Quaternary Science Reviews xxx (2015) 1–19

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

A fluvial record of the mid-Holocene rapid climatic changes in the middle Rhone valley (Espeluche-Lalo, France) and of their impact on Late Mesolithic and Early Neolithic societies

Jean-François Berger [a, *], Claire Delhon [b], Frédéric Magnin [c], Sandrine Bonté [d], Dominique Peyric [e], Stéphanie Thiébault [f], Raphaele Guilbert [g], Alain Beeching [h]

[a] Université de Lyon, CNRS, Université Lyon 2-Lumière, UMR 5600 EVS, F-69007, France
[b] Univ. Nice Sophia Antipolis, CNRS, CEPAM, UMR 7264, F-06300 Nice, France
[c] IMBE, Aix-Marseille Université, CNRS, IRD, Avignon Université, Europôle Méditerranéen de l'Arbois, BP 80, F-13545 Aix-en-Provence Cedex 4, France
[d] 10 place Achille Jubinal, 65200 Bagneres de Bigorre, France
[e] Musée Pierre Martel de Vachères, F-04110 Vachères, France
[f] Muséum national d'Histoire naturelle, CNRS, Archéozoologie, Archéobotanique, UMR 7209, F-75005 Paris, France
[g] Université de Lyon, INRAP, Université Lyon 2-Lumière, UMR 5133 Archéorient, F-69007, France
[h] Université de Lyon, Université Lyon 2-Lumière, MOM-UMR 5133 Archéorient, F-69007, France

ARTICLE INFO

Article history:
Received 8 April 2015
Received in revised form
11 November 2015
Accepted 30 November 2015
Available online xxx

Keywords:
Mid-Holocene
Rapid climatic change
8.2 and 7.7/7.1 events
Middle Rhone valley
fluvial metamorphosis
Palaeosoil
Early Neolithic
Ecological successions

ABSTRACT

This multi-proxy study of a small floodplain in the Rhone catchment area, at the northern edge of the Mediterranean morphoclimatic system, provides valuable information concerning the impact of mid-Holocene climate variability (8.5–7.0 ka) and the effects of two *rapid climatic changes* (8.2 and 7.7/7.1 ka) on an alluvial plain, its basin and the first farming societies of the Rhone valley. Around 7.7/7.1 ka, the combined effects of (1) a strong rate of change in insolation and (2) variations in solar activity amplified marine and atmospheric circulation in the north-west Atlantic (Bond event 5b), which imply continental hydrological, soil and vegetation changes in the small catchment area. For this period, strong fluctuations in the plant cover ratio have been identified, related to a regime of sustained and regular fires, as well as abundant erosion of the hill slopes and frequent fluvial metamorphoses which led to braiding of the watercourse in this floodplain. There are few data available to evaluate the impact of natural events on prehistoric communities. This continental archive offers clear multi-proxy data for discussion of these aspects, having 4 cultural layers interbedded in the fluvial sequence (1 Late Mesolithic, 3 Cardial/Epicardial). Earlier data indicate the difficulty in recognizing such cultural features in the low alluvial plains of southern France during the Mesolithic/Early Neolithic transition, which should lead to caution when developing settlement models for this period.

1. Introduction

There is very little precise geomorphological and palaeohydrological data for the Middle Holocene in the north-west Mediterranean basin, where the Neolithic colonization front known as *Impressa-Cardial* developed between 7.8 and 6.8 ka. Moreover, the links between the transformation of river systems and climatic changes at high temporal resolution are still barely known. However, since the Rapid Climatic Changes (RCC) of the Holocene have been confirmed on a hemispheric scale (Alley et al., 1997; Mayewski et al., 2004; Magny, 2004; Fleitmann et al., 2007, Combourieu-Nebout et al., 2013), firmly correlated to Bond events in the North Atlantic (Bond et al., 2001), the variability of the climate and of the continental ecosystems has become controversial, particularly concerning the mid-Holocene 'thermal maximum' (also designated as Atlantic period) which is still considered to be a long period of stability for landscapes and watercourses. Most of the scientific publications concern the *8.2 ky event*, which is the best known and best recorded of the Holocene RCCs (Baldini et al., 2002; Magny et al., 2003; Alley and Agustsdottir, 2005; Rohling and Pälike, 2005; Weninger et al., 2006; Berger and Guilaine, 2009). The other oscillations in the first half of the Holocene, identified in

