Quaternary Science Reviews 74 (2013) 115–138

Contents lists available at SciVerse ScienceDirect

Quaternary Science Reviews

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

Post-glacial sea-level changes around the Australian margin: a review

Stephen E. Lewis[a,*], Craig R. Sloss[b], Colin V. Murray-Wallace[c], Colin D. Woodroffe[c], Scott G. Smithers[d]

[a] Catchment to Reef Research Group, TropWATER, James Cook University, Townsville, Queensland 4811, Australia
[b] Earth, Environmental and Biological Sciences, Queensland University of Technology, GPO Box 2434, Brisbane, Queensland 4001, Australia
[c] School of Earth & Environmental Sciences, University of Wollongong, Wollongong, New South Wales 2522, Australia
[d] School of Earth and Environmental Sciences, James Cook University, Townsville, Queensland 4811, Australia

ARTICLE INFO

Article history:
Received 28 March 2012
Received in revised form
2 September 2012
Accepted 6 September 2012
Available online 6 October 2012

Keywords:
sea level
Australia
Sea-level indicators
Sea-level change
Holocene
Post-glacial

ABSTRACT

It has been known since Rhodes Fairbridge's first attempt to establish a global pattern of Holocene sea-level change by combining evidence from Western Australia and from sites in the northern hemisphere that the details of sea-level history since the Last Glacial Maximum vary considerably across the globe. The Australian region is relatively stable tectonically and is situated in the 'far-field' of former ice sheets. It therefore preserves important records of post-glacial sea levels that are less complicated by neotectonics or glacio-isostatic adjustments. Accordingly, the relative sea-level record of this region is dominantly one of glacio-eustatic (ice equivalent) sea-level changes. The broader Australasian region has provided critical information on the nature of post-glacial sea level, including the termination of the Last Glacial Maximum when sea level was approximately 125 m lower than present around 21,000–19,000 years BP, and insights into meltwater pulse 1A between 14,600 and 14,300 cal. yr BP. Although most parts of the Australian continent reveals a high degree of tectonic stability, research conducted since the 1970s has shown that the timing and elevation of a Holocene highstand varies systematically around its margin. This is attributed primarily to variations in the timing of the response of the ocean basins and shallow continental shelves to the increased ocean volumes following ice-melt, including a process known as ocean siphoning (i.e. glacio-hydro-isostatic adjustment processes).

Several seminal studies in the early 1980s produced important data sets from the Australasian region that have provided a solid foundation for more recent palaeo-sea-level research. This review revisits these key studies emphasising their continuing influence on Quaternary research and incorporates relatively recent investigations to interpret the nature of post-glacial sea-level change around Australia. These include a synthesis of research from the Northern Territory, Queensland, New South Wales, South Australia and Western Australia. A focus of these more recent studies has been the re-examination of: (1) the accuracy and reliability of different proxy sea-level indicators; (2) the rate and nature of post-glacial sea-level rise; (3) the evidence for timing, elevation, and duration of mid-Holocene highstands; and, (4) the notion of mid- to late Holocene sea-level oscillations, and their basis.

Based on this synthesis of previous research, it is clear that estimates of past sea-surface elevation are a function of eustatic factors as well as morphodynamics of individual sites, the wide variety of proxy sea-level indicators used, their wide geographical range, and their indicative meaning. Some progress has been made in understanding the variability of the accuracy of proxy indicators in relation to their contemporary sea level, the inter-comparison of the variety of dating techniques used and the nuances of calibration of radiocarbon ages to sidereal years. These issues need to be thoroughly understood before proxy sea-level indicators can be incorporated into credible reconstructions of relative sea-level change at individual locations. Many of the issues, which challenged sea-level researchers in the latter part of the twentieth century, remain contentious today. Divergent opinions remain about: (1) exactly when sea level attained present levels following the most recent post-glacial marine transgression (PMT); (2) the elevation that sea-level reached during the Holocene sea-level highstand; (3) whether sea-level fell

* Corresponding author. Tel.: +61 7 4781 6629; fax: +61 7 4781 5589.
E-mail address: stephen.lewis@jcu.edu.au (S.E. Lewis).

0277-3791/$ – see front matter
http://dx.doi.org/10.1016/j.quascirev.2012.09.006

smoothly from a metre or more above its present level following the PMT; (4) whether sea level remained at these highstand levels for a considerable period before falling to its present position; or (5) whether it underwent a series of moderate oscillations during the Holocene highstand.

1. Introduction

The relative tectonic stability of the Australian continent is due to its intra-plate setting. It is also far from the major ice sheets that covered large areas of the northern hemisphere continents during the Last Glacial Maximum (LGM) and has thus been unaffected by significant ice accumulation or the effects of glacio-isostatic rebound. Accordingly, the Australian margin is a suitable place to examine evidence of former shorelines dominated by glacio-eustatic sea-level changes with variable influences of hydro-isostasy (Nakada and Lambeck, 1989; Murray-Wallace and Belperio, 1991; Bryant et al., 1992). The relative tectonic stability and limited isostatic influence around the Australian coastal margin renders the region an important setting for reconstructing post-glacial glacio-eustatic (ice-equivalent) sea-level changes during the most recent marine transgression which followed the LGM (Ferland et al., 1995; Murray-Wallace et al., 1996, 2005). However, much of the Australian coast is bounded by a relatively shallow continental shelf of variable width that has experienced limited hydro- and sedimentary isostasy during the Last Glacial cycle which has had an influence in terms of the Holocene highstand (Larcombe et al., 1995; Baker and Haworth, 2000a; Belperio et al., 2002; Collins et al., 2006; Sloss et al., 2007; Lewis et al., 2008; Woodroffe, 2009). In 1983, David Hopley and colleagues published a synthesis of Holocene sea-level data from around the Australian mainland highlighting the key sites and studies up to that time (Hopley, 1983a). This review reflects on the continued influence of the key sites identified in Hopley's synthesis, and critically reviews the palaeo-sea level evidence presented in subsequent studies.

