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### ► To cite this version:

Christophe Cupillard, Michel Magny, Hervé Bocherens, Anne Bridault, Carole Bégeot, et al.. Changes in ecosystems, climate and societies in the Jura Mountains between 40 and 8 ka cal BP. *Quaternary International*, 2015, Volume 378 (18 August 2015), pp.40-72. 10.1016/j.quaint.2014.05.032 . hal-01294941

**HAL Id: hal-01294941**

**<https://hal.science/hal-01294941v1>**

Submitted on 28 Oct 2019

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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.

### Keywords:

Last Glacial Maximum  
Early Holocene  
Jura Mountains  
Palaeoclimates  
Palaeoenvironment  
Upper/Late Palaeolithic–Mesolithic societies

## 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

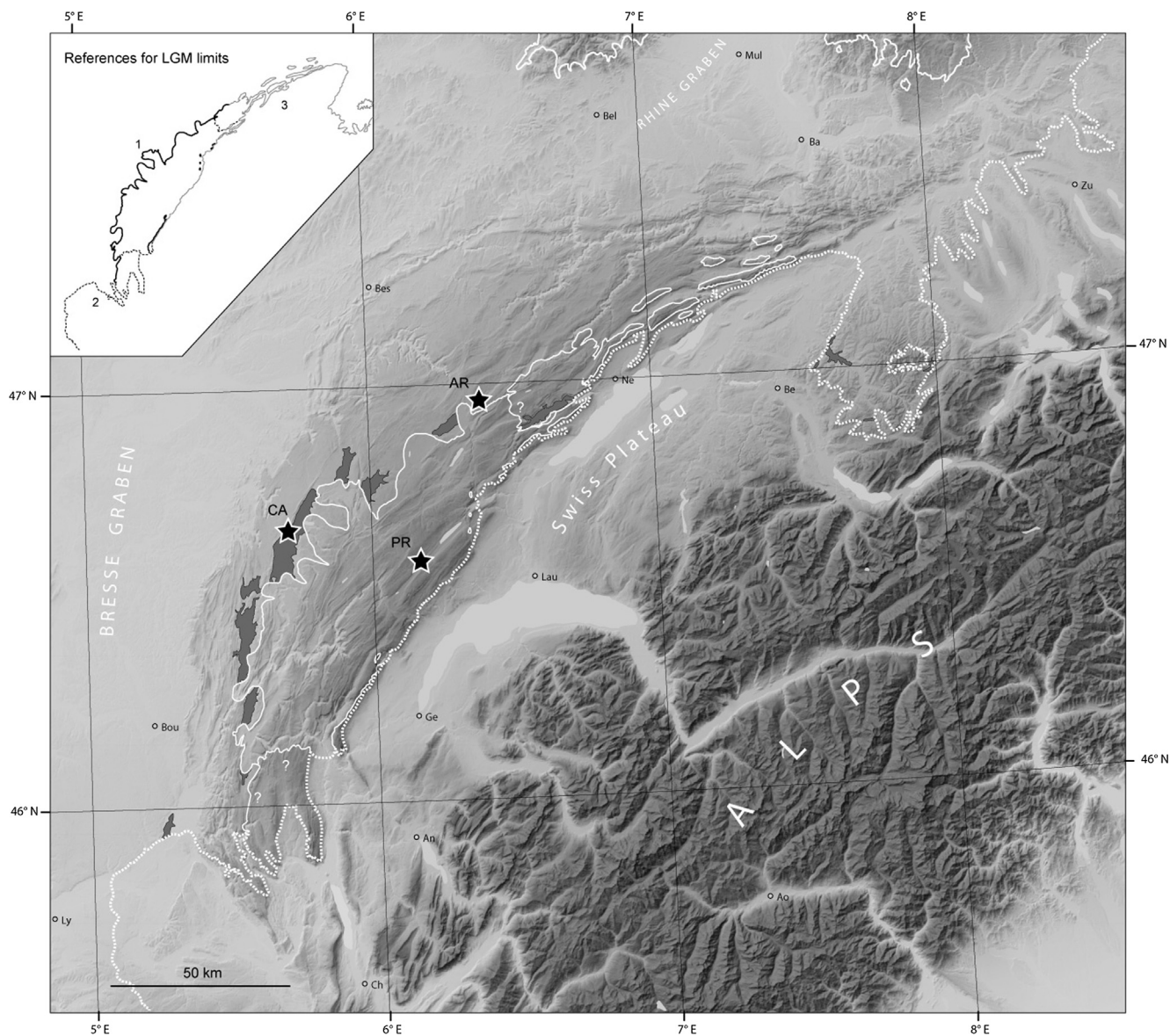
In the Jura Mountains, only the last glacial extents are currently recorded by glacial deposits (Campy, 1992; Buoncristiani and Campy, 2011). The most extensive glaciation represented by lines of strongly eroded end moraines shows a westward extension to the Jura/Bresse limit around 300 m a.s.l. According 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  $\delta^{18}\text{O}$  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

