Quaternary Science Reviews 200 (2018) 160–177

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

Relative sea-level change during the Last Interglacial as recorded in Bahamian fossil reefs

Alexandra Skrivanek*, Jin Li [1], Andrea Dutton

Department of Geological Sciences, University of Florida, Gainesville, FL, USA 32611

ARTICLE INFO

Article history:
Received 1 June 2018
Received in revised form
10 September 2018
Accepted 24 September 2018

Keywords:
Quaternary
Last interglacial
Coral
Bahamas
U–Th

ABSTRACT

Despite an abundance of U–Th age data for Last Interglacial fossil corals in the Bahamas, the accuracy and precision of corresponding elevation data are poor, casting uncertainty on existing estimates of peak relative sea level and rates of sea-level change inferred from these deposits. We revisited two key sites at Great Inagua (GI) and San Salvador (SS) Island to test existing hypotheses about (1) the rate of sea level changes during the Last Interglacial period and (2) a possible gradient in peak sea level between these sites. Here, we provide precise elevation survey results for discrete stratigraphic horizons preserved at both locations, where two stages of reef growth are separated by a discontinuity that truncates corals in the lower reef. The discontinuity at Great Inagua manifests as a sharp wave-cut bench, with a maximum elevation of +1.14 m above mean sea level (MSL), that is sub-horizontal on the promontories and gradually slopes seaward in the embayments. At San Salvador, we observed a discontinuity that undulates between +0.85 and + 1.52 m. The uppermost surface of corals in growth position was measured at +1.94 m (GI) and +2.76 m (SS), although *in situ* collapse and truncation of large *Acropora palmata* colonies at the latter site implies that primary coral elevations were somewhat higher. Ultimately, assumptions regarding the amount of material truncated and paleowater depth of the observed reef facies at both sites dominate the uncertainty in calculating past sea level position and hence rates of sea-level change. Full consideration of errors associated with age and elevation data implies an ephemeral sea level drop of at least 1 m over a time frame of approximately one thousand years between two peaks in sea level.

1. Introduction

Projecting rates of sea-level change in the future requires a better understanding of ice-sheet dynamics under sustained global warming conditions (e.g., Pollard and DeConto, 2016). One approach to acquire this knowledge is to study geologic records of sea level during past warm periods, when polar ice-sheets had retreated beyond their present position, such as during Marine Isotope Stage (MIS) 5e, also known as the Last Interglacial (~129-116 thousand years ago (ka)). This is the most recent warm period that can be studied to understand the dynamics of polar ice sheets when sea levels were higher than present (e.g., Dutton et al., 2015a). Independent assessments from two different groups based on global compilations of coastal sea level markers and glacial isostatic modeling placed peak sea level during the Last Interglacial in the range of ~6–9 m (Kopp et al., 2009, 2013; Dutton and Lambeck, 2012). Subsequent work has shown that dynamic topography of the earth's surface due to mantle convection has the potential to influence the elevation MIS 5e shorelines, but the degree to which this might modify the ~6–9 m estimate remains uncertain (Austermann et al., 2017). Nonetheless, geochemically-derived estimates of sea level and reconstructions of a smaller Greenland ice sheet support the interpretation of data from coastal sediment records that sea level was higher than present during the Last Interglacial (see summary in Dutton et al., 2015a).

Several studies have posited interpretations for the evolution of global mean sea-level (GMSL) during the Last Interglacial, including stable sea level (Stirling et al., 1998), two sea-level peaks separated by a an ephemeral fall in sea level (Chen et al., 1991; Hearty et al., 2007), stable sea level followed by rapid sea-level rise (Blanchon et al., 2009; O'Leary et al., 2013) and multiple oscillations in

---

* Corresponding author.
E-mail address: lexask@ufl.edu (A. Skrivanek).

[1] Present address: The Ministry of Education Key Laboratory of Coast and Island Development, Nanjing University, China, 210023.

https://doi.org/10.1016/j.quascirev.2018.09.033
0277-3791/

GMSL throughout the highstand (Rohling et al., 2008; Thompson et al., 2011). The hypothesis that at least two sea-level peaks occurred during this period was inspired by observations at several sites, including two clusters of coral U–Th ages from Huon Peninsula (Stein et al., 1993), an erosional surface separating two generations of reef growth in the Bahamas (Chen et al., 1991; White et al., 1998; Wilson et al., 1998; Thompson et al., 2011), two superimposed reef tracts in the Yucatán (Blanchon et al., 2009; Blanchon, 2010), and other geomorphological observations at several sites around the globe summarized in Hearty et al. (2007). Reconciling suborbital sea-level peaks from coastal deposits remains a challenge due to contrasting observations and stratigraphic interpretations between sites (e.g., Blanchon et al., 2009; Thompson et al., 2011), as well as within a single site (e.g., Chen et al., 1991; Thompson et al., 2011). Furthermore, assigning a precise chronology to stratigraphic events within the Last Interglacial has been challenging due to post-depositional alteration of coralline aragonite that can lead to open-system behavior of the coral with respect to U and Th isotopes.

