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Changes in ecosystems, climate and societies in the Jura Mountains between 40 and 8 ka cal BP

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ABSTRACT

We present radiometric, palaeoclimatological, palaeoenvironmental and archaeological data for the period 40 000–8000 cal BP in the Jura Mountains (eastern France). These mountains culminate at ~1700 m a.s.l. and are today characterised by a semi-continental climate. During the Last Glacial Maximum, the range supported a local ice cap. While recent data suggest a possible early ice-cap development during MIS 4, the chronology of the regional LGM and following deglaciation has still to be refined. The complete disappearance of the local ice cap at ca 17 000–16 600 cal BP marked the beginning of accumulation of sediment archives in the Jurassian lakes and mires, which favoured the reconstruction of past changes in climatic and environmental conditions, in addition to faunal remains found in caves and in archaeological sites. Three main successive stages may be distinguished regarding the history of societies. The first stage at ca 40 000–18 700 cal BP was characterized by very few archaeological sites with only discontinuous intermittent occupations, always located outside the Jura range. The second stage, around 18 700–11 700 cal BP, corresponded to an increase in the population density, as suggested by an increasing number of archaeological sites and a progressive colonisation of elevated areas of the Jura Mountains. The third stage at ca 11 700–8000 cal BP coincided with a reinforcement of settlement in the lowland areas as well as a development of long-term occupations in elevated areas. The millennial-scale GS-1 cold event had a more long-lasting and stronger impact on societies than did the 200 year-long 8.2 ka cold event.

1. Introduction

Following the aims of the INTIMATE Working Group 4, the present paper endeavours to provide a tentative synthesis of palaeoclimatic, palaeoenvironmental and archaeological data for the period 60–8 ka in the Jura Mountains. Along the border between eastern France and western Switzerland, the Jura Mountains are a medium-sized range mainly composed of Mesozoic limestone. Their western slope is characterised by a succession of plateaus from around 300 to ~800 m a.s.l. To the east, the 'Haute Chaîne' is marked by a folded structure and culminates at ~1700 m a.s.l. with an abrupt transition to the Swiss Plateau located at ~400/500 m a.s.l. At present, the climate of the region is semi-continental with strong contrasts between seasonal temperatures. The mean annual temperature is ~9°–10 °C in Besançon and Geneva, but only ~3°–4 °C at the highest parts of the range. Due to the influence of westerlies and the orographic effect, the annual rainfall ranges from ~1000 mm in Besançon to ~2000 mm in the most elevated areas. Concerning the present-day vegetation, the plateaus are dominated by deciduous forests (*Quercus*, *Fraxinus*, *Fagus*) and the Haute-

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Chaîne by *Abies-Picea* forests above 800–900 m a.s.l. and (subalpine) meadows above ~1400–1500 m a.s.l. Over three decades, numerous multidisciplinary papers have been dedicated to the second half of the Holocene and the possible interactions in the Jura Mountains between climate variations, environmental changes and the history of the first agricultural societies (e.g. Gauthier, 2004; Pétrequin et al., 2005; Magny et al., 2009). However, relatively few studies have focused on the time interval from 40 to 8 ka, and they often deal with the Jura range only in part, depending on the space, the time interval, and/or the domains considered (palaeoclimates, palaeoenvironments, archaeology) (e.g. Wohlfarth et al., 1994; Leesch, 2000; Cupillard and Perrenoud-Cupillard, 2003; Leesch et al., 2012; Cupillard et al., 2013). In this general context, the paper attempts (1) to present available palaeoclimatic, palaeoenvironmental and archaeological data to document the 40–8 ka time window in the Jura Mountains, and (2) to outline a tentative reconstruction of possible changes in societies in relation to changes in climatic and environmental conditions. Finally, 1) we point out some methodological problems in the development of this synthesis, 2) we propose a general model of regional archaeological evolution, and 3) we develop remarks regarding further investigations for a better understanding of past interactions between climate, environment and societies.

