Geomorphology 228 (2015) 579–596

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Geomorphological evidence of neotectonic deformation in the Carnarvon Basin, Western Australia

Beau B. Whitney *, James V. Hengesh

The Centre for Offshore Foundation Systems, The University of Western Australia, M053, 35 Stirling Highway, Crawley, Perth, Western Australia 6009, Australia

ARTICLE INFO

Article history:
Received 16 May 2014
Received in revised form 1 October 2014
Accepted 13 October 2014
Available online 23 October 2014

Keywords:
Fluvial geomorphology
Avulsion
SCR
Neotectonic
Western Australia

ABSTRACT

This study examines channel-scale morphodynamics of ephemeral streams in the onshore Carnarvon basin in arid west-central Western Australia. The rivers in this region have low gradients, the landscape has low relief, and the rates of climatically and tectonically driven geomorphic processes also are low. As a result, the rivers in the Carnarvon alluvial plain are highly sensitive to minor perturbations in base level, channel slope, and fluvial energy. We use channel planform adjustments, stream gradient changes, and floodplain profiles across multiple ephemeral streams within a variety of catchments and flow regimes to determine if tectonically driven land level changes are affecting channel form and fluvial processes. Growth of individual fold segments is shown to have altered stream and floodplain gradients and triggered repeated avulsions at structurally controlled nodes. Aligned perturbations in channel form across multiple channel-fold intersections provide systematic geomorphic evidence for the location and orientation of neotectonic structures in the region. These features occur as a belt of low relief anticlines in the Carnarvon alluvial plain.

© 2014 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

1. Introduction

This study assesses the fluvial geomorphology of the Gascoyne and Lyndon rivers and adjacent streams within the Carnarvon basin in west-central Western Australia (Fig. 1). The region herein referred to as the Carnarvon alluvial plain is arid with ephemeral low gradient alluvial rivers and includes the Minilya plain of Hocking et al. (1985a, b) in the north and the Gascoyne alluvial plain or old delta system of Passmore (1968) in the south. We use channel planform characteristics and avulsion histories to assess whether previously unidentified tectonic deformation is evident in the fluvial geomorphological record. Channel characteristics are mapped and evaluated using digital elevation data on a number of channels that range in size from the 865-km-long Gascoyne River, Western Australia's longest river, to unnamed streams just a few kilometers long. Channel response to gradient changes observed across this range of scales varies systematically in relation to stream characteristics (e.g., discharge, flow frequency) and variations in fold amplitudes.

River channels and bedforms are highly sensitive to changes in fluvial gradients (Holbrook and Schumm, 1999) and arguably the lower a river's gradient the more sensitive it is to these changes. Ephemeral dryland rivers may not adjust their gradients in response to allogenic controls as rapidly as perennial streams (Schumm et al., 2000), and as a consequence, evidence of channel gradient changes can have greater longevity in the landscape (Bull and Kirkby, 2002; Nanson et al., 2002). Tectonic influences have been identified as amongst the most significant allogenic control at the field and at the laboratory scale (Ouchi, 1985).

Digital elevation models (DEMs) have been used extensively to identify and assess tectonic control on alluvial systems (e.g., Timár, 2003; Timár et al., 2005; El Hamdouni et al., 2008; Petrovski and Timár, 2010; Zámolyi et al., 2010; Özkaymak and Sözbilir, 2012; Bagha et al., 2014). We utilize the approaches of Willemin and Knuepfer (1994) and Pearce et al. (2004) applied to digital elevation data. We first mapped the fluvial geomorphological characteristics in the vicinity of a known Quaternary active fold and document the fluvial response. We then use the results to identify similar stream channel responses elsewhere in the Carnarvon alluvial plain and test whether these channel responses are related to underlying folds.

Our investigation builds on the approach presented by Pearce et al. (2004) for analyzing ephemeral stream response to active tectonics. We demonstrate the use of remotely sensed data in recognizing neotectonic structures in arid land settings and document a regional-scale pattern of neotectonic deformation in this part of Western Australia.

