Quaternary International 364 (2015) 172–180

Contents lists available at ScienceDirect

Quaternary International

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

Relative sea-level changes in the Basque coast (northern Spain, Bay of Biscay) during the Holocene and Anthropocene: The Urdaibai estuary case

Ane García-Artola [a, b, *], Alejandro Cearreta [a], Eduardo Leorri [c]

[a] Departamento de Estratigrafía y Paleontología, Facultad de Ciencia y Tecnología, Universidad del País Vasco UPV/EHU, Apartado 644, 48080 Bilbao, Spain
[b] Sociedad de Ciencias Aranzadi, Zorroagagaina kalea 11, 20014 Donostia-San Sebastian, Spain
[c] Department of Geological Sciences, East Carolina University, Greenville, NC 27858-4353, USA

ARTICLE INFO

Article history:
Available online 13 July 2014

Keywords:
Foraminifera
Sea-level changes
Holocene
Anthropocene
Northern Spain

ABSTRACT

In order to reconstruct the environmental evolution process of the Urdaibai estuary in response to sea-level changes in the Basque coast (northern Spain, Bay of Biscay) during the last 8500 years, 10 boreholes were drilled in different estuarine areas using a rotary drill until the pre-Quaternary basement was reached. One manual short core (50 cm) was obtained from a salt marsh environment located in the middle part of the estuary. Micropalaeontological (benthic foraminifera), sedimentological (grain size) and geochemical (^{14}C, ^{210}Pb and ^{137}Cs radioisotopes and total Pb and Zn) analyses were performed on these materials aiming to quantify the sea-level changes both of natural origin (Holocene) or derived from recent human activities (Anthropocene). Based on the obtained results, and by comparison with previously published information for this coastal area, the Holocene environmental evolution of the Urdaibai estuary has been interpreted as the result of relative sea-level variation that exhibits a rapid rise until 7000 cal BP followed by a moderate rise since then, and a stabilization during the last 3000 years until modern rates of sea-level rise (20th century: 1.7 ± 0.2 mm y^{-1}) were reached.

1. Introduction

A substantial and rapidly increasing proportion of global population lives in the coast (within 100 km of a shoreline and 100 m above sea level; Small and Nicholls, 2003), which occupies 18% of the world's land mass (Smith et al., 2005). In Spain, 44% of people live in coastal cities and towns that represent only 7% of the total national land area (Dias et al., 2013). As a result of the great human concentration in this coastal fringe, it is essential to understand the anthropogenic impacts on coastal zones derived from major drivers such as recent global sea-level rise (1.7 ± 0.2 mm y^{-1} during the period 1900–2009 following Church and White, 2011), resulting from thermal expansion of seawater due to ocean warming and water mass input from land ice melt and land water reservoirs (IPCC, 2014). More recently, the analysis of satellite altimeter records (available since 1993) provided a global sea-level rise rate of 3.1 ± 0.4 mm y^{-1} for the period 1993–2012 (Henry et al., 2013), suggesting an acceleration in the last few decades.

The IPCC AR5 report (2014) predicted that global mean sea-level rise rate during the 21st century (median values: 4.4–11.2 mm y^{-1}) will exceed the observed rate for the period 1971–2010 of 2.0 (1.7–2.3) mm y^{-1} under all Representative Concentration Pathways (RCP) scenarios. Regional factors such as tectonic and glacial isostatic movements need to be considered (Gehrels et al., 2011, 2012; Engelhart and Horton, 2012). Results obtained by Marcos et al. (2012) predict that mean sea level (MSL) might increase by up to 40 cm by the end of the 21st century with respect to modern values in northern Spain, resulting in up to 202 ha of supratidal coastal areas under risk of flooding. Hence, sea-level rise presents a hazard and elevated economic costs regarding coastal flood damage and adaptation. Bosello et al. (2012) estimated US$ 13.52 million of land losses by floods and US$ 2.95 million needed for coastal protection in Spain by 2085. The variability in costs of flooding and damage are related in part to the imprecision of the projections.

These future estimates are constrained by the tide-gauge instrumental records which are geographically-limited and

* Corresponding author. Departamento de Estratigrafía y Paleontología, Facultad de Ciencia y Tecnología, Universidad del País Vasco UPV/EHU, Apartado 644, 48080 Bilbao, Spain.
E-mail addresses: ane.garcia@ehu.es (A. García-Artola), alejandro.cearreta@ehu.es (A. Cearreta), leorrie@ecu.edu (E. Leorri).

http://dx.doi.org/10.1016/j.quaint.2014.06.040
1040-6182/

usually cover only the last 60 years (even a shorter period covered by satellite altimetry), with the exception of a few tide-gauge records concentrated in the northern hemisphere that can reach up to the last 150 years (Woodworth et al., 2011). The brief instrumental period captures only a single mode of rising sea level. Geological reconstructions extend the instrumental records of sea level back in time and, therefore, can capture multiple phases of climate and sea-level behaviour for model calibration (Bittermann et al., 2013) and predictions.

