Quaternary International xxx (2015) 1–9

Contents lists available at ScienceDirect

Quaternary International

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

Using archaeological shell middens as a proxy for past local coastal upwelling in northern Chile

Claudio Latorre [a, b, 1], Ricardo De Pol-Holz [c, 1], Chris Carter [d], Calogero M. Santoro [e, *, 1]

[a] Departamento de Ecología, Pontificia Universidad Católica de Chile, Alameda 340, Santiago, Chile
[b] Institute of Ecology & Biodiversity (IEB), Casilla 653, Ñuñoa, Santiago, Chile
[c] GAIA-Antártica, Universidad de Magallanes, Punta Arenas, Chile
[d] School of Archaeology & Anthropology, Australian National University, Canberra, ACT 0200, Australia
[e] Laboratorio de Arqueología y Peleoambiente, Instituto de Alta Investigación, Universidad de Tarapacá, Antofagasta 1520, Arica, Chile

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Shell middens
Coastal upwelling
Marine radiocarbon reservoir effect
Atacama Desert
Northern Chile

ABSTRACT

Shell middens, large heaps of refuse materials that are often interspersed with burials, hearths and other cultural features, provide important data regarding the lifestyles of past coastal and maritime dwellers. Despite the abundance of organic materials, radiocarbon ages from shell middens can be a challenge to interpret because marine shells are depleted in radiocarbon with respect to their contemporaneous atmosphere, known as the "reservoir effect" (R). This issue is particularly problematic in regions like the coastal Atacama Desert where the upwelling of subsurface radiocarbon-depleted waters creates a shell "local" reservoir effect (ΔR) with a time-variable intrinsic uncertainty. Here we review and discuss how the dating of diverse materials from these deposits, including the shells themselves, can reveal large shifts between the terrestrial (atmospheric) and marine carbon cycles. Furthermore, a chronology of such shifts can be used as a proxy of upwelling intensity and to help establish the duration of strong versus weak local upwelling episodes. To test and evaluate these ideas, we present a chronology of R and ΔR variations from a 2-m shell midden sequence from Caleta Vitor in northern Chile that spans the middle Holocene, which remains underrepresented by regional ΔR values. The ~2000 y sequence of Caleta Vitor, located onshore from a major upwelling center, displays dramatic shifts in radiocarbon reservoir effects which we hypothesize are linked to strong changes in the intensity of local upwelling. Further replication of such archaeomalacological records will be key for not only solving methodological problems regarding the dating of coastal sites but can provide further insights into the evolving terrestrial and marine carbon cycles and how these relate to past climate change.

1. Introduction

Shell middens or shell mounds are anthropogenic accumulations formed by the discarded remains of several successive human occupations, either permanent or discontinuous. They are common worldwide and linked to freshwater and coastal marine habitats (Andrus, 2011). The exploitation of marine resources and shell midden formation has been common in Europe since the Mesolithic, but evidence of the use of marine resources worldwide goes back to the middle Palaeolithic (Andrus, 2011; Balbo et al., 2011; Gutiérrez-Zugasti et al., 2011). Shell middens are excellent archives for paleoenvironmental research, although their integrity can be compromised by successive phases of regression and transgression, and other post-depositional natural and cultural transformations (Balbo et al., 2011; Habu et al., 2011; Álvarez et al., 2011). They are also considered important archives for understanding how human societies organized themselves as they adapted and thrived in coastal marine environments (Marquet et al., 2012).

Different methodological approaches have been developed for understanding the depositional processes involved in the formation of shell middens (Balbo et al., 2011). Increasing methodological efforts have focused on the socio-ecological factors

* Corresponding author.
E-mail addresses: clatorre@bio.puc.cl (C. Latorre), ricardo.depol@umag.cl (R. De Pol-Holz), christopher.carter@anu.edu.au (C. Carter), calogero_santoro@yahoo.com (C.M. Santoro).
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.quaint.2015.11.079
1040-6182/

hidden in the complex depositional and post-depositional processes generating these deposits, including analyses of stable isotopes to establish the periodicity of use of coastal habitat, settlement pattern and mobility (Nadal de Masi, 2001; Roberts et al., 2013).

Radiocarbon dates from shell middens, however, are often difficult to interpret and convert into calendar years despite the abundance of organic materials. This is because marine shells are often depleted in radiocarbon with respect to their contemporaneous atmosphere, a phenomenon referred to as the marine "reservoir effect" (R). This issue becomes particularly problematic at the upwelling centers located off the coast of northern Chile such as Caleta Vitor (Fig. 1) (Roberts et al., 2013). Charcoal dates from shell middens can be further "contaminated" by the "old wood problem" (Schiffer, 1986; Kennett et al., 1997, 2002). The presence of old wood in radiocarbon dating archaeological sites, is a particular issue in arid regions and has been known for some time (Schiffer, 1986; Latorre et al., 2013). The presence of old shells in shell middens, however, has not received the same attention (Rick et al., 2005). All of these issues need to be considered *a priori* before attributing the discrepancies between terrestrial versus marine organic materials to marine reservoir effects and other factors (Southon et al., 1995; Glassow, 2002; Owen, 2002; Jones et al., 2007, 2010a, 2010b; Ortlieb et al., 2011; Kennett et al., 2012; Etayo-Cadavid et al., 2013).

