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Comment on "Formation of chenier plain of the Doñana marshland (SW Spain): Observations and geomorphic model" by A. Rodríguez-Ramírez and C.M. Yáñez-Camacho [Marine Geology 254 (2008) 187–196]

J. Rodríguez-Vidal [a,*], A.M.M. Soares [b], F. Ruiz [a], L.M. Cáceres [a]

[a] Dep. Geodinámica y Paleontología, Universidad de Huelva, 21071-Huelva, Spain
[b] Laboratório de Radiocarbono, Instituto Tecnológico e Nuclear, 2686-953 Sacavém, Portugal

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ABSTRACT

The speculative method and data suggested by Lario et al. [J. Lario, C.J. Dabrio, C. Zazo, J.L. Goy, F. Borja, A. Cabero, T. Bardají, P.G. Silva, 2010, Comment on "Formation of chenier plain of the Doñana marshland (SW Spain): Observations and geomorphic model" by A. Rodríguez-Ramírez and C.M. Yáñez-Camacho [Marine Geology 254 (2008) 187–196], Marine Geology, this Issue] and other researchers in their papers and comments about the marine radiocarbon reservoir effect in the Gulf of Cádiz are unreliable. The previous regional investigations (Soares's comment [A.M.M. Soares, 2010, Comment on "Formation of chenier plain of the Doñana marshland (SW Spain): Observations and geomorphic model" by A. Rodríguez-Ramírez and C.M. Yáñez-Camacho [Marine Geology 254 (2008) 187–196], Marine Geology, this Issue] and others papers) about the calibration of radiocarbon marine samples cannot be ignored or undervalued. At present, accurate and reliable ΔR values exist and must be used when building up chronological frameworks for the interpretation of Holocene marine environments. During the interval 2000–200 BP or *circa* 4500 BP ΔR values from the Andalusian coast of the Gulf of Cádiz are invariably lower than those from the Algarvian coast. Its calculated weighted mean is -135 ± 20 ^{14}C yr. Between 4000 BP and 2000 BP ΔR data are still lacking but a conservative ΔR value of 100 ± 100 ^{14}C yr can be adopted.

1. Introduction

Radiocarbon dates on marine samples have not been used as extensively as terrestrial biosphere (charcoal or bone) dates for the setting up of absolute chronologies because interpreting those dates is complicated by oceanographic factors. To set up chronologies for a particular coastal area using marine samples, previous research concerning the oceanographic conditions and the marine reservoir effect for that coastal area is needed in order to obtain accurate and reliable results. Lario et al. (2010-this issue), like other recent papers (Morales et al., 2008; Rodríguez-Ramírez and Yáñez-Camacho, 2008; Rodríguez-Ramírez et al., 2009; Gutiérrez-Mas et al., 2009a,b), forgot the oceanographic conditions in the Gulf of Cádiz in their publications with the consequences that will be mentioned straight forwards.

Lario et al. (2010-this issue) talk about "an ongoing discussion about the validity of radiocarbon ages". We think that the discussion is more about the misuse of radiocarbon dates of marine samples as it is also explained ahead.

2. The mistaken use of *R versus* ΔR in the former regional papers

As Lario et al. (2010-this issue) comment in their manuscript we also believe that "… the erroneous values used by us [Lario, Dabrio and other collaborators] to correct the reservoir effect in ^{14}C dating from the Gulf of Cadiz derive from a misunderstanding of the terms: global average *R*, regional *R* and ΔR". This misunderstanding of the terms, namely those of regional *R* and ΔR continues in the Lario et al. (2010-this issue) comment. It is clear that regional methodological work, previously published on this topic (Soares, 2005, 2008; Soares and Dias, 2006a,b, 2007; Soares and Martins, 2009), have not been applied to the research of coastal evolution and Lario et al. (2010-this issue) have failed to understand how radiocarbon ages of marine samples must be correctly calibrated.

Stuiver et al. (1986) modeled the response of the world's oceans to atmospheric ^{14}C variations. The marine calibration curve (Marine09 and also the previous curve Marine04) is based in this model (Reimer et al., 2009; Hughen et al., 2004). Regional differences in radiocarbon content between the sea surface water of a specific region and the average world sea surface water are due to several causes and

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* Corresponding author. Dep. Geodinámica y Paleontología, Facultad de Ciencias Experimentales, Universidad de Huelva, c/ Tres de marzo, s/n–21071 Huelva, Spain. Tel.: +34 959219862; fax: +34 959219440.
E-mail address: jrvidal@uhu.es (J. Rodríguez-Vidal).

