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Radiocarbon dating of marine shell samples. The marine radiocarbon reservoir effect of coastal waters off Atlantic Iberia during Late Neolithic and Chalcolithic Periods

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ABSTRACT

Radiocarbon dates on marine shells have not been used as extensively as charcoal or bone dates for the setting up of absolute chronologies because interpreting these dates is complicated by the marine radiocarbon reservoir effect. Nevertheless marine shellfish were used widely at least during the Holocene and their shells are abundant and usually well preserved in archaeological deposits located near shorelines. Consequently prior research concerning the oceanographic conditions and the marine radiocarbon reservoir effect of a particular coastal area is needed in order to set up reliable chronologies for that region. Values of regional marine radiocarbon reservoir effect – ΔR – of coastal waters off Atlantic Iberia, some of its variability along the Holocene and its correlation with the upwelling phenomenon were determined during previous research. More data related to the ΔR values for western Portuguese coastal waters during the Late Neolithic and the Chalcolithic, a time interval badly sampled in previous research, were recently obtained. These values can be compared with ΔR values already determined for the Gulf of Cadiz. Besides the importance of these values for a better knowledge of the palaeoceanography and palaeoclimatology of Atlantic Iberia, from now on archaeologists can set up reliable chronologies for Late Neolithic and Chalcolithic contexts using marine shell samples of that origin for radiocarbon dating.

1. Introduction

As is well known, the ocean reservoir is deficient in radiocarbon (^{14}C) compared with the atmosphere – so, a ^{14}C reservoir age exists for the ocean, i.e. an offset in ^{14}C age exists between coeval samples containing marine carbon versus those containing terrestrial carbon. Stuiver et al. (1986) modeled the response of the world oceans to atmospheric ^{14}C variations. From this modeling, two calibration curves for marine samples have been derived – one related to deep ocean and the other to the sea surface water (mixed layer). Regional differences in ^{14}C content between the sea surface water of a specific region and the average sea surface water are due to several causes and anomalies, namely the upwelling of deep water. A parameter, denoted as ΔR, can be defined as the difference between the reservoir age of the mixed layer of the regional ocean and the reservoir age of the mixed layer of the average world ocean in AD 1950 (Stuiver et al., 1986). ΔR values are often determined for a particular geographical region by ^{14}C dating of pairs of samples of same age but of different reservoir origin (terrestrial and marine) and converting the terrestrial biosphere sample ^{14}C age into a marine model age; this marine model age is then deducted from the ^{14}C age of the associated marine sample to yield ΔR (Stuiver and Braziunas, 1993).

Since the residence time of carbon in the deep ocean is of the order of one thousand years (Sigman and Boyle, 2000), a fraction of the ^{14}C atoms has time to decay (the ^{14}C half-life is 5730 yr), while the deep water is out of contact with the atmosphere. Therefore, the deep ocean is depleted in ^{14}C relative to the atmosphere and the surface sea water (mixed layer) has a ^{14}C specific activity lower than that one of the atmosphere but greater than that of the deep ocean. Consequently, upwelled waters are depleted in ^{14}C relative to surface sea water. Since rates of regional upwelling can vary in the course of time and the intensity of ^{14}C depletion in the mixed layer depends upon the upwelling activity, it is likely that values of ΔR can also vary in the course of time (Stuiver and Braziunas, 1993:155, Kennett et al., 1997, Ingram, 1998; Ascough et al., 2005). Thus, as a measure of the regional enhancement or depletion of ^{14}C, ΔR can also be used as an upwelling proxy, which provides the most direct signal of upwelling activity (Diffenbaugh et al., 2003).

Along the western coasts of Europe, active wind-driven coastal upwelling is, at present, practically restricted to the Atlantic coast of the Iberian Peninsula, particularly from Cape Finisterre to Cape São Vicente (Wooster et al., 1976) and, although with less intensity, along

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the southern coast of Portugal (Fiúza, 1982, 1983). The western Iberian coast extends along the 9° W meridian between 37° N and 43° 30′ N and the southern coast (Algarve) is oriented along 37° N, between 7° 20′ W and 9° W (see Fig. 1). The regime of winds is strongly correlated with latitudinal migration of the subtropical front and with the dynamics of the Azores anticyclone cells. Hence, the atmospheric circulation associated with the Azores high corresponds to westerly winds in winter off the Atlantic Iberian coast and to northerly and northwesterly winds with considerably more strength in summer. These northerly summer winds induce Ekman transport offshore along the western coast, i.e. they are clearly upwelling favorable from June to September. The surface water circulation off the southern coast must be considered in relation to the Northeastern Atlantic circulation. Due to the dynamic effect of Cape São Vicente the upwelled water in the western coast moves southeastward and eastward, creating a quasi-permanent upwelling area around the Cape, as a prolongation of the western coastal upwelling system (Fiúza, 1982, 1983; Fiúza et al., 1982; Ferreira, 1984). When prevailing winds in the Gulf of Cadiz are from the west, the upwelled waters travel east along the southern coast and a minor upwelling area is found to the east of Cape Santa Maria, Faro (Vargas et al., 2003). Nevertheless, due to the configuration of the eastern coastline of the Gulf of Cadiz wind-driven coastal upwelling is nonexistent off south-western Atlantic Spain (Soares, 2005), contrarily to the situation occurring off other coasts of the Atlantic Iberia, from Cape Ortegal to Cape São Vicente and even at the southern coast of Portugal.

