Determining the relationships between fluvial activity and climatic variability during the Holocene in Spain

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Abstract

A database of radiocarbon dates from Holocene fluvial environments in Spain has been compiled. The dates have been classified according to the different types of depositional environments and ensembles from which the samples were collected. The sampling locations have been categorised according to geographical region, elevation and drainage basin area. The results of the analysis indicate a number of phases of increased fluvial activity: 11,280-10,230 cal. BP; 9565-8785 cal. BP; 7975-7090 cal.BP; 5740-4135 cal. BP; 3880-3085 cal. BP; 2895-1820 cal. BP; and 1300-0 cal. BP. A review of the radiocarbon dating evidence combined with palynological data of Holocene vegetation changes indicate that increased fluvial activity and geomorphc effectiveness coincide with periods with a more open landscape indicating the importance of sediment supply in the formation of the depositional landforms. Detailed analysis of the record has enabled the relative forcing of climatic variability and anthropogenic impacts to be determined. The major climatic perturbations of the Holocene that are recorded in the fluvial record are the 8200 BP, 2650 BP and Little Ice Age periods of climatic deterioration, with increased flood frequency also related to the Medieval Warm Period.

Key words: Radiocarbon chronology; Holocene; Alluvial terraces; Palaeofloods; Climatic variability

Introduction

To date, determining the fluvial response to Holocene climatic and anthropogenic changes in the Mediterranean region has been restricted by the scarcity of radiocarbon dates from fluvial sedimentary contexts. Reviews have traditionally focused on fluvial sediments dated by archaeological associations (e.g. Vita-Finzi, 1969). Since the turn of the millennium however, there has been an increase in the number of radiocarbon dates published within Spain, therefore, it is timely to analyse and review the available dating evidence.

Methodology

A database was compiled of radiocarbon dates that were sampled from fluvial sedimentary contexts in Spain. In total 97 entries were made with the original dates and their errors recorded. Subsequent calibration of all the radiocarbon dates was carried out using the OXCAL calibration program (dates presented are at the two sigma level of confidence). For each radiocarbon date additional data was collated concerning geographical information (e.g. catchment area, elevation etc) and the sample's sedimentary provenance (e.g., sedimentary context, depositional environment). Dates from sedimentary contacts were classified as *change* dates and were considered the best samples within the database. With regards to palaeoflood deposits that result from individual flood events, sequences with multiple dates were considered as equivalent to *change* dates from alluvial terraces. Analysis of the compiled data-set was primarily carried out using the sum probability command within OXCAL that produces a plot illustrating the temporal distribution of the dates entered into the analysis (e.g. Figure 1). The *y* axis, probability per year, reflects the probability of the sampled date coming from that particular year, therefore, clustering of dates results in a greater peak. A number of probability plots were produced by entering different sets of radiocarbon dates into the sum probability calculation, for example according to different geographical area or different depositional environments (e.g. Figure 2).

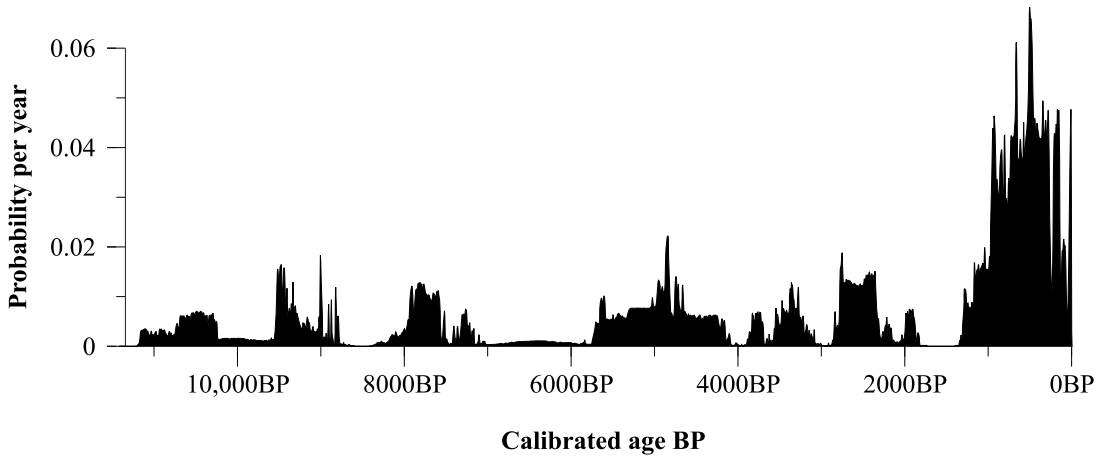

Figure 1. Sum probability of all radiocarbon dates sampled from fluvial environments in Spain

Results and Discussion

The summed probability plot based on all 97 radiocarbon dates is shown in Figure 1. From the graph, the Holocene radiocarbon chronology can be broadly divided into seven distinct periods with a clustering of dates from fluvial environments: 11,280-10,230 cal. BP; 9565-8785 cal. BP; 7975-7090 cal. BP; 5740-4135 cal. BP; 3880-3085 cal. BP; 2895-1820 cal. BP; and 1300-0 cal. BP.

