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Geomorphological evidence for late Quaternary tectonic deformation of the Cape Region, coastal west central Australia

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ABSTRACT

A late Pleistocene (Marine Isotope Stage 5e) emergent marine sequence fringes the coastline of the Cape Region of coastal west central Australia and provides elevation and age control to characterize the locations and rates of crustal deformation. There is a systematic measurable change in relative paleo sea-level elevations across the Cape Region. High-precision leveling of modern and Pleistocene shoreline features indicates the minimum elevation range of MIS 5e shoreline features along the coast is 10.4 m. This compares with the 2.5 m elevation range for observed modern shoreline analogs. The lack of continuity of MIS 5e shoreline elevations along 300 km of coastline demonstrates continuing tectonic deformation along coastal anticlines in the Cape Region. Topographic expression of MIS 5e features indicates tectonic uplift consistent with late Neogene to Quaternary deformation on the Cape Cuvier and Cape Range anticlines. Post-MIS 5e tectonic uplift rates are up to 0.054 ± 0.035 mm/yr at fold axial locations. Estimated subsidence rates are −0.013 ± 0.034 mm/yr on fold limbs. While the estimated vertical tectonic deformation is small and the rates are low, the geomorphological data also demonstrate tectonic activity, not stability.

1. Introduction

This study investigates elevations of previously dated paleo-shoreline features and rates of neotectonic deformation within the onshore Carnarvon basin in coastal west central Australia. The study area extends along the coast from Cape Cuvier to the northern tip of the Cape Range (~21.5°S to 25°S) and is herein referred to as the Cape Region (Fig. 1). The generally low-lying landscape of the Cape Region is punctuated by a series of topographically prominent anticlines that deform the Miocene Trealla and Tulki limestones and other undifferentiated Miocene to younger sedimentary deposits (e.g., Hocking et al., 1987). We utilize coastal geomorphology and nearshore stratigraphy related to the last interglacial (LIg) period to assess whether the late Neogene folds in the Cape Region have been tectonically active since Marine Isotope Stage 5e (MIS 5e). The MIS 5e shoreline sequence is characterized by a fringing reef platform, nearshore sediments, a geomorphologically distinct abrasion surface, a paleo-shoreline angle, and the adjacent paleo sea cliff or terrace riser. Geomorphic features of both the modern (active) shoreline and the emergent MIS 5e paleo-shoreline were mapped and surveyed to document the relative positions and elevations of shoreline features and to determine the elevations of paleo sea-level indicators.

Elevations from LIg shoreline features are compared with analog features from the modern (active) shoreline in order to assess the variability in elevations (or unit thicknesses) within the late Quaternary section. Survey points were located on in situ corals, nearshore deposits, marine abrasion surfaces, and wave-cut notches. Preservation of the late Pleistocene section varies along the coast, as does the range of elevations for various components within the coastal sequence. Although the thicknesses and elevations of individual components within the late Pleistocene section vary, the stratigraphic positions of individual components are consistent and can be correlated from site to site.

The positions and elevations of coastal features were analyzed at individual study sites, across folds, and across the 300 km-long study area. These elevation data were then compared to a range of eustatic sea-level estimates for the LIg (MIS 5e) highstand in order to establish the range of possible rates of tectonic uplift and subsidence.

2. Background

A number of researchers have addressed the topics of tectonic stability and paleo sea level using data gathered from the MIS 5e features preserved in the Cape Region (e.g., Denman and van de Graaff, 1977; Kendrick et al., 1991; O'Leary et al., 2008a). The products of these investigations are two contrasting sets of literature: the first recognizes late Quaternary tectonic deformation in the region; while the second considers western Australia as tectonically stable and thereby providing a paleo sea-level datum.