^{14}C dates on marine shells have not been used as extensively as charcoal or bone dates for the setting up of absolute chronologies because interpreting these dates is complicated due to the existence of a marine radiocarbon reservoir effect, which value (ΔR) is sometimes unknown, or when known, the knowledge of its eventual variability usually is lacking. Nevertheless, marine shellfish were used widely at least during the Holocene and their shells are abundant and usually well preserved in archaeological deposits located near shorelines. Therefore, to set up chronologies for a particular area using this kind of samples prior research concerning the oceanographic conditions and the marine radiocarbon reservoir effect of that area is needed in order to obtain accurate results. Values of regional marine radiocarbon reservoir effect of coastal waters off Atlantic Iberia, some of its variability along the Holocene and its correlation with the upwelling phenomenon were determined during previous research. ΔR values range from 940 ± 50 to -160 ± 40 ^{14}C yr (Fig. 2) consistent with a significant fluctuation with time in the strength of the coastal upwelling in the Portuguese coast, between Aveiro and Faro (Soares and Dias, 2006a). A similar situation was determined for western and north-western Galicia (Soares and Dias, 2007) with ΔR values ranging from -280 ± 70 to 270 ± 40 ^{14}C yr (Fig. 3). Concerning the eastern zone of the Gulf of Cadiz some variability of the ocean reservoir effect can be observed too (Soares and Dias, 2006b). Here (see Fig. 4), positive ΔR values were determined for the interval 4400–4000 BP, contrarily to what happens c. 4500 BP or between 2000 BP and today, when ΔR takes negative values.

In the present study, we present the results concerning the determination of ΔR values for western Portuguese coastal waters during the Late Neolithic (*c.* 3500–3200 BC) and the Chalcolithic (*c.* 3200–2000 BC) Periods (Soares and Cabral, 1993), time intervals poorly sampled in previous research. These results will be compared with those from the Gulf of Cadiz mentioned above. Besides the importance of these values for a better knowledge of the palaeoceanography and palaeoclimatology of Atlantic Iberia, from now on archaeologists can also set up more accurate and reliable ^{14}C chronologies for Late Neolithic and Chalcolithic contexts using marine shell samples collected from the Atlantic Iberian coast.

2. Methodology

2.1. Sampling

Pairs of closely associated archaeological samples (marine shells/charred wood or bones) from each depositional context were collected from Late Neolithic and Chalcolithic contexts of some Portuguese archaeological sites, namely from Olelas (Gonçalves,

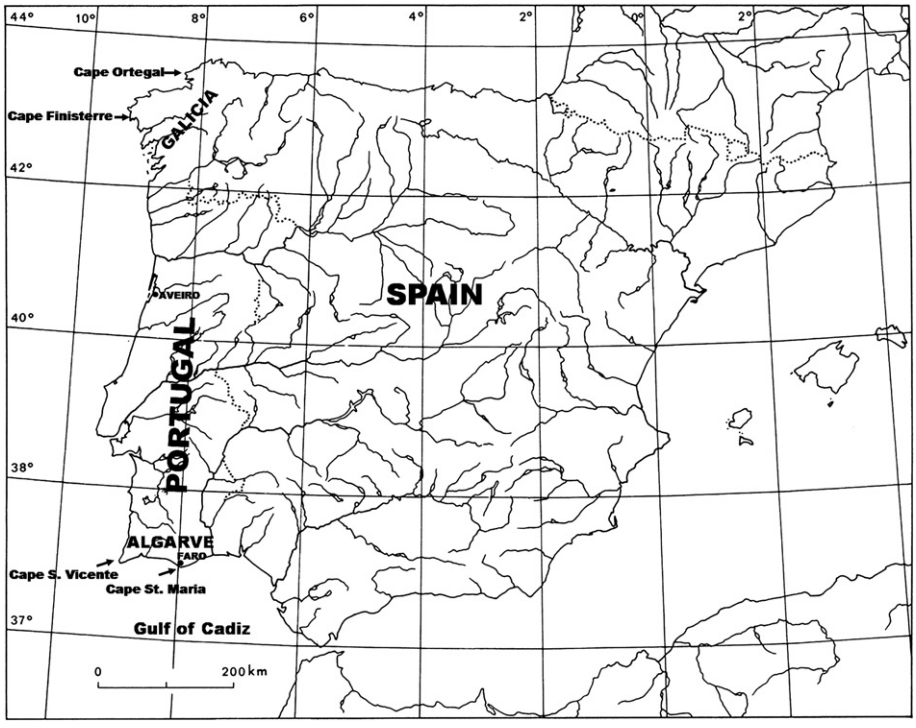

Fig. 1. Map of the Iberian Peninsula showing locations of the capes referred in the text.