Holocene coastal peats have been widely used as sea-level indicators in other regions (Allen, 1995), but in northern Spain they are not present. Therefore, precise sea-level indicators (SLIPS: sea-level index points) were obtained by combining the indicative depositional meaning (micropalaeontological and sand content) and radiocarbon ages (Leorri et al., 2012). Scott and Medioli (1978) first explained qualitatively, and later quantitatively (Scott and Medioli, 1980), the vertical distribution of salt marsh foraminifera, together with plants, with respect to the tidal frame, proving their value as proxies for salt marsh elevation. In recent decades, quantitative studies have developed into transfer functions, in order to obtain high-resolution reconstructions (e.g. Horton et al., 1999; Gehrels, 2000; Gehrels et al., 2005; Kemp et al., 2011b), which are the most used tool to reconstruct past sea-level variations in temperate regions. Foraminiferal distribution in estuaries from northern Spain was determined by both elevation respect to the tidal frame and salinity, which represent the main controls respect to other environmental variables (Cearreta et al., 2002; Leorri and Cearreta, 2009a). Elevation is the dominant environmental parameter in foraminiferal distribution in salt marshes on the SW European coast (Leorri et al., 2010). Foraminifera present in sedimentary records from salt marshes have been used as indicators of salt marsh palaeoelevational changes based on the quantification of the modern relationship between these microorganisms (the relative abundance of different species) and the environmental data (elevation as a proxy of tidal flooding frequency).

In this work, the analysis of foraminiferal assemblages together with radiometric dating (radiocarbon and short-lived radionuclides) and heavy metals of various Holocene and Anthropocene sedimentary sequences have allowed the reconstruction of relative sea level (RSL) in northern Spain. Based on the micropalaeontological and sedimentological content of modern sedimentary environments and their relationship with topographic elevation, the original depositional environment of the borehole samples (depositional elevation range of the SLIPs) were deducted by Leorri et al. (2012) following Gehrels et al. (2006) and Mauz and Bungenstock (2007).

Previous studies in northern Spain have shown that foraminifera correlate to elevation with respect to mean tidal level (Cearreta and Murray, 1996; Leorri and Cearreta, 2004; Leorri et al., 2008b). To date, only regional transfer functions have been carried out in the Basque coast (Leorri et al., 2008a,b, 2010) and used for the reconstruction of sea level in different salt marshes from this region (Leorri et al., 2008b; García-Artola et al., 2009; Leorri and Cearreta, 2009b). Therefore, it has been demonstrated that the observed recent sea-level rise during the 20th century represents a regional rather than a local process (García-Artola et al., 2011). Woodroffe and Long (2010) concluded that local transfer functions are more appropriate than regional ones. In this work, relative sea level is reconstructed using a short core obtained from recent materials by comparison with the modern distribution of similar elevation local surface samples. These results were compared with Holocene records from 10 long boreholes obtained in the Urdaibai estuary, with the aim to study the sea-level changes during the last 8500 years in northern Spain.

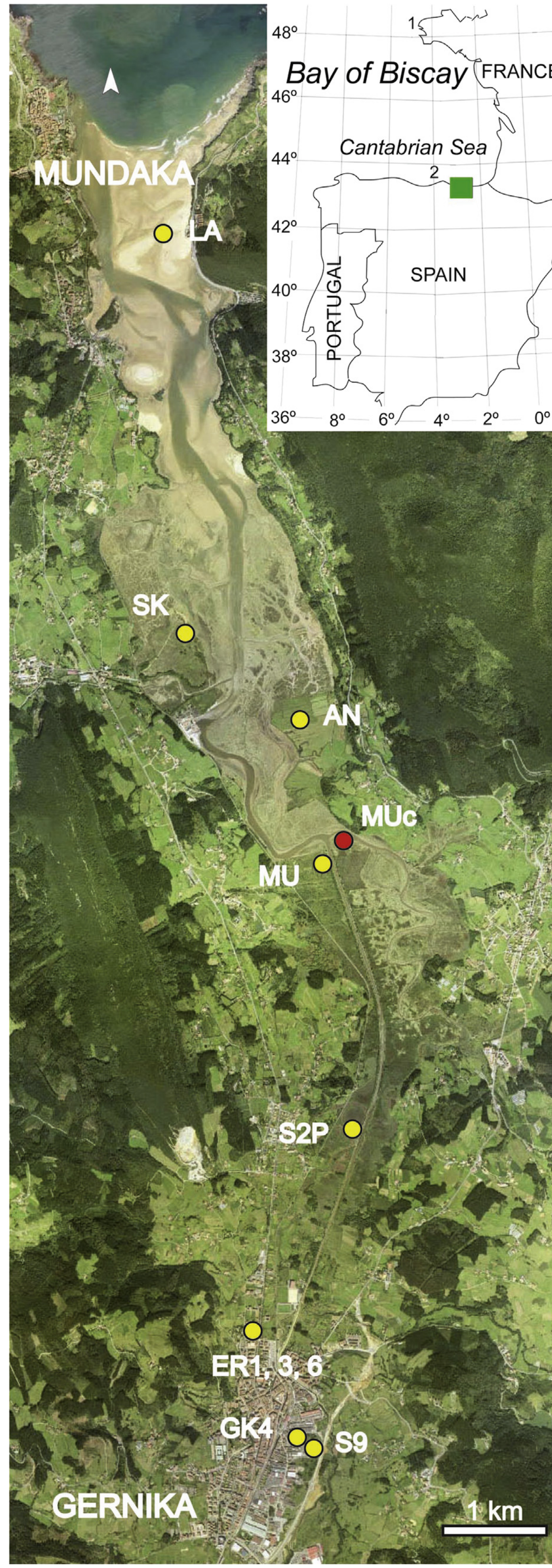

Fig. 1. Geographic location of the Urdaibai estuary in the Basque coast (northern Spain, Bay of Biscay), collected boreholes and short core. 1: Brest tide gauge. 2: Santander tide gauge.