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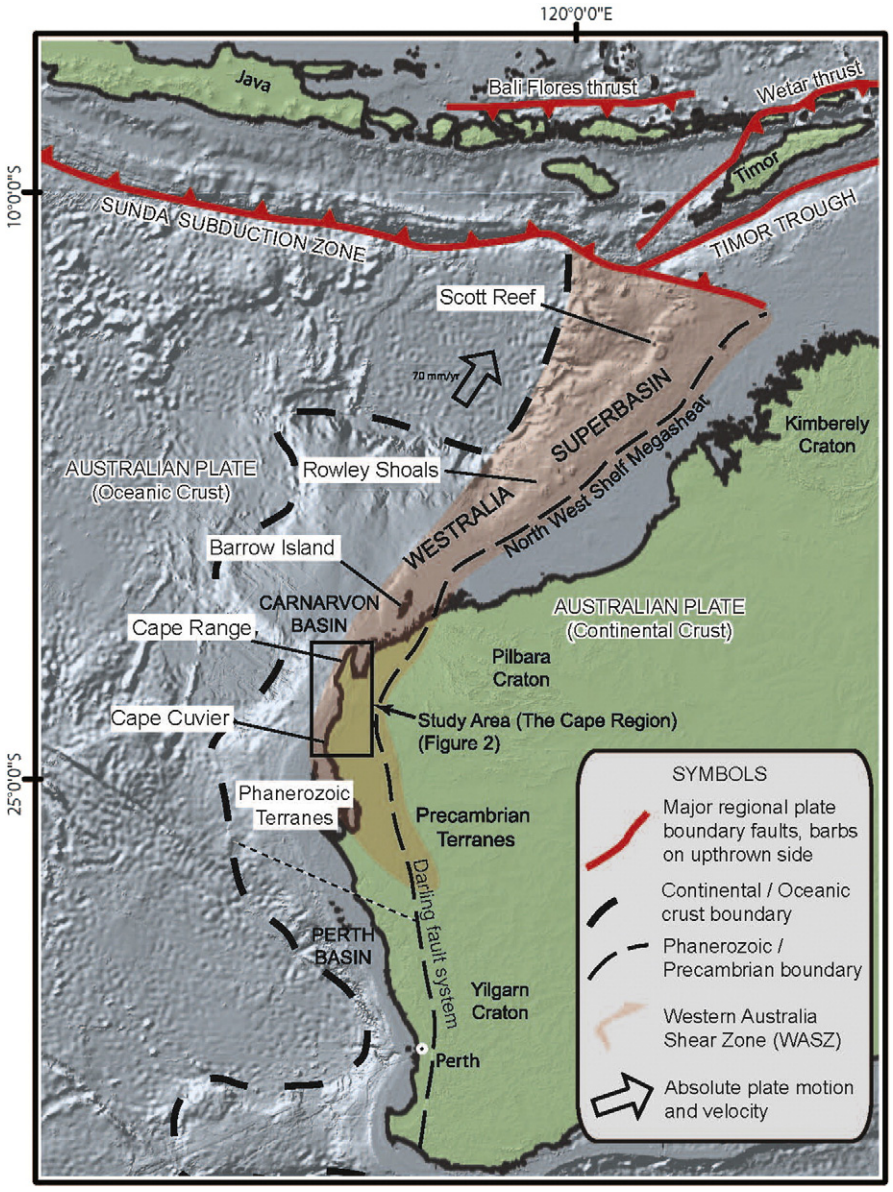

Fig. 1. Regional map showing principal geological provinces and structural trends. For legibility, individual structures within the WASZ are omitted. The principal structural fabric within the WASZ is parallel to the Darling fault and NWSM trends. Plate motion data from Bock et al. (2003).

Many researchers have documented evidence for Late Neogene and younger deformation within the extended crust of the Carnarvon basin both onshore and offshore (Table 1). In addition, a number of researchers have documented evidence for Quaternary tectonic activity in the Cape Region (e.g., Condon et al., 1955, 1956; Boutakoff, 1963; Hancock, 1969; Logan et al., 1970; Allen, 1972b; van de Graaff et al., 1976; Denman and van de Graaff, 1977; Veeh et al., 1979; Kendrick et al., 1991; Clark, 2010; Clark et al., 2012). Folding of late Quaternary sediments in the Cape Range and Carnarvon Basin (Whitney and Hengesh, 2015), the presence of fault scarps (Whitney and Hengesh, 2013), and the occurrence of several historical large magnitude earthquakes (McCue, 1990; Leonard, 2008) clearly indicate that although western Australia may have low rates of tectonic deformation, it is not stable. Neotectonic deformation of this region has been recognized for more than 75 years. However, an influx of recent literature uses paleo sea-level data from western Australia under the assumption that the coastline is tectonically stable (e.g., Stirling et al., 1995, 1998; Hearty et al., 2007; Siddall et al., 2007; O'Leary et al., 2008a, 2008b; Kopp et al., 2009). Moreover, two recent studies refute the concept of stable continental marine platforms altogether in terms of providing a datum around which eustatic sea level oscillates (Moucha et al., 2008; Pedoja et al., 2011). The opposing views of tectonic stability vs. tectonic activity have significant implications for studies of paleo sea level, intraplate tectonics, and seismic hazard.

Table 1
Literature that present data for Quaternary tectonic deformation the Carnarvon Basin.

Raggatt (1936), Clarke (1938), Teichert (1948), Condon et al. (1955), Condon et al. (1956), McWhae et al. (1956), Boutakoff (1963), Raynor and Condon (1964), Baxter (1967), Wyatt (1967), Hancock (1969), Allen (1972b), van de Graaff et al. (1976), Denman and van de Graaff (1977), Veeh et al. (1979), Megallaa (1980), Hocking (1985), Hocking et al. (1987), Hocking (1988), Malcolm et al. (1991), Kendrick et al. (1991), Wyrwoll et al. (1993), Baillie and Jacobson (1995), Crostella (1995), Logan (1987), Crostella and Iasky (1997), Keep et al. (1998), O'Brien et al. (1999), Keep et al. (2000), Ellis and Jonasson (2001), Hearty et al. (2002), Keep et al. (2002), Longley et al. (2002), Cathro and Karner (2006), Clark (2006), Keep et al. (2007), Hillis et al. (2008), Revets et al. (2009), Hengesh (2010), Hengesh et al. (2011a, b), Clark et al. (2011), Keep et al. (2012), Müller et al. (2012), McPherson et al. (2013), Whitney and Hengesh (2013), Whitney et al. (2014), Hengesh and Whitney (2014).