While the Australian continental margin reveals evidence for localised neotectonic uplift and subsidence (up to 10 m but typically <2 m) based on the displacement of last interglacial (marine isotope sub-stage 5e ca 125 ka) coastal successions that clearly relate to different geotectonic domains (Murray-Wallace, 2002), these rates of crustal movement have had negligible influence on resolving the general pattern of Holocene sea-level changes. For example, one of the more tectonically active regions in southern Australia has experienced uplift of approximately 0.7 m during the Holocene (Cann et al., 1999). This contrasts with adjacent plate-margin sites such as the Huon Peninsula in Papua New Guinea which has undergone rapid and apparently constant tectonic uplift of 20–30 m over the same period, where one of the most detailed records of relative sea-level changes for the past ~400 ka has been established (e.g. Chappell and Shackleton, 1986; Chappell et al., 1996).

The analysis in this review uses a similar approach to previous studies; it emphasises the continued significance of the previously published data (particularly age estimates and the reliability of proxy data to contemporary sea levels) and presents additional marine (corals) and estuarine (sedimentary and mangrove deposits) proxy indicators, together with other proxies now being examined using new techniques (e.g. fixed intertidal biological indicators or encrusting organisms). This work also examines the principal research trends over the past 25 years that recognised regional and local tectonic influences around the Australian margin, and regional variations in eustatic influences, leading to the reconstruction of sea-level histories on a more localised scale. Improved methods of dating enable a greater precision in the assignment of ages to fossil material, but the accuracy with which any inference about sea level can be made means that each sample must be interpreted in the context of the geomorphological setting in which it occurred. Indeed the review highlights the potential problems associated with the interpretation of sea-level indicators, most notably the assumptions that coastal boundary morphodynamic conditions have been constant through time.

The key sites with ongoing research on post-glacial sea-level changes examined in this review include (Fig. 1): The Huon Peninsula, Papua New Guinea (Chappell and Polach, 1991; Ota and Chappell, 1999) and the Joseph Bonaparte Gulf (Yokoyama et al., 2000, 2001a) and its comparison with the Sunda Shelf (Hanebuth et al. 2000, 2009); Spencer Gulf and the Gulf of St Vincent (Belperio et al., 2002); eastern Australia (Baker et al., 2001a,b; Sloss et al., 2007; Lewis et al., 2008); and Western Australia (Searle and Woods, 1986; Baker et al., 2005; Collins et al., 2006). To accurately examine the sea-level histories following the LGM, this review synthesises available data for sea-level change around the Australian margin over the past 20,000 years. We focus on two separate intervals: (1) during the post-glacial transgression (20,000 to 7000 years BP); and (2) the mid–late Holocene (8000 years BP to present). We examine the key mechanisms that appear to explain sea-level change since the LGM at regional and local scales, recognising the legacy provided by the pioneering researchers and identifying remaining gaps in our understanding.

2. Background

The significance of both the relatively tectonically stable continent of Australia and the uplifted coast of Papua New Guinea for palaeo-sea-level investigations was realised by Rhodes W. Fairbridge. His studies in Western Australia in collaboration with Curt Teichert (Teichert, 1950) identified a series of well-preserved sea-level indicators on the Western Australian coast at Point Peron, and offshore on Rottnest Island and the Abrolhos Islands. Fairbridge also realised the potential of the uplifted suite of reef terraces on the north coast of the Huon Peninsula (Fairbridge, 1960). In 1961, Fairbridge presented a thorough global synthesis and critique of sea level and climatic studies and painstakingly considered (and discounted) several alternative explanations for sea-level variability since the LGM including continental flexure, the 'oscillating margin' hypothesis, geodetic forcing and different forms of eustasy (listed below). He produced an integrated theory based on changes in ice volume (glacio-eustasy), tectonic influences (tectono-eustasy), sediment deposition in ocean basins (sedimento-eustasy) and other influences such as inputs from volcanic activity and thermo-expansion/contraction. Fairbridge (1961) also recognised the influence of local tectonic processes and crustal adjustments to water loading and unloading (hydro-isostasy) on sea-level records, although he did not attempt to quantify them in his work.

Fairbridge's sea-level curve of global eustasy (Fairbridge, 1961), developed from a series of studies undertaken in the 1940s and 1950s with Teichert, propelled the evidence from emergent shorelines in Western Australia onto the world stage as key type localities for several highstands. At this time the prevailing view was that sea level had risen gradually up to present at a decelerating rate (e.g. Jelgersma and Pannekoek, 1960; Shepard, 1961). In light of that, Fairbridge included post-glacial sea-level evidence