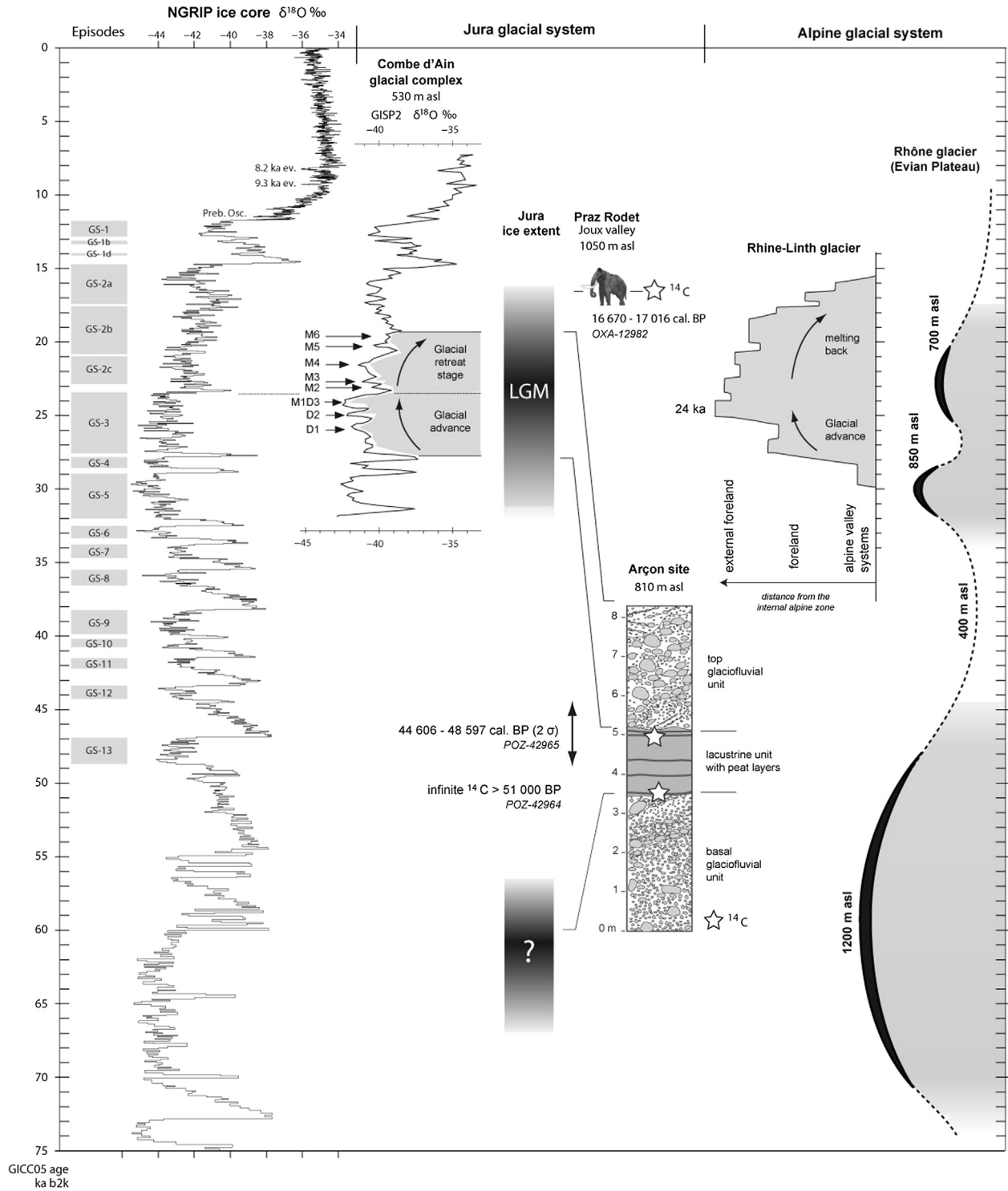


**Fig. 1.** Maximal extent of the glaciers and ice cap in the Jura Mountains (white line) and the Northern Alps (white dotted line) during the Last Glacial Maximum (LGM). Grey areas correspond to temporary proglacial lakes. In the inset, numbers refer to the authors for the limits: 1 (black line) = (Campy, 1992) and (Buoncristiani and Campy, 2004); 2 (dotted line) = (Coutterand, 2010); 3 (grey line) = (Schlüchter et al., 2010). Black stars refer to the sites mentioned: CA = Combe d'Ain glacial complex; PR = Praz Rodet mammoth; AR = Arçon site.

LGM is consistent with the pattern found in Western and Central Europe (Pacher and Stuart, 2009). This dated cave bear specimen also documents a longer survival of the specific genetic lineage *Ursus spelaeus* in the French Jura in contrast to the Swabian Jura (Southwestern Germany) where it was replaced by the *Ursus ingressus* type of cave bear around 31 500 cal BP (Münzel et al., 2014). A late survival of the cave hyena (*Crocota spelaea*) to the Late Glacial in the French Jura was previously suggested by the direct radiocarbon dating of a femur from the Grappin cave (Cupillard and Welté, 2006). However, the stable isotope analyses performed since this publication on the same bone have revealed that it was misidentified and belongs to a herbivore (Drucker, unpublished data). There is thus so far no clear data of attested hyena during the post-LGM period, and therefore no data from the French Jura speaks against the general pattern of extinction of the cave hyena before the LGM (Stuart and Lister, 2007).

## 2.2. Lateglacial period (ca 17 000–11 700 cal BP)

The local ice cap prevented the accumulation of sediment in the lake basin of the Jura Mountains during the Last Glacial Maximum. As a consequence, the pollen records documenting the vegetation history in the region begin only with the deglaciation, i.e. after ca 17–16 ka cal BP (Oldest Dryas pollen zone) for the highest parts of the range (Campy et al., 1985). The Lateglacial vegetation of the Jura Mountains and their western and northern margins has been revealed by 18 palynological records (Wegmüller, 1966; Richard, 1988, 1996; Ruffaldi, 1993, 2009; Schoellammer, 1998; Bégeot, 2000; Bégeot et al., 2000; Bégeot, 2006; Leroux et al., 2008). The cores analysed were collected at different altitudes ranging from 198 m to 1370 m (Fig. 4) in various geomorphological contexts such as lakes (i.e. Lakes Saint Point, Chalain, Abbaye, Etival, Bellefontaine, and Petit Maclu), mires with residual lakes (Cerin, Lautrey, Onoz and les Cruilles (CH)), bogs