* Corresponding author.
E-mail address: Jean-Francois.Berger@univ-lyon2.fr (J.-F. Berger).

http://dx.doi.org/10.1016/j.quascirev.2015.11.019
0277-3791/

the polar ice fields, are rarely detected or dated in the continental ecosystems (Hoek and Bos, 2007; Fleitmann et al., 2008).

Lacustrine data are useful for the establishment of age models, providing the advantage of detailed chronology. These data come mainly from the continental Alpine region (Jura, northern Alps, Swiss plateau, Bavaria, northern Italy) (Kalis et al., 2003; Magny, 2004). In the Mediterranean area these data are mainly concentrated in Italy (Sadori and Narcisi, 2001, Magny et al., 2007, 2012), Turkey (Roberts et al., 2008) and secondarily in the Iberian peninsula (Carrión, 2002). The latest results show palaeo-hydrological variations strongly related to the climatic fluctuations in the northern hemisphere, which are connected to variations in solar activity and ocean circulation (Magny et al., 2003).

Alluvial valley landforms are the geomorphic expression of river response to combined internal (autogenic) controls and changes in external (allogenic) forcing factors (Erkens et al., 2009). Studies of the Rhone river region (Bravard et al., 1997; Bravard, 2010) and other regions (Starkel, 1983; Brown, 1997; Macklin, 1999) have demonstrated that changes in the type and output of a river are good indicators of the hydro-climatic evolution in the drainage basins. However, concerning the first millennia of the Holocene, which correspond to the optimum of landscape stabilization by vegetation, the fluvial chronology is often not accurate enough to match this period with the chronocultural framework established by archaeology for the last hunter-gatherers and the first agricultural societies. This information gap is mainly due to (1) a frequently imprecise chronology for valley fills (limited ^{14}C, too large sampling interval …), still partly based on palynological evidence, which may provide reliable points of reference but cannot replace absolute dating (Kozarski, 1991; Dambeck and Thiemeyer, 2002), (2) the poor preservation of the alluvial records from this period, because of later riverbed evolution, often characterized by high mobility and torrential features in the north-west Mediterranean region (Berger, 2006, 2011), and finally (3) to the difficulties of accessing the fluvial records for this period, which are deeply buried, particularly in coastal environments (deltas and rias) (Arnaud-Fassetta et al., 2005; Vött et al., 2006). There are new opportunities for detection of Holocene oscillations through the very high chronological resolution of channel filling (Toonen et al., 2012; Salvador and Berger, 2014).

Indeed, some regional studies carried out in central Europe have diagnosed fluctuations in watercourses during the Early Holocene based on morphodynamic and sedimentary criteria: Kalicki (2006) in Poland and Bielorussia, Becker and Schirmer (1977) as well as Delorme and Leuschner (1983), through the study of sub-fossil oak trunks deposited in Holocene valley fills in south-west Germany. Recently, quantitative studies carried out using cumulative probability distribution functions (CPDF) of ^{14}C ages pinpointed the major Holocene hydrological events in large areas or countries, especially for the mid-Holocene (Great Britain, Germany, Poland, Tunisia) (Starkel et al., 2006; Hoffmann et al., 2008; Zielhofer and Faust, 2008; Macklin et al., 2010).

In the Rhone catchment area (100,000 km^2), the region of Lyon has produced much evidence thanks to rescue archaeology (Bravard et al., 1997; Berger et al., 2008); the high marly basins of the Durance river system in the limestone pre-Alps in southern France, which were highly sensitive to the palaeoclimatic variations of the early Holocene, present sequences that have been accurately dated by dendrochronology (Sivan and Miramont, 2008); the upper Rhone area, around Lake Bourget, provides evidence for major well-defined and regular detrital events in the northern slopes of the Alps (Arnaud et al., 2005, 2012) (Fig. 1A). Elsewhere, the first half of the Holocene has attracted little research except for some studies on the early/mid-Holocene in the southern Mediterranean (Tunisia and Morocco) along riverbanks that were deeply incised during the Late Holocene (Zielhofer and Faust, 2008).