2. Palaeoenvironmental and palaeoclimatic data

2.1. The Last Glacial extent in the Jura Mountains

In the Jura Mountains, only the last glacial extents are currently recorded by glacial deposits (Campy, 1992; Buoncristiani and Campy, 2011). The most extensive glaciation represented by lines of strongly eroded end moraines shows a westward extension to the Jura/Bresse limit around 300 m a.s.l. According to palynological studies (Beaulieu de, 1984; Beaulieu de and Reille, 1989) and multi-approach dating studies on proglacial deposits (Dehnert et al., 2010) in neighboring areas, this morainic complex, called External Moraine Complex (EMC), is related to the classical Riss Glaciation and is correlated to Marine Isotope Stage (MIS) 6. The last main ice extent, the so-called Last Glacial Maximum (LGM), is identified by a large number of exposures and the palaeogeography of glacial limits for the Jura and northwest Alps can be drawn with relative confidence. The proposed limits (Fig. 1) are compiled from Campy and Arn (1991), Campy (1992), Coutterand (2010), and Schlüchter et al. (2010). These authors have synthesized several previous studies. During the LGM, a discrete icecap covered the Jura Mountains. The Internal Moraine Complex (IMC) indicates a more limited westward extension than the EMC. Ice did not extend below 530 m a.s.l. on the western margin where ice tongues have impounded some large proglacial lakes. The ice cap culminated around 1800 m a.s.l. in the central part of the Jura and only some of the higher summits of the upper range emerged from the eastern slope of the glacier (nunataks). On the eastern margin of the Jura, the icecap flowed in contact with the Rhone glacier at the mean altitude of 1200 m a.s.l. The petrographical nature of deposits of the IMC, exclusively local calcareous material, demonstrates that during the LGM, the Rhone glacier never penetrated the Jura Mountains. Due to the lack of studies and the unclear disposal of moraines, geometry and limits of the northern and the southern ends of the Jura icecap are still unclear. However, north of 47°N, it seems that the icecap was scattered in small units limited to the highest part of the relief (Aubert, 1965; Schlüchter et al., 2010). Southwards, Buoncristiani and Campy (2004) propose a maximum extension of the icecap to the edge of the Rhone Glacier. Coutterand (2010) indicates a disconnected limit and a termination of the Jura glacier close to 46°N.

The chronology for the IMC is not clear. Biotic remains have never been found in the moraines and the calcareous material, subjected to weathering and pedogenetic processes, does not allow for classical luminescence or cosmogenic dating. Based on the examination of outcrops of the Combe d'Ain proglacial lake filling (mainly the assemblage of delta sediments and moraines) (Fig. 2), Buoncristiani and Campy (2004) show that IMC was marked at its margin by three stages of stabilization during the advance and five episodes of stabilization in the course of glacial recession (Fig. 2). Comparison with $\delta^{18}O$ data from GISP2 (Grootes et al., 1993) allows a possible chronology for the last glacial maximal advance at 27 500–24 000 cal BP and glacial retreat at 24 000–19 000 cal BP. That chronology, indicating a maximal extent during the MIS 2 at 24 000 cal BP, is notably consistent with the synchronous extent of the Rhine-Linth glacier on the northern Swiss Plateau (Preusser et al., 2011) and in phase with the Rhone glacier variations (Ivy-Ochs et al., 2004; Triganon et al., 2005; Guiter et al., 2005).

Further north from the Combe d'Ain, the recent discovery of a section near Arçon at 850 m a.s.l., located on the limit of the LGM glacier extension, reveals a two-phase glacial extent for the IMC (unpublished data). The sequence consists of two main outwash glaciofluvial gravel deposits situated within a thin lacustrine complex (Fig. 2). This intermediate unit is composed of silt to sand layers with, at least, four centimetric peat horizons. The radiocarbon dates give an infinite chronology for the older peat horizon (>51 000 BP – lab. ref. POZ 42964) and 48 600–44 600 cal BP (lab. ref. POZ- 4265) for the uppermost one. This unit indicates a temperate climate and definitely an unglaciated area. Chronology and sediment characteristics lead to a possible correlation with the Gossau-interstadial-Complex in lowland Switzerland (Preusser et al., 2003) at the end of MIS 3. Based on the dating of the lacustrine unit, the basal glaciofluvial unit could correspond to a first early/lower Würmian glacial advance during MIS 4, according to the data from the Swiss Plateau (Preusser and Schlüchter, 2004) and the Evian Plateau (Guiter et al., 2005) (Fig. 2). The top glaciofluvial unit corresponds to an outwash deposit linked with a second and a last extent (or readvance?) of the glacier. Because of its location on the IMC, this deposit must be considered as synchronous of the Combe d'Ain ice front. Paleogeography and timing of the glacial retreat in the inner Jura after 19 000 cal BP remain unclear and poorly studied. Moraines and subglacial deposits related to the retreat indicate a progressive reduction of the ice cap from the external limits to the upper range (Campy, 1992). However, the discovery of a mammoth skeleton at Praz Rodet (Fig. 2) in a proglacial deposit of the Vallée de Joux (Weidmann, 1969; Aubert, 1971), at 1050 m a.s.l. in one of the upper valleys of the Jura Mountains, highlights the terminal stage of the melting. The recent dating of the mammoth (Lister, 2009) indicates that the valley, and probably the almost entirely upper range of the Jura, were ice-free at 17 000–16 600 cal BP.

LGM environmental change had a major impact on the terrestrial biota, particularly well documented in the Jura area (Fig. 3). Mammal faunal species responded at a different rate according to their individual ecologies and the degree of constraints they had to cope with. During pre-LGM times, there is evidence of a first wave of extinction concerning the cave bear and probably also the cave hyena. The earliest definite radiocarbon dated cave bear comes from Rochedane, and yielded a radiocarbon date of 23 900 + 110 -100 BP (28 730–28,500 cal BP, one sigma range) (Bocherens et al., 2013). This date which corresponds to the period just before the glacial advance of the

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