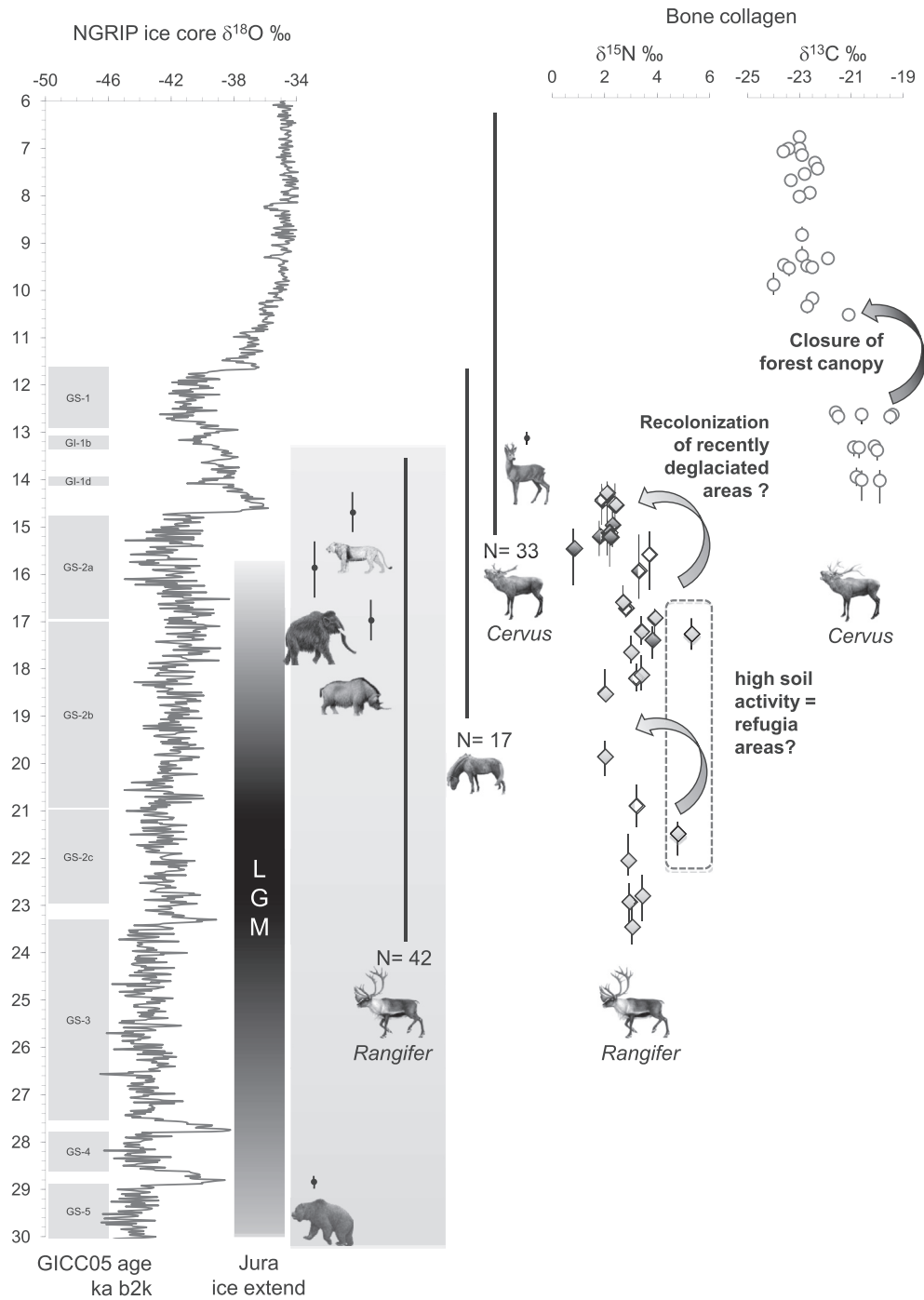


**Fig. 2.** Chronology of the Last Glacial Maximum in the Jura Mountains compared to the Alpine glacial system and the Greenland ice sheet climate (NGRIP). The NGRIP oxygen isotopes curve is based on the INTIMATE event stratigraphy (Blockley et al., 2012) for the period 48–0 ka, and the NGRIP Project data (NGRIP Members, 2004) for the period 75–48 ka. The GISP2 oxygen isotopes record (Groote et al., 1993) associated to the Combe d'Ain glacial stages refer to Buoncristiani and Campy (2004). Data for the Alpine glacial system are from Preusser et al. (2011) for the Rhine-Linth glacier and Triganon et al. (2005) for the Rhône glacier (Evian Plateau).

(Creux du Coure (CH) and Arinthod), and marshes (Pré Mourey, Le Locle-Col des Roches (CH), le Miroir, Morteau-Montlebon and Mont Roux (CH)).

