, 2005). In many cases on the Upper Guadalupe River, the small narrow channel on the outer bend is incised into bedrock and the wider, elevated inner channel is cut through coarse alluvial sediments. Between these channels, on the inside bends of the outer channels, are large gravel deposits stabilized by vegetation which contribute to the persistence of the form through high flows (e.g. Baker, 1977; Abernethy and Rutherfurd, 1998; Tooth and Nanson, 2000; Gurnell et al., 2001; Brooks and Brierley, 2002; Brooks et al., 2003; Pollen et al., 2004).

Coarse grained fluvial deposits are exposed in channel cut banks, suggesting a complex history of aggradation and incision (Fig. 4). Baker (1977), in an tributary catchment of the Guadalupe River downstream of our study reach, observed a similar sedimentary stratigraphy which he identifies as a series of ancient flood deposits and buried torrifluvents. Mid-channel, lateral, and point bars up to 2 km long are present in both alluvial and bedrock reaches. Bars are predominantly composed of rounded pebbles to cobbles although some point bars also have thin sand lenses along the inside of the bend

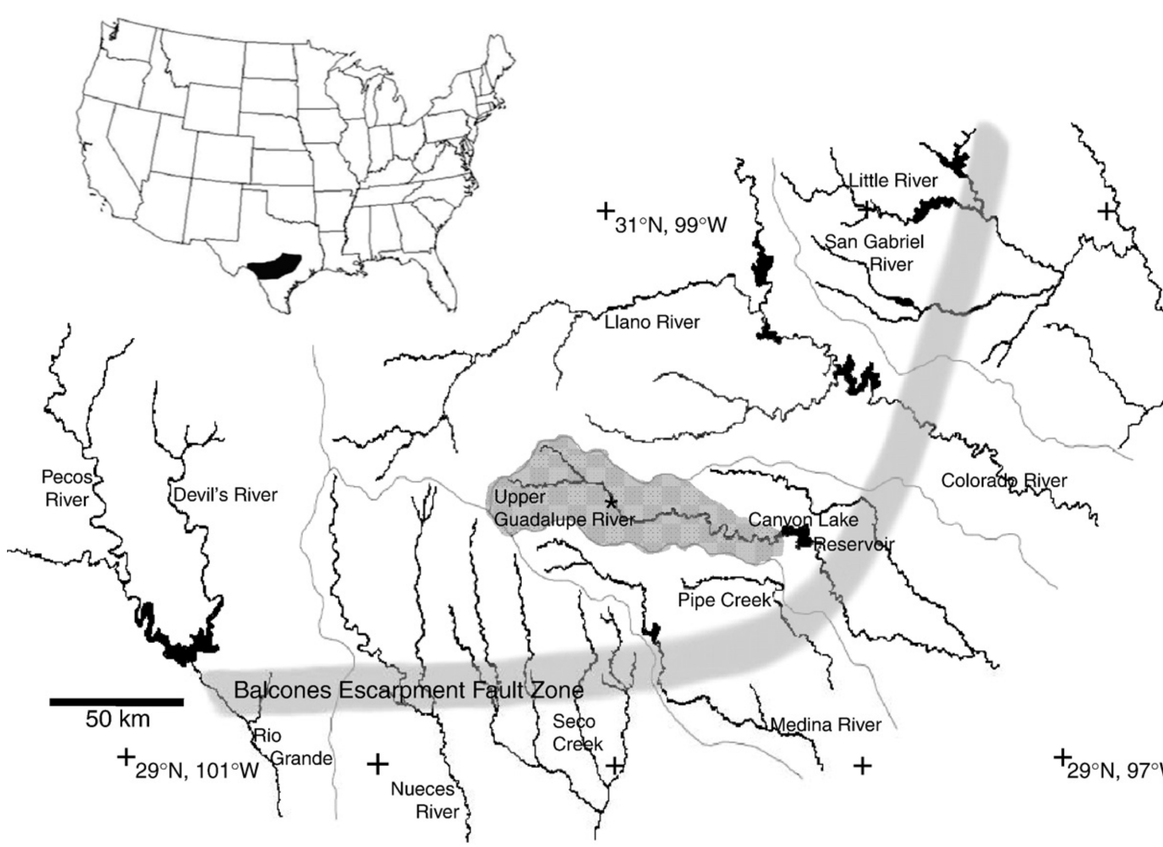

Fig. 1. The location of the Balcones Escarpment Fault Zone and major streams and watersheds in central Texas. The upstream end of the study reach is indicated by * within the Upper Guadalupe River watershed. The study reach extends 140 km downstream to the Canyon Lake Reservoir. Adapted from Caran and Baker (1986, Fig. 1 pg. 3).