A common method that has been used to reconstruct Last Interglacial sea level is to measure elevations and U–Th ages of fossil corals (Edwards et al., 2003; Stirling and Andersen, 2009). Despite numerous U–Th data of corals from a global distribution of sites (Dutton and Lambeck, 2012; Hibbert et al., 2016), rates of sea-level change during this time remain loosely constrained. At Xcaret, the Yucatan Peninsula, Blanchon et al. (2009) speculated a rapid sea-level rise from +3 m to a +6-m peak highstand on the order of tens of m/kyr (or mm/yr), similar to rates of sea-level change reconstructed for the last deglaciation. This rate is based on estimated reef accretion rates and stratigraphic evidence of sea-level change from two superimposed generations of reef growth in the Yucatán, not on radiometric age data (Blanchon et al., 2009). Unfortunately, the Yucatan corals display heterogeneous preservation, with U–Th ages that vary by up to ~20,000 years within a single coral head, making it impossible to calculate robust rates of sea-level change from the radiometric ages (Blanchon et al., 2009). Thompson et al. (2011) estimated the minimum rate of sea level change to be 2.6 m/kyr, which is based on a large and rigorously collected coral U–Th data from open-system corals sampled at Great Inagua and San Salvador islands in the Bahamas but did not report elevation data for the measured samples to support calculations for the rate of sea-level change. Oxygen isotope data from planktonic foraminifera in the Red Sea have also been used to assess rates of sea level change, with reported rates of sea-level rise during the Last Interglacial highstand of 6–25 m/kyr, and sea-level fall of (−)13–18 m/kyr (Rohling et al., 2008). However, the meter-scale sea-level fluctuations inferred from this record were within the bounds of the 1σ uncertainties and were not replicated between the two cores analyzed from this location. Furthermore, the age model has since been adjusted in such a way that would lower these rates (Grant et al., 2012). In light of these observations, we consider the rates of sea-level change from Red Sea record to have high uncertainty (Rohling et al., 2008). Additionally, a probabilistic assessment based on an analysis of a variety of archives (geomorphological indicators, coral age-elevation data, and oxygen isotope data) combined with glacial isostatic adjustment (GIA) modeling (Kopp et al., 2013) estimated maximum rates of sea-level change during the sea level highstand to be in the range of 3–7 m/kyr. Kopp et al. (2013) concluded that it was extremely likely (95% probability) that the Last Interglacial was characterized by at least two distinct peaks in sea level and likely (67% probability) that the low to high swings in peak sea level exceeded 4 m. These rates should be recalculated, however, owing to a tie point of 125 ka that was used in this analysis to anchor the onset of the sea level highstand for some of the records that is about 4-kyr shy of the onset (~129 ka) as recorded by corals at far-field sites (e.g., Australia (McCulloch and Mortimer, 2008) and the Seychelles (Dutton et al., 2015b)). Correcting this tie-point would likely lower the inferred rates of sea-level change. In summary, the challenges posed by age models in all of these records, data uncertainty and/or a lack of transparency and standardization of data reporting of sea level elevation estimates renders all of these rates as highly uncertain (Dutton, 2015; Düsterhus et al., 2016).

Here, we focus on the extensively-dated fossil reef deposits at Great Inagua and San Salvador in the Bahamas (Fig. 1), providing paleowater depth interpretations and adding new elevation measurements to the stratigraphic units to re-assess rates of sea-level change during the Last Interglacial published by Thompson et al. (2011). Several publications have interpreted the reefs exposed in outcrops at both sites to record evidence of an ephemeral sea–level fall followed by a sea-level rise of similar or slightly greater magnitude, based on the observation of indicators of subaerial exposure on an unconformable surface separating two generations of reef growth (Chen et al., 1991; White et al., 1998; Wilson et al., 1998; Hearty et al., 2007; Thompson et al., 2011). Thompson et al. (2011) described additional stratigraphic units and interpreted each as a separate peak in sea level.

Calculating rates of sea-level change through time fundamentally requires two pieces of data: age and elevation of sea-level indicators. Despite numerous U–Th age data from these two sites (47 U–Th measurements of 32 individual corals from Chen et al. (1991) that have reported elevation data and 146 U–Th measurements from 122 samples of 87 individual corals provided with no

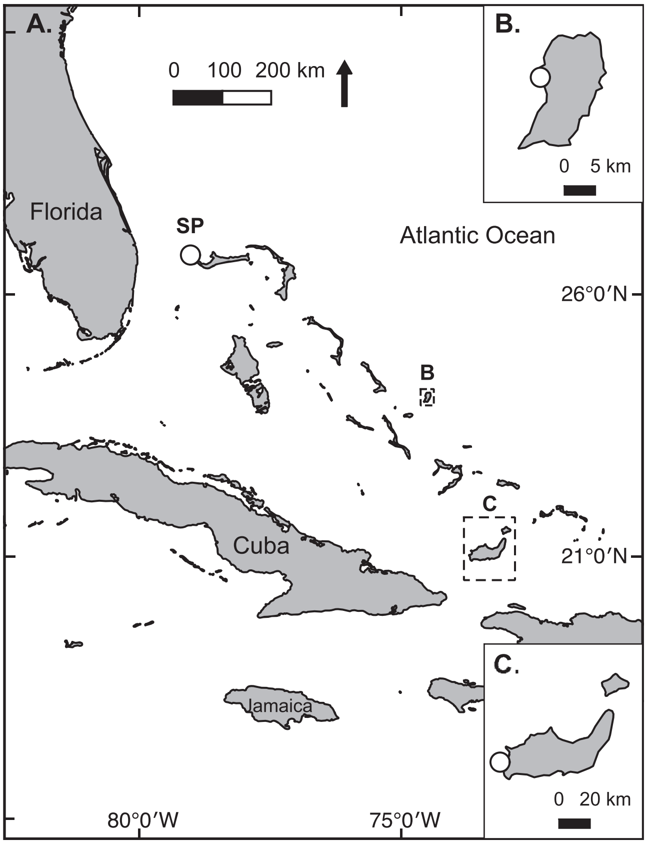

Fig. 1. (A) A map of the Bahamas Islands. The location of the Settlement Point (SP) tide gauge is marked by a white circle. (B) Inset map of San Salvador Island and the approximate location of the Cockburn Town reef exposure surveyed for this study represented by a white circle. (C) Inset map of Great Inagua Island and the approximate location of surveyed reef units at Devil's Point represented by a white circle.