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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. ΔR values are often determined for a particular geographical region by radiocarbon dating of pairs of samples of the same age but of different reservoir origins (terrestrial and marine) and converting the terrestrial biosphere sample radiocarbon age into a marine model age; this marine model age is then deducted from the radiocarbon age of the associated marine sample to yield ΔR (Stuiver and Braziunas, 1993).

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 radiocarbon 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 in those regions where this phenomenon exists. Positive high ΔR values can be correlated with a strong upwelling, while low or negative ΔR values correspond with a weak, or even nonexistent, upwelling.

3. The regional reservoir value of Lario et al. (2010-this issue) and their former papers

The value of 440 ± 85 ^{14}C yr for $R(t)$ at 2490 ± 60 BP published in 1996 by Lario (see Comment by Lario et al., 2010-this issue), which corresponds to a value of 35 ± 85 ^{14}C yr for ΔR (following the same Comment) has little reliability. This value of ΔR that appears in the Comment of Lario et al. (2010-this issue) is mentioned for the first time in this paper, never before. The way followed by those authors was to deduct from the marine radiocarbon date the apparent age $R(t)$, that was considered as a constant, and then the resulting date was calibrated using a calibration curve for terrestrial samples.

Following Dabrio et al. (1999, p. 269; 2000, p. 384) the calculation of this value of the marine reservoir effect was done "by means of two accelerator mass spectrometry (AMS) ablation probes carried out on organic material and on a shell collected in the same layer of a core drilled in the lower reaches of the Guadalquivir River". The organic material is twigs (Dabrio et al., 1999, Table 1; Dabrio et al., 2000, Table 1) or peat following the Comment of Lario et al. (2010-this issue). Twigs or peat must never be used for the determination of a radiocarbon reservoir effect, since it will be very doubtful to be certain of the contemporaneity between this kind of sample and an associated marine sample. On the other hand, Lario et al. (2010-this issue) say, and we partially agree, that "estuarine mollusc shells cannot be calibrated directly using the marine reservoir effect" and for the same and better reason that an estuarine mollusc shell cannot be used for the determination of a marine radiocarbon reservoir effect. Was the shell dated by Lario (1996) a marine shell? From what mollusc species was it? These questions are not clarified in any place. Its isotopic composition (−2.9‰) is in the threshold between marine and brackish waters. 21 shell samples from the eastern zone of the Gulf of Cádiz were radiocarbon dated till now (Soares, 2005, 142–149; Soares and Martins, 2009). The most part of the samples have a positive $\delta^{13}C$, while −2.0‰ is the most negative value determined for a sample of *Venerupis decussatus* collected in an archaeological site near El Puerto de Santa María, Cádiz (Soares, 2005, 143). We doubt that the radiocarbon dated shell by Lario (1996) was a marine shell; otherwise, it must be noted that it was "a shell collected in the lower reaches of the Guadalquivir River".

Besides the doubts mentioned above about the accuracy and reliability of the value calculated by Lario (-440 ± 85 ^{14}C yr: Lario, 1996, p. 172, Table 4.4), it must be noted that the first value published by Lario is a negative value instead of the correct positive value of $R(t)$ 440 ± 85 ^{14}C yr (1), according to the definition of Stuiver et al. (1986).

$$R(t) = 2930 - 2490 \pm \sqrt{(60^2 + 60^2)} = 440 \pm 85\ ^{14}\mathrm{Cyr} \quad (1)$$

However, this incorrect negative value of $R(t)$ was published in the subsequent papers of Dabrio et al. (1999, 2000) and none of their marine radiocarbon dates was converted into calendar dates using any ΔR value. Since then, several regional publications about Holocene coastal evolution (e.g. Borja et al., 1999; Lario et al., 2002) have used that roughly approach to carry out the calibration of sea shell samples or re-used the Lario's (1996) calibrated dates.