Despite the geographical heterogeneity, the pollen records provide very similar trends of main taxa that characteristically

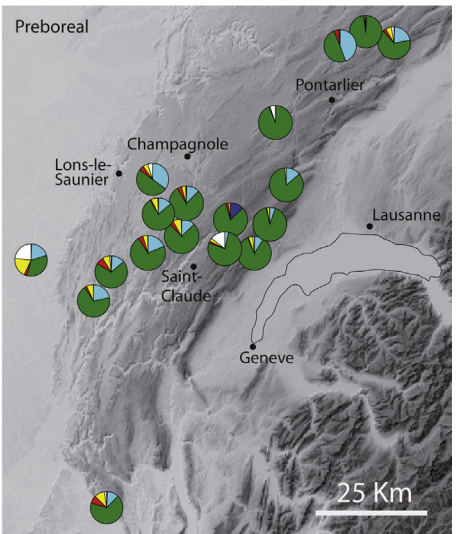
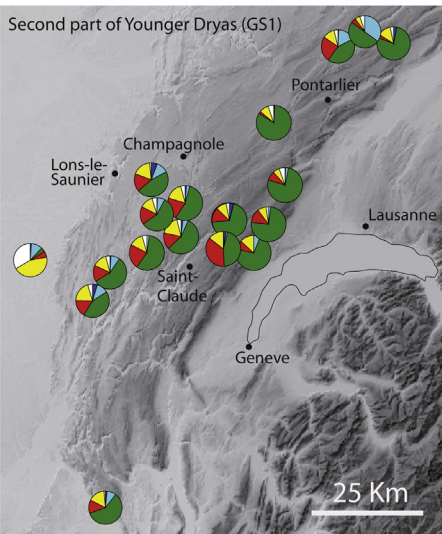
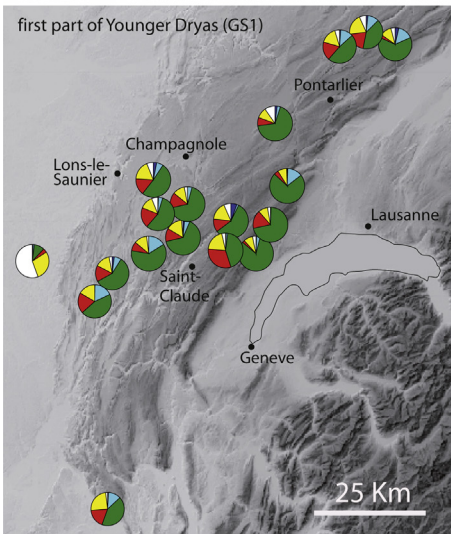
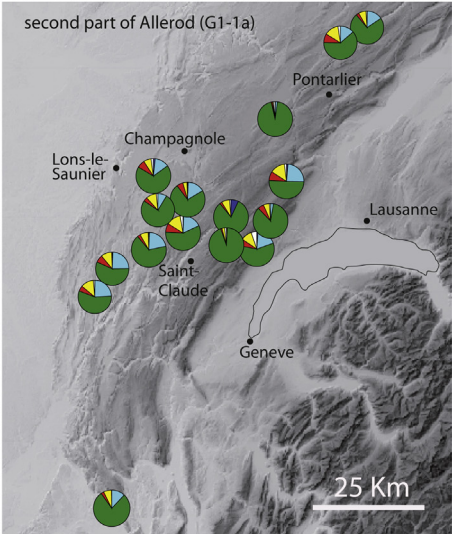
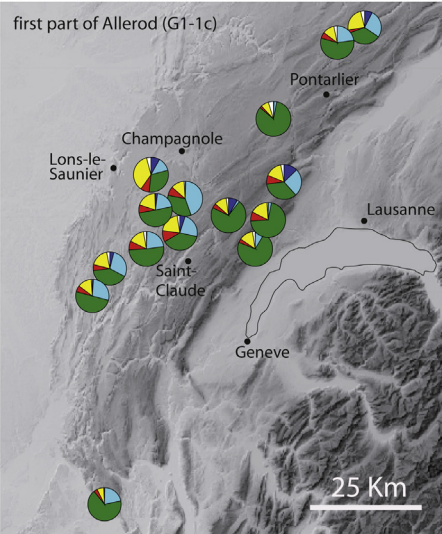
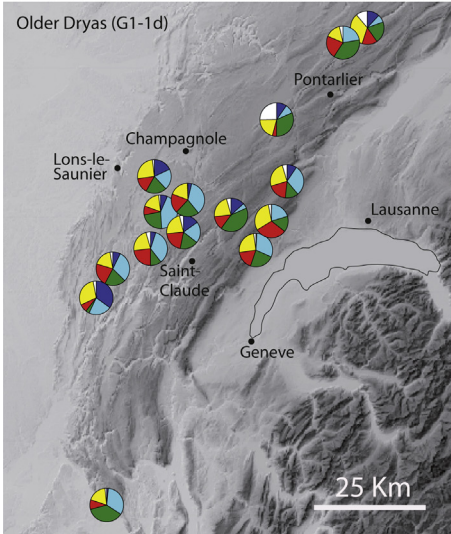
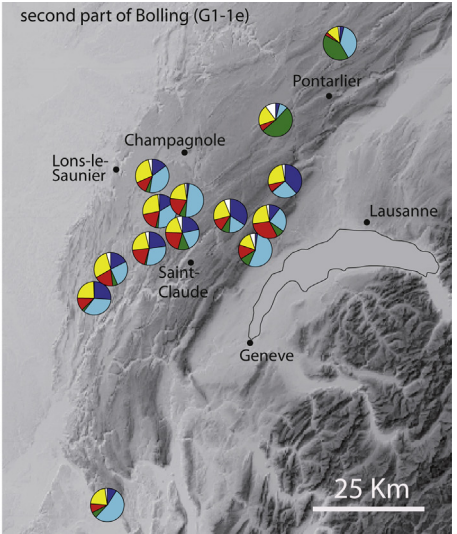
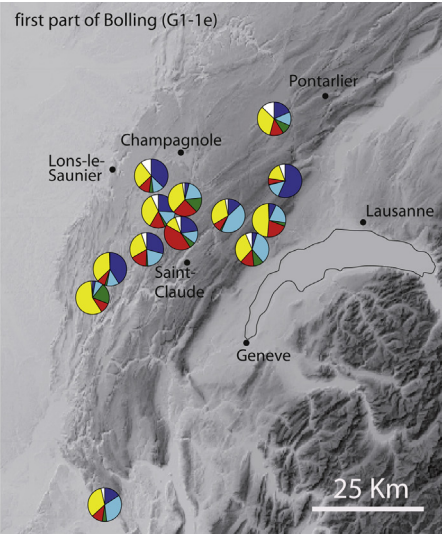
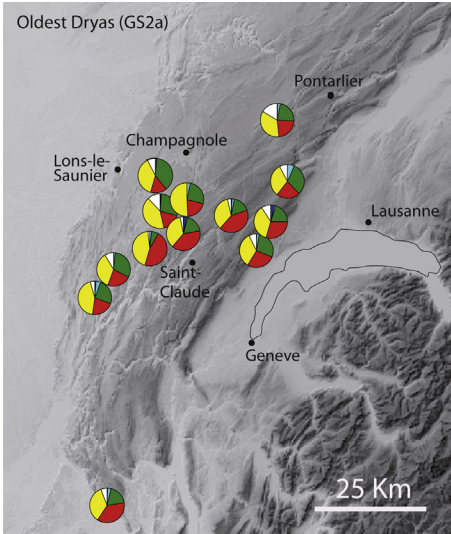
dominate the Lateglacial i.e. *Juniperus*, *Betula*, *Pinus*, *Artemisia* and *Poaceae* whose percentages are shown in Fig. 1. The regional biostratigraphy was inferred by correlation of common pollen events which were supposed to be synchronous : the start of the Bølling pollen zone was indicated by the first consequent increase