2. Regional setting

2.1. Geology

The Carnarvon basin contains over 13 km of Palaeozoic and Mesozoic marine sedimentary rocks overlying crystalline basement (Playford and

---

* Corresponding author. Tel.: +61 4 1221 4726.
E-mail addresses: bbwhitney@gmail.com, beau.whitney@research.uwa.edu.au (B.B. Whitney), james.hengesh@uwa.edu.au (J.V. Hengesh).

http://dx.doi.org/10.1016/j.geomorph.2014.10.020

0169-555X/© 2014 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

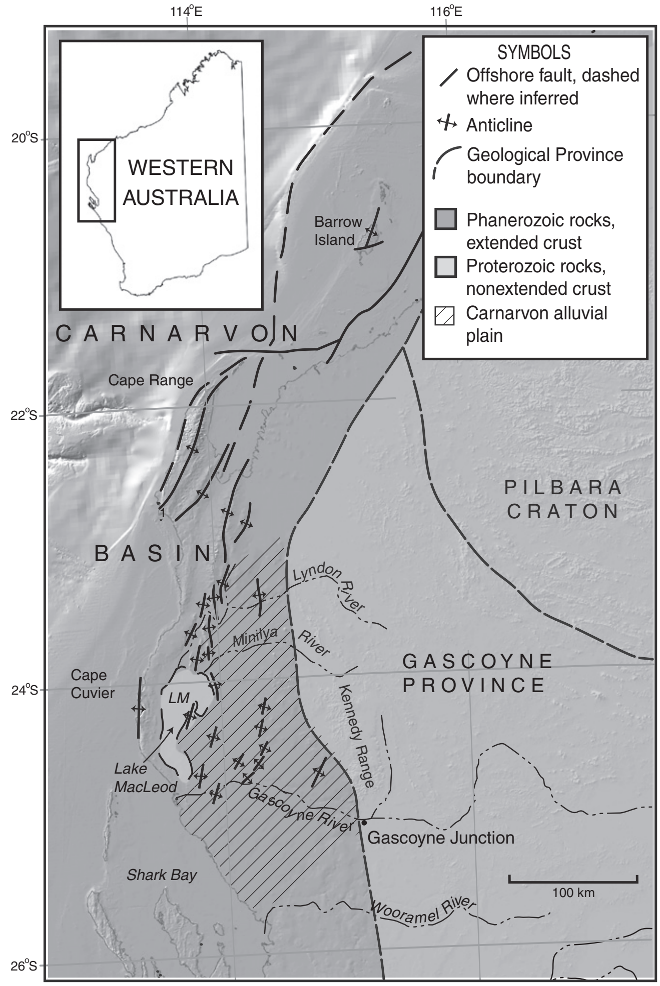

Fig. 1. Map of the study region showing geologic provinces and neotectonic structures.

Johnstone, 1959; Hocking et al., 1987; Hocking, 1990). Near the lower Gascoyne River, the Mesozoic package is about 450 m thick (Allen, 1972b). The Cenozoic section consists of over 60 m of marine carbonates unconformably overlain by terrigenous floodplain deposits (Allen, 1972b). The Carnarvon alluvial plain is an aggrading surface with many tens of meters of Quaternary alluvium overlying Cenozoic and Cretaceous bedrock (Baxter, 1966; Allen, 1972a,1972b). The entire sedimentary package thickens and dips gently to the west.

The Carnarvon alluvial plain is a low-relief feature, dropping ~1 m per 1000 m from the base of the Kennedy Range escarpment to the coast (Fig. 1). The Kennedy Range escarpment rises abruptly 100 m in elevation and demarcates where west-flowing drainages transition from bedrock to alluvial systems. The Lyndon, Minilya, and Gascoyne rivers flow from east to west across the Carnarvon alluvial plain. The rivers locally have incised into older floodplain deposits, but underlying Cenozoic or Cretaceous bedrock outcrops are rare. Near the coast, Pleistocene and Holocene nearshore deposits (beaches and dunes) are preserved.

The most conspicuous surface features on the Carnarvon alluvial plain are NW–SE oriented longitudinal dunes that overlie aggraded alluvial floodplain deposits. The dunes commonly are over 100 km long and 10 m high with a ridge-form pattern. The interdune troughs commonly are a few hundred meters wide. The troughs locally channelize surface flow and are dotted with clay pans.