4. The need to review ΔR for the area: what reservoir effect correction should be used in the Gulf of Cádiz?

Research concerning the variability of the marine radiocarbon reservoir effect in the Gulf of Cádiz, and consequently of the upwelling phenomenon in the same region, during the Holocene, has been and is under way (Soares and Dias, 2006b). Results were presented during the IGCP#495 Annual Conference (2008) that took place at Faro (Portugal) and where at least some of Lario's collaborators were present. For these reasons the comments by Lario et al. (2010-this issue) about this research, namely about "location of particular samples, radiocarbon ages, ΔR values, sample material, laboratory code, etc." do not seem elegant. Meanwhile, these results were published (Soares and Martins, 2009). In Fig. 1 ΔR data determined for the Gulf of Cádiz are plotted against time. Besides the variability of the marine reservoir effect shown in the plot, two interesting and important features can be easily identified, comparing the results from the southern Portuguese coast (northwestern zone of the Gulf of Cádiz) with those from the eastern zone of the Gulf of Cádiz (Andalusian coast): (i) during the last three Millennia the ΔR values from the Andalusian coast are invariably lower than those from the Algarvian coast; (ii) positive ΔR values were determined for the time interval 4500–4000 BP for the entire Gulf of Cádiz.

As referred to above, due to the configuration of the eastern coastline of the Gulf of Cádiz wind-driven coastal upwelling is nonexistent in this coastal region, and the negative ΔR values determined for the interval 2000–200 BP or *circa* 4500 BP are in accordance with this fact. Conversely, for the southern Portuguese coast the ΔR values are positive implying the existence of an active upwelling off the coast. A weighted mean value for ΔR can be calculated for this coast taking into account all the values determined for the last three Millennia with three exceptions—the modern value, the peak at 1140 ± 45 BP and the negative value at 1280 ± 40 BP (see Soares and Martins, 2009, Table 1)—since the remaining seven values are statistically the same at 95.4% level. The calculated mean for ΔR will be 65 ± 20 ^{14}C yr. On the other hand, using the six negative values for the eastern coast of the Gulf of Cádiz and the same statistical criteria the calculated weighted mean for ΔR will be -135 ± 20 ^{14}C yr.

Before and after the time interval 4500–4000 BP the eastern coast seems to be characterized by the absence of an active upwelling as is the case today, while the southern Portuguese coast seems to have been subject to an active and variable wind-driven upwelling. ΔR data are still lacking between 4000 BP and 2000 BP but a conservative ΔR value of 100 ± 100 ^{14}C yr can be adopted and applied (Rodríguez-Vidal et al., 2009).

5. Final considerations

Soares (2005) was the first to determine an accurate marine radiocarbon reservoir effect ΔR for the eastern coast of the Gulf of Cádiz, which was published 1 year later (Soares and Dias, 2006b). From this date, and until 2009 (Rodríguez-Vidal et al., 2009), several publications concerning the Gulf of Cádiz have not used the available values of ΔR (e.g. Morales et al., 2008; Gutiérrez-Mas et al., 2009a, b; Zazo et al., 2009). The successive Comments and Replies published in Marine Geology during 2009 and 2010 indicate an evident persistence of certain teams in not recognizing the new contributions on this matter (see Soares, 2010-this issue). This was the principal circumstance that led us to recommending that "all published works in the Atlantic Iberian Spanish coast from the year 1996 have an incorrect