**Fig. 3.** AMS radiocarbon and isotopic records of selected fauna species from the Jura area. The latest date (2 sigmas) is given for the extinct species (*Panthera leo*, Stuart and Lister, 2011; Bocherens et al., 2011; *Coleodonta antiquitatis*, Cupillard and Welté, 2009; *Mammuthus primigenius*, Bridault and Chaix, 2009). The earliest date is given for *Capreolus capreolus*, unpubl. For the three other herbivore hunted species, *Rangifer tarandus*, *Equus ferus* and *Cervus elaphus*, the time range is given as well as the number of dates. The bone collagen  $\delta^{15}\text{N}$  values of reindeer over time reflect the intensity of soil processes which depends mainly on the temperature and permafrost influence (e.g. Drucker et al., 2012). Increasing soil activity as a result of decreasing permafrost intensity lead to increasing  $\delta^{15}\text{N}$  values in soils, plants and animals of the ecosystem. The diamonds in dark grey correspond to reindeer remains found in archaeological sites that were not accessible during the main part of the Last Glacial Maximum. The bone collagen  $\delta^{13}\text{C}$  values of red deer are an indicator of the density of the forest cover. Under a dense canopy, the depleted  $\delta^{13}\text{C}$  values of plants are passed on to the large herbivores feeding regularly on them (e.g. Drucker et al., 2008, 2011a). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of the pioneer shrub values (*Hippophae*, *Juniperus* and *Salix*), the Older Dryas biozone was marked by an increase in Non Arboreal Pollen (NAP) values, the beginning of the Allerød pollen zone corresponds to an increase in *Pinus* values, the transition to the

Younger Dryas pollen zone was marked by the increase of *Artemisia* values which decrease at the onset of the Preboreal pollen zone. As most profiles from pioneer studies have not been radiocarbon dated, the chronological context was deduced by comparisons with



*Juniperus* percentages  
 *Betula* percentages

*Pinus* percentages  
 *Poaceae* percentages

*Artemisia* percentages  
 *Cyperaceae* percentages

dated sequences, in particular the well radiocarbon-dated and high-resolution pollen records from Lake Lautrey which appear to show strong similarities with the Gerzensee and Greenland palaeoclimatic records (Magny et al., 2006).

In general, the base of the profiles was dominated by high percentages of herbaceous pollen, mainly *Artemisia*, Poaceae and other heliophilous taxa including Chenopodiaceae and *Helianthemum*. These palynological data indicate a largely open herbaceous landscape and can be correlated with the Oldest Dryas pollen zone (GS-2, before ca 14 600 cal BP; Blockley et al., 2012). Low *Pinus* values (less than 20%) occurred as a result of long distance transport (Fig. 4). The spread of shrubby vegetation in response to climate warming of the Bølling pollen zone (GI-1e) was characterized at first part by the dominance of *Juniperus* percentages in the lowest altitude up to around 1000 m asl and secondly by the dominance of *Betula* percentage at lowest altitude and *Juniperus* percentages at around 1000/1100 m asl. Pollen evidence for an altitudinal distribution of the shrubby suggests that *Betula* and *Juniperus* reached ~800/1000 m asl and ~1000/1200 m a.s.l. respectively. This is confirmed by the presence of macroremains of *Betula* (*B. pendula*, *B. nana* and *B. pubescens*) in the Bølling infilling from Lautrey (800 m asl) but not in the Bellefontaine sample (1093 m). The highest sites remained covered by steppe-like herbaceous vegetation and the occurrences of tree (essentially *Betula*) pollen were attributed to pollen transport from the valleys. Fig. 4 shows the drop in *Pinus* values in the second part of the Bølling for two northern sites (Saint point and Morteau Montlebon) that could suggest the regional migration of this taxa from the north. The Older Dryas cold event (ca 14 050–13 850 cal BP) was recorded as a regressive phase in the vegetation succession with an increase in NAP values associated with the increase in *Juniperus* percentages in sites below 800 m a.s.l. and with the increase of *Pinus* values in the highest sites. This last event can be interpreted as the expansion of *Pinus* forests from the north via the higher altitude areas or as a result of long distant transport into treeless areas above 800 m a.s.l. The absence of arboreal macrofossils in the Older Dryas infilling from the Bellefontaine and Mont Roux seems to indicate the depletion of the vegetation in altitude zones in response to the colder climate, but this should be verified by other macrofossils studies for this altitude. The regional immigration of pine forests was confirmed by the gradual but consistent rise of *Pinus* percentages during the Allerød (ca 13 850–12 700 cal BP). However, high values of *Juniperus* and NAP in the first part of the zone revealed that the landscape remained open. The forests became denser towards the end of the zone, as shown by the decrease of light demanding taxa. The presence of *Betula* macrofossils (wood and fruit) in the whole of the sequence from the Lautrey site combined with high pollen values of this taxa indicated that it remained a significant element in the vegetation at this altitudinal range. The presence of *Pinus* in the vicinity of Bellefontaine Lake and Mont Roux was attested by the occurrence of some needles in the sediment. There was no evidence for *Pinus* stands below 1000/1100 m a.s.l. The Younger Dryas pollen zone (ca 12 700–11 700 cal BP) was recorded by a major rise in NAP