Radiocarbon dating assumes that biological samples are in equilibrium with atmospheric CO_2 at the time of death (Bronk-Ramsey, 2008). The problem of dating marine organic materials in shell middens is that these organisms draw most of their CO_2 from ^{14}C-depleted waters generated by near-shore upwelling. Upwelling water masses ventilate significant amounts of "old" carbon that is then incorporated into all the biological systems that feed off the marine primary producers (Southon et al., 1995; Ortlieb et al., 2011). This results in apparent radiocarbon ages that are much older than the concomitant atmospheric ages (summarized by the term "R"), effectively skewing the archaeological radiocarbon dates beyond the normal "marine" correction.

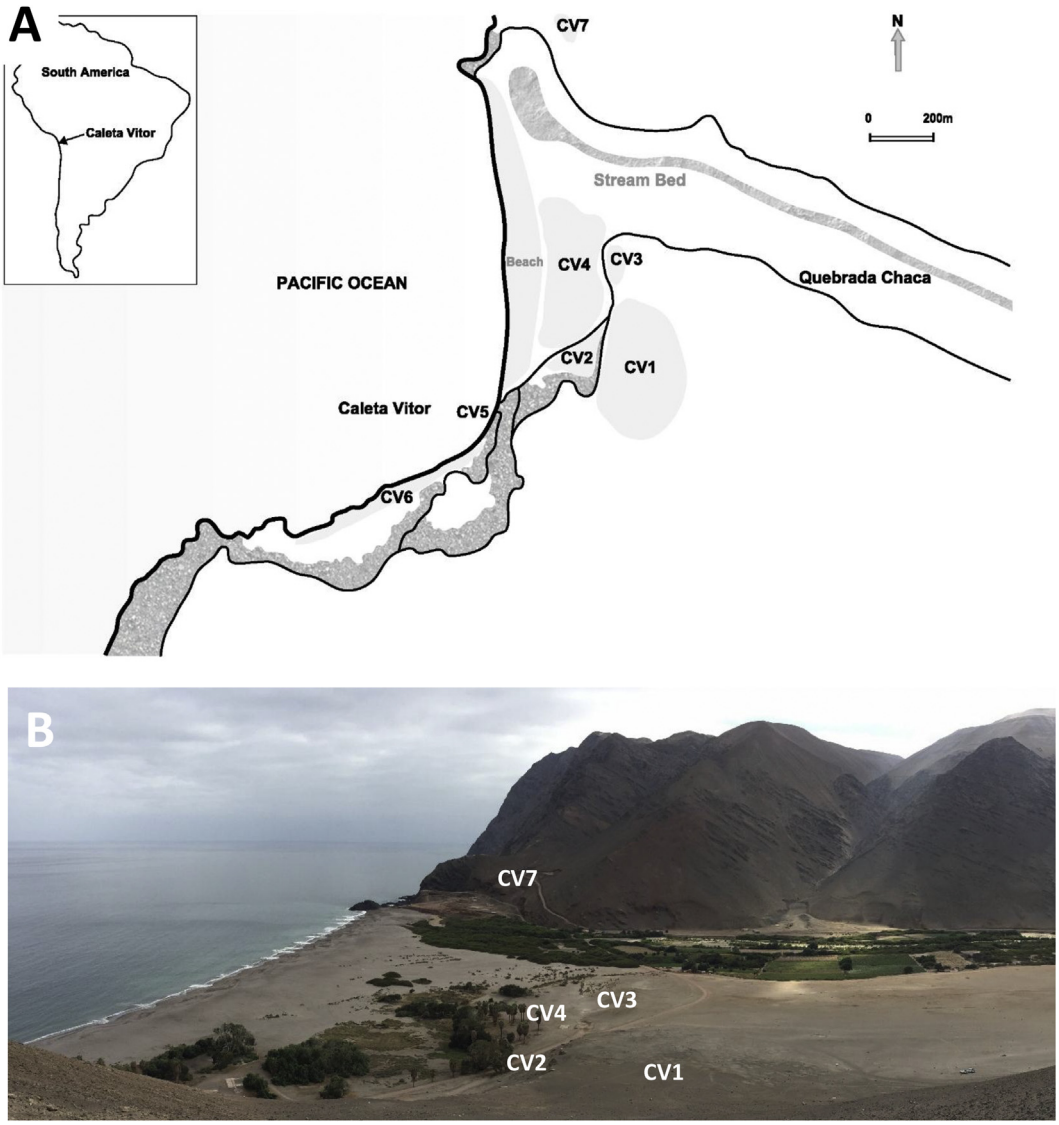

Fig. 1. A) Map of Caleta Vitor showing previously excavated archaeological shell middens. The sites span more than 9000 years and occur on slopes adjacent to the valley (CV1, CV2, CV7) or along the coastal escarpment (CV3, CV4, CV5, CV6) (modified from Roberts et al., 2013), B) Panoramic view looking north towards Caleta Vitor, showing excavated sites visible in the foreground.

Please cite this article in press as: Latorre, C., et al., Using archaeological shell middens as a proxy for past local coastal upwelling in northern Chile, Quaternary International (2015), http://dx.doi.org/10.1016/j.quaint.2015.11.079