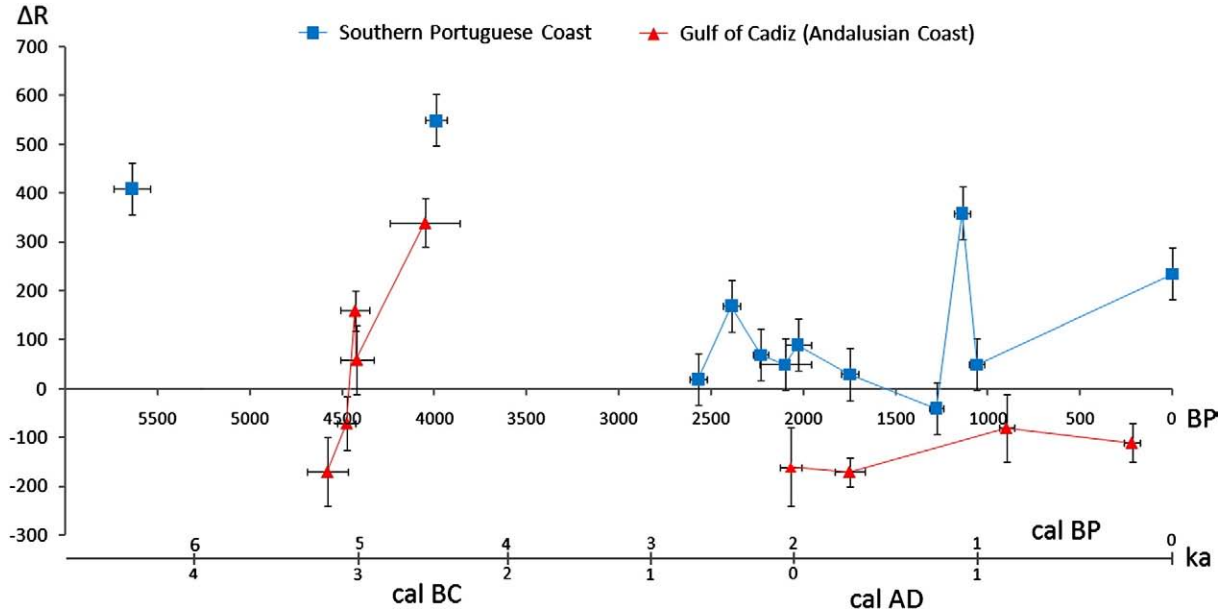

Fig. 1. ΔR ($\pm 1\sigma$) values for the Gulf of Cádiz plotted versus terrestrial ^{14}C ages ($\pm 1\sigma$) (Soares and Martins, 2009).

value of regional reservoir (ΔR) and, therefore, all calibrated ages and obtained conclusions must be kept in quarantine, until new revision" (Rodríguez-Vidal et al., 2009), which is now criticized by Lario et al. (2010-this issue).

The final conclusion of Lario et al. (2010-this issue) estimates that "the more reliable values of ΔR in the Gulf of Cádiz for middle-late Holocene samples seem to range between $\Delta R = 35 \pm 85$ yr and $\Delta R = 95 \pm 15$ yr". This last value was determined for the Portuguese coast, which is characterized by an active and variable upwelling conversely to what happens in the Andalusian coast of the Gulf of Cádiz. Consequently this value is meaningless concerning its application to marine radiocarbon dates of samples collected at this location. The values of $35 \pm 85\ ^{14}C$ yr, $80 \pm 110\ ^{14}C$ yr (Lario et al., 2010-this issue, Fig. 2) or $75 \pm 100\ ^{14}C$ yr (Soares, 2010-this issue) determined with the pair of samples from Lucio del Pescador must be discarded taking into consideration the kind of terrestrial sample and the doubts about the shell sample that were radiocarbon dated, as discussed above. On the other hand, we cannot foresee what meaningful conclusion can be drawn for the Fig. 2 presented by Lario et al. (2010-this issue). What they did only was to play with numbers or with statistics. The calibration of marine radiocarbon dates using anyone of the following ΔR values 35 ± 85, 80 ± 110, 95 ± 15, or $100 \pm 100\ ^{14}C$ yr, due to their mean values and large associated errors, will lead to statistically not distinct calendar ages. Nevertheless, for several reasons mentioned and explained above, the first three values would have an inadequate use, due to their inaccuracy or unreliability, if they were applied on the calibration of marine radiocarbon dates.

Of course, further research is needed to obtain more ΔR data in order to reliably calibrate conventional radiocarbon dates from marine shell samples with ages ascribed to Holocene time intervals badly sampled or not sampled at all. Nevertheless, scientific evidence points out that, during Late Holocene, the eastern coast of the Gulf of Cádiz is characterized by the absence of an active upwelling as is the case today. A mean ΔR value of $-135 \pm 20\ ^{14}C$ yr has been calculated for this last situation.

Therefore, and in contrary of Lario et al.'s (2010-this issue) opinion, in their final paragraph, there are now reliable values of ΔR to calibrate Mid–Late Holocene marine samples in the Gulf de Cádiz, and were so applied by Rodríguez-Vidal et al. (2009).

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