values and a return of low *Juniperus* values. The low altitude site of Le Miroir was dominated by Cyperaceae rather than by *Artemisia*. *Betula* decreased in all sites. *Betula* macroremains disappeared from the sequence of Lautrey as did the *Pinus* macroremains of Bellefontaine and Mont Roux. A large reduction of the forested surface areas over a large part of the Jurassian massif seems to be recorded in response to cold climatic conditions.

With regard to the Lateglacial fauna, the available data taken as a whole (faunal spectra and isotopes) reveals a major phase of rapid ecosystem reorganisation at the end of Lateglacial, which is part of a multifactorial and longer process that spans from pre-LGM to Early Holocene. The human factor, because of the pressure of hunting and demographic expansion, is another piece of the puzzle, but difficult to measure directly for this period.

Typical large species of the Pleniglacial period are rare in the Lateglacial record. Woolly rhinoceros (*Coelodonta antiquitatis*), mammoth (*Mammuthus primigenius*), and cave Lion (*Panthera spelaea*) were on the final step of their extinction process (Stuart et al., 2004; Stuart and Lister, 2007; Lister and Stuart, 2008; Stuart and Lister, 2011), and the Jura area provides some of the latest specimens during GS-2a (Fig. 3; Bridault and Chaix, 2009; Cupillard and Welté, 2006). The presence of reindeer (*Rangifer tarandus*) is dated 23.8–22.5 ka in the northern Jura, in sites located away from the ice margins (Fig. 1). These animals fed on plants of very open habitat and poor soil maturity as shown by the relatively low  $\delta^{15}\text{N}$  values of reindeer bone collagen (e.g., Drucker et al., 2011b, 2012). Such areas at the periphery of recently deglaciated zones were subject to rapid recolonization by animal species, and reindeer were among the species best adapted to the prevailing harsh conditions. The existence of northern refugia in the vicinity of this Jura region may explain the early presence of reindeer there. This rapid recolonization reflects the high reactivity of the ecosystems, which could respond quickly to the retreat of the Jura glacier by a rapid re-expansion that probably favoured the survival of human populations. Reindeer was the main targeted game species, outstripped by the horse (*Equus ferus*) soon before the onset of the Bølling (GI-1e).

The arrival of red deer (*Cervus elaphus*) in the area started at the GS2a-GI-1e transition, when reindeer populations were already probably declining, but both species coexisted, as indicated by the remains of these two hunted cervids at Rochedane D1 (Doubs), where red deer is predominant (Bridault and Chaix, 2009). Red deer expansion took place in open habitats, as shown by the  $\delta^{13}\text{C}$  values of their bone collagen (e.g., Drucker et al., 2011a). In addition to climate change, interspecific competition could have been a worsening factor that firstly caused the regional demise of reindeer by 14 ka and later, the retreat of horse by 12 ka. No evidence has been found until now to support a reappearance of reindeer populations in the Jura area during the last cold oscillation (GS-1). The onset of the Bølling is therefore a key period: the pleniglacial legacy was vanishing and some species reputed as temperate-adapted, such as the red deer and moose (*Alces alces*), appeared and expanded. These two

**Fig. 4.** Pollen representation of main taxa from the Jura Mountains and marginal sites during the Lateglacial : In the lowest part : Le Miroir at 198 m a.s.l. (Richard, 1996), Arinthod at 450 m a.s.l., Chalain at 488 m asl (Wegmüller, 1966), Onoz at 560 m a.s.l. (Magny and Ruffaldi, 1994); In the middle part : Pré Mourey at 750 m a.s.l. (Cupillard et al., 1994), Morteau-Montlebon at 752 m a.s.l. (Campy et al., 1985), Cerin at 764 m a.s.l. (Ruffaldi, 1993, 2009), le Petit Maclu at 778 m a.s.l. (Wegmüller, 1966), le Lautrey at 788 m a.s.l. (Vannière et al., 2004; Peyron et al., 2005; Magny et al., 2006), Etival at 800 m a.s.l. (Richard, 1988), Abbaye at 871 m a.s.l. (Wegmüller, 1966), Saint-Point at 890 m a.s.l. (Leroux et al., 2008), Le Locle at 910 m a.s.l. (Schoellammer, 1998; Magny and Schoellammer, 1999; Magny et al., 2001) In the highest part : Les Cruilles at 1035 m a.s.l. (Wegmüller, 1966), Bellefontaine at 1093 m a.s.l. (Bégoat, 2000), Mont Roux at 1240 m a.s.l. (Bégoat, 2000; Bégoat et al., 2000), Amburnex at 1300 m a.s.l. (Wegmüller, 1966), Creux de Croue at 1370 m a.s.l. (Bégoat, 2000). Each pollen zone has been divided into two equal parts. Pie charts display the proportion of taxa at the middle level of the each "half zone".