The purpose of this paper is to present the results of a multi-proxy study based on a transverse section of the Citelle alluvial plain (middle Rhone Valley, France) carried out in the course of the excavation of the Lalo archaeological site, at Espeluche (Drôme). The alluvial terrace consists of a 3-m-thick sedimentary load and is located 2 m above the current plain of the Citelle river (Fig. 2). It contains a thick fluvial sequence for the period 8.5–7.0 ka. The preservation of the pedosedimentary archive is due to an overbank flow of the Citelle river linked to a general entrenchment of the river system around 7 ka, equivalent to the incision that revealed the "main Holocene fill" in the Durance catchment area (Jorda et al., 2002).

The section also revealed cultural horizons that are rarely found other than in karst cavities in the north-western Mediterranean (Castelnovian Late Mesolithic and several Cardial/Epicardial Early Neolithic layers) (Guilaine, 1996). Unfortunately, the open-air Neolithic sites in the western Mediterranean are "flat" in the alluvial plains and are thus difficult and even impossible to detect with traditional survey methods. Their presence demonstrates the incomplete state of regional archaeological archives and represents an opportunity for the local chronostratigraphic building and the discussion of hydrogeomorphological impacts on mid-Holocene settlement systems.

1.1. Environmental and archaeological contexts

1.1.1. Geological, hydrological and bioclimatic context

The Citelle basin forms the lower part of the Jabron and Roubion catchment areas (total 610 km^2) and extends over more than 27 km^2 in the middle Rhone, east of the city of Montélimar. It culminates at 495 m in the foothills of the calcareous French pre-Alps (Fig. 1A and B). This river is the major left bank tributary of the Jabron river, which joins the Roubion river at the point of its confluence with the Rhone (Fig. 1B). The Citelle basin consists principally of Secondary marine formations and of Tertiary (Oligocene) lacustrine formations which lie discordantly upon the marine formations towards the south, near the Aleyrac-Montjoyer plateau. In the middle and upper parts of the catchment area, the marls of soft glauconite sandstone and sand are very erodible and abundant. On abrupt slopes, they form typical badlands, currently in a phase of stabilization by the vegetation cover. The downstream part of the basin, where Lalo is located, is mainly composed of Quaternary formations: very gravelly terraces or alluvial fans, under red, slightly fersiallitic or leached brown soils. The site is found some metres above the present-day alluvial plain, on an early Holocene terrace, in the apex of the Holocene alluvial fan of the Citelle river (Fig. 1B). The basin of the Citelle presents high slopes, which explains the reactivity of the hydrological system during the Holocene.

It is located in the Mediterranean climatic zone influenced by tropical high pressure but at the edges of the medio-European and Alpine climatic influences, which are influenced by the westerlies throughout the year. The climate is thus transitional between the Mediterranean, continental and Atlantic climates. The total average annual precipitation is 900 mm, with important annual variations (300–1700 mm) and a high inter-annual variability in precipitation pattern (Blanchet, 1990). The area is affected by an attenuated Mediterranean summer drought (1–2 months of water deficit according to the Thornthwaite water balance) with concentration of rainfalls in autumn and spring. The vegetation of the Citelle basin is typical of the supra-Mediterranean stage. Besides cultivated areas, deciduous oak (*Quercus pubescens*) formations and degradation facies characterised by the abundance of box (*Buxus sempervirens*) are characteristic of the middle Rhone valley landscape.

Please cite this article in press as: Berger, J.-F., et al., A fluvial record of the mid-Holocene rapid climatic changes in the middle Rhone valley (Espeluche-Lalo, France) and of their impact on Late Mesolithic and Early Neolithic societies, Quaternary Science Reviews (2015), http://dx.doi.org/10.1016/j.quascirev.2015.11.019