The only fluvial sediments radiocarbon dated to the Early Holocene are the palaeoflood sequences of the Tagus River (Benito *et al*., 2003). Multiple dates have identified two periods of increased flood frequency at 10,700-10,300 cal. BP and 9600-8800 cal. BP. (Figure 2). Early Holocene pollen records from Spain indicate short climatic events during this period, for example the return to steppe-type vegetation with herbaceous pollen values reaching 85% at Las Tablas de Daimiel (Dorado Valiño *et al*., 2002), a response to the 8200 BP climatic event, a brief period of widespread increased aridity and cooler temperatures (Alley et al., 1997), calibrated to 9280-9030 cal. BP. The implication is that although the slackwater flood deposits indicate that this was a phase of large magnitude flooding (Benito *et al*., 2003), the physical presence of this sedimentary record may also relate to the increased sediment supply brought about by the reduced arboreal vegetation cover at this time.

During the Mid Holocene the radiocarbon samples in the record come from fine-grained floodbasin or palustrine sedimentation. These periods coincide with the Holocene climatic optimum when there was a greater taxonomical diversity and a greater tree cover with increases in *Quercus*, *Olea* and *Pinus*. The end of the palustrine phase in the fluvial record (*ca*. 4700 cal. BP) corresponds to a phase of greater aridity.

A cluster of samples date from the first millenium B.C., with all of these identified as *change* dates in the database indicating a significant change in sedimentation at the sites. This period appears to coincide with the 2650 BP climatic event, especially as pollen curves indicate that human activity did not severely affect the vegetation cover until around 2000-1700 years ago.

The highest density of radiocarbon dates in the record occurs from A.D. 650 onwards, with the majority of dates coming from alluvial terraces and slackwater flood deposits. Indeed, there appear to be two distinct records preserved by these distinct depositional environments. The majority of the fine grained alluvial facies date to the period A.D. 1000-1500, with two dates from gravel facies ca. A.D. 1500. The radiocarbon dates from palaeoflood deposits cluster in two periods, A.D. 800-1200 and A.D. 1400-1700 (Figure 2). Documentary records also indicate two periods of increased flood frequency, A.D. 1150-1290 and A.D. 1500-1850, separated by a period of reduced flooding (Benito *et al*., 1996). The increased frequency of palaeofloods dated to A.D. 800-1200 may be a response to the Medieval Warm Period that

lasted from A.D. 800-900 to A.D. 1200-1300 and appears to have had an impact on fluvial systems elsewhere in Europe (Brown, 1998). The latter period reflects the climatic deterioration of the Little Ice Age.

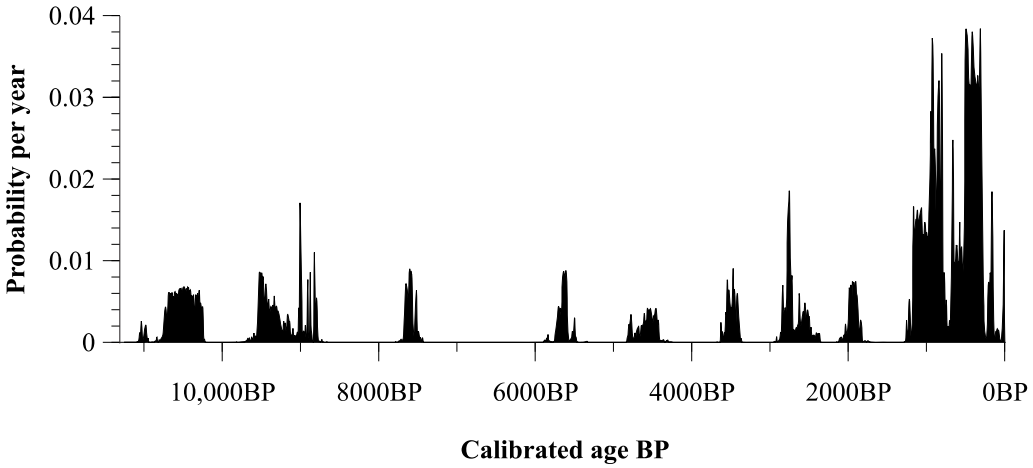

Figure 2. Sum probability of radiocarbon samples from palaeoflood deposits in Spain

Conclusions

1) The greatest fluvial activity (or geomorphic effectiveness) during the Holocene coincides with periods of open landscape with reduced tree cover, as inferred from radiocarbon dated pollen records. The presence of slackwater flood sediments and alluvial terraces are dependent primarily upon sediment supply and landscape stability that is linked to vegetation cover.

2) The major climatic perturbations of the Holocene that appear to be recorded in the fluvial record are the 8200 BP, 2650 BP and Little Ice Age periods of climatic deterioration. In addition there appears to be a period of increased flood frequency related to the Medieval Warm Period.

3) The greatest frequency of dates in the record come from the last 1300 years. In part, this may reflect increased preservation potential but additional evidence from archaeologically dated fluvial sequences in Spain indicate the importance of human impact on the landscape acting as a geomorphological trigger (Butzer, 1980) for increased landscape instability and increased sediment supply.

4) During the last 1300 years there appear to be distinct records from palaeofloods and alluvial terraces. This reflects the different temporal scales of the two sedimentary records with slackwater flood deposits resulting from single hydrological events, whereas alluvial terraces respond to longer-term shifts in sediment supply or hydrological regime. A combined analysis of palaeoflood sequences and alluvial

terraces appears a valid means of distinguishing climatic and anthropogenic forcing of change in the fluvial environment.

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