cervids probably benefited from the spread of shrubs and small trees that provided abundant grazing. A transitional state of the ecosystems is reflected in the non-analogous combination of taxa that characterizes the faunal spectra of this short stage. Despite the spread of woody plant species, the landscape was still very open and, thus, the impact of the faunal corpus change on the hunting strategy of the human population was probably more influenced by the differences in their ethology (large herds of migrating reindeer were replaced by small groups of territorial red deer and moose) than by the change of species composition (e.g. [Bridault and Chaix, 2009](#)). After the first warm oscillation, the fauna reorganisation seems to have accelerated and consolidated. Red deer become the predominant hunted species during the Allerød. Together with wild boar (*Sus scrofa*) and roe deer (*Capreolus capreolus*), they are the main prey species throughout the early Holocene.

### 2.3. The early to mid-Holocene (ca 11 700–7000 cal BP)

Pollen records of the Preboreal pollen zone (ca 11 700–10 200 cal BP) show a very similar picture to those observed during the second part of the Allerød. *Pinus* values were very high above 1000 m a.s.l. and their presence with *Betula* was attested by the occurrence of macrofossils at Bellefontaine and Mont Roux. Below 1000 m a.s.l., only the presence of *Betula* stands was confirmed by macroremains records at Lautrey.

From ca 10 200 to ca 9000 cal BP, during the Boreal pollen zone, *Pinus* remains dominant above 1100 m a.s.l. and masks *Corylus* which shows a clear domination everywhere else, while mesophilous trees expand, with a domination of *Ulmus* at the end of the pollen zone. The analysis of the peat-bog of Mouthé, in the high chain at 960 m a.s.l., shows abnormal variations in the hazel ratio at the end of the Boreal ([Cupillard et al., 1994](#)). These fluctuations could have a natural cause such as, for instance, spontaneous fires followed by regeneration of the vegetation ([Richard, 1995](#)), but might also result from human activity ([Cupillard, 2010](#)), but this needs to be confirmed by further studies.

Finally, the older Atlantic pollen zone (i.e. ca 9000–7000 cal BP) was characterized by an expansion of the *Quercetum mixtum*. However, the forest composition is closely related to the local climatic and edaphic conditions. Thus, the expansion of *Fraxinus* and *Tilia* depends on the altitude: above 1100 m a.s.l., *Tilia* shows relatively low percentage values, whereas it attains a maximum around 8000 cal BP at 1000 m a.s.l. and as early as 9000 cal BP below 800 m a.s.l. ([Beaulieu de et al., 1994](#)). The most ancient pollen from cereals found in the region was dated to the latter half of the Atlantic about 7700/7800 cal BP, and it is observed on two Jura sites ([Richard and Ruffaldi, 2004](#); [Gauthier and Richard, 2008](#)). This very early evidence must be questioned, even though similar evidence was observed near the lake of Zurich on the Swiss Plateau ([Haas, 1996](#); [Erny-Rodmann et al., 1997](#)) and in the upper Rhône valley ([Welten, 1982](#)). Around 7300/7000 cal BP, human impact and pollen from cereals are recognised at the lake of Chalain on the lower western plateau ([Richard, 1997](#)) and on different lacustrine or peat bog sequences of the high range ([Cupillard et al., 1994](#); [Buttler et al., 2002](#); [Gauthier, 2004](#); [Richard and Ruffaldi, 2004](#); [Leroux et al., 2008](#)). These various sites indicate that by that time, neolithisation was accomplished throughout the Jura, at least since 7300 cal BP ([Gauthier and Richard, 2008](#)).

Regarding the fauna, the depleted  $\delta^{13}\text{C}$  values of the red deer in the early Holocene indicate a high degree of closure of the forest canopy ([Drucker et al., 2011a](#)). In such a landscape, the acquisition of large game (i.e. the main animal food supply of the mesolithic

subsistence) probably involved a great change of hunting practices and settlement-procurement systems.

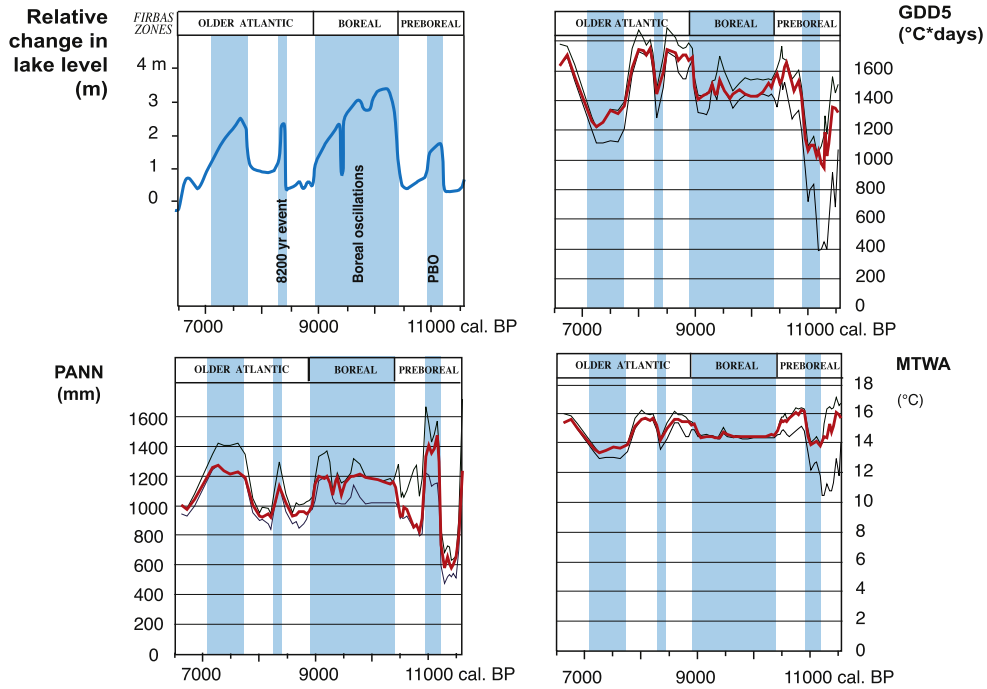
### 2.4. Quantitative estimates of climatic variations