2.2. Tectonics

The western margin of the Australian continent was extended and thinned during the Late Triassic to Early Cretaceous rifting and fragmentation of Gondwana (AGSO North West Shelf Study Group, 1994). Reactivation of Gondwana era rift-related structures is well documented in the Carnarvon basin (cf, Clark et al., 2012). The most recent structural reactivation is widely attributed to the reorganization of the northern Australian plate boundary that initiated during the Neogene (Densley et al., 2000; Kaiko and Tait, 2001; Audley-Charles, 2004, 2011; Cathro and Karner, 2006; Keep et al., 2007; Hengesh et al., 2011) when the horizontal stress field in the Carnarvon basin realigned to east–west compression (Hillis and Reynolds, 2000, 2003; Hillis et al., 2008; Müller et al., 2012).

Old rift-related normal structures act as zones of weakness and are being preferentially exploited to accommodate crustal shortening (Sykes, 1978; Crone et al., 1997; Cathro and Karner, 2006; Revets et al., 2009; Keep et al., 2012; Müller et al., 2012; McPherson et al., 2013). Former rift-related extensional structures have undergone transform and contractional reactivation leading to structural inversion of basin sequences (Densley et al., 2000; King et al., 2010).

A system of late Neogene to Quaternary anticlines occurs onshore and offshore. The anticlines are commonly developed as fault propagation folds above blind oblique reverse faults (McWhae et al., 1956; Boutakoff, 1963; Hocking, 1988; Hillis et al., 2008). Many of the reactivated faults show little evidence for net-reverse slip motion (Iasky and Mory, 1999), indicating either limited reverse slip or recent onset of inversion.

The most topographically expressed folds in the Carnarvon basin occur in the Cape region and include the Cape Range, Rough Range, Cape Cuvier, Giralia, and Minilya anticlines (Fig. 2). A number of researchers have documented the tectonic deformation of the Cape region and suggest this deformation may be ongoing (Raggatt, 1936; Clarke, 1938; Teichert, 1948; Condon et al., 1955, 1956; Raynor and Condon, 1964; Logan et al., 1970; Hocking et al., 1987; Kendrick et al., 1991; Clark et al., 2012). Folding of the last interglacial shoreline deposits demonstrates growth of these anticlines through late Quaternary time (Denman and van de Graaff, 1977; Veeh et al., 1979; Clark et al., 2012; McPherson et al., 2013). The Rocky Pool anticline located southeast of the Cape region is the most prominent structure in the Carnarvon alluvial plain, and late Quaternary deformation has been documented (Allen, 1972a).

2.3. Climate

The Carnarvon alluvial plain is an arid region with ~220 mm average annual precipitation and 2900 mm average annual evaporation (Dodson, 2009). Rainfall generally is attributed to tropical depressions and cyclones and falls in abrupt high-intensity summer downpours (Wyrwoll et al., 2000). As a consequence, precipitation varies considerably from year to year. On average, the Gascoyne River flows for only 2 to 4 months 1.5 times per year; two years in a decade it fails to flow altogether (Allen, 1972b). Average annual discharge is between ~450 and 864 × 10^6 m^3. However, during major floods it may exceed 3700 × 10^6 m^3 (Allen, 1972b; Dodson, 2009). Typically discharge decreases downstream from flow loss through infiltration (Dodson, 2009). The sporadic and dynamic nature of the Gascoyne River is illustrated by rainfall data collected over the past century. At Gascoyne Junction (Fig. 1) the *average annual* rainfall over the past century is 214 mm, whereas the highest recorded *daily* rainfall during the same period is 293 mm (Dodson, 2009).

2.4. Fluvial geomorphology

The Gascoyne River is the longest river in Western Australia and has a drainage basin area of ~79,000 km^2 (Dodson, 2009). The Gascoyne River is an ephemeral dryland river and has a dendritic channel form

Download English Version:

https://daneshyari.com/en/article/6432314

Download Persian Version:

https://daneshyari.com/article/6432314

Daneshyari.com