Quantitative estimates of climatic variations in the Jura Mountains during the period 40–8 ka have been mainly reconstructed using pollen and chironomid data from lake sediment sequences. However, due to environmental conditions, i.e. the overall covering of the Jura Mountains by an ice cap above ~500 m a.s.l. and the quasi-absence of lake basins in the lower parts of the Jura, no data is available to establish a regional paleoclimate record for the interval 40–17 ka. Fortunately, the two sites of La Grande Pile (330 m a.s.l.) and Les Echets (267 m a.s.l.) located close to the northern and the southern extremities of the Jura Mountains ([Fig. 5](#)) have provided long pollen records which have been used for quantitative reconstructions of palaeoclimates during the whole Last Glacial/Interglacial cycle ([Guiot et al., 1989](#)). Both records suggest that the period 40–30 ka was characterised by relatively less cold and less dry conditions than the LGM marked by very cold and very dry conditions ([Guiot et al., 1989](#); [Guiot, 1990](#)). In addition, using pollen data showing only organic matter content and beetle data, [Guiot et al. \(1993\)](#) have indicated that the interval 60–15 ka in the palaeoclimatic record of La Grande Pile was punctuated by cold peaks in phase with Heinrich events defined in the North Atlantic Ocean.

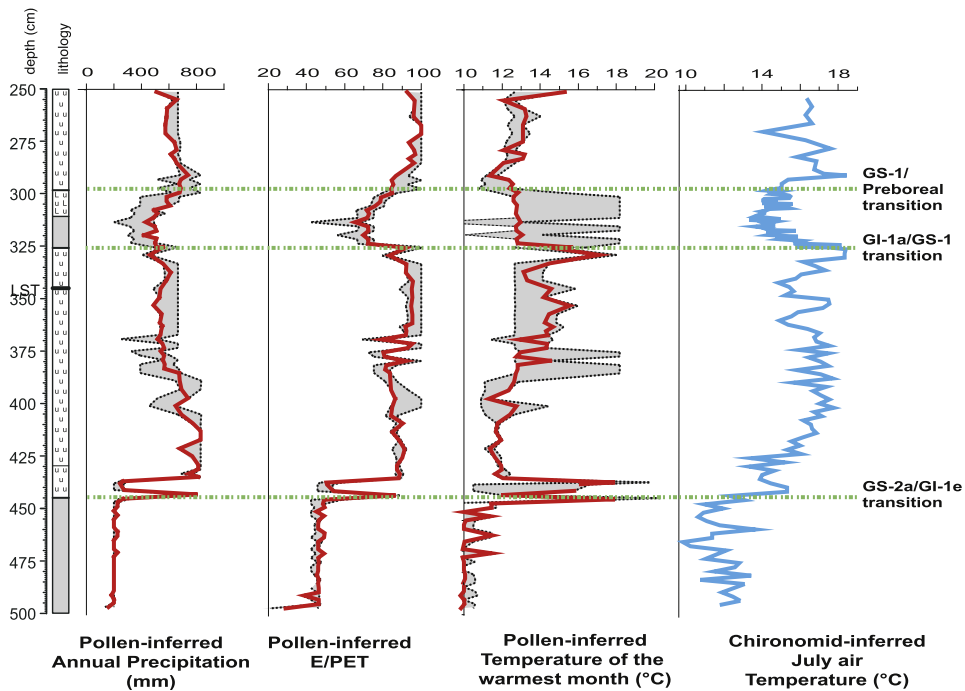
The general retreat of the ice cap after ca 17–16 ka favoured the accumulation of sediments in the ice-free Jurassic lake basins and, as a result, the establishment of regional palaeoclimatic and palaeoenvironmental records for the Lateglacial and the early Holocene. Based on a multi-proxy reconstruction using pollen and chironomid data, the well-dated high-resolution palaeoclimatic record of Lake Lautrey spans the Late Glacial–early Holocene transition in the central Jura range ([Heiri and Millet, 2005](#); [Peyron et al., 2005](#); [Magny et al., 2006](#)). Major abrupt changes in climatic conditions appear to have been associated with the GS-2a/GI-1a, GI-1a/GS-1, and GS-1/Preboreal transitions. The temperature of the warmest month increased by ~5 °C at the start of GI-1 and by 1.5°–3 °C at the onset of the Holocene, while it fell by ~3°–4 °C at the beginning of GS-1. In addition, the pollen-based quantitative estimates suggest that the Lateglacial interstadial was punctuated by three successive minor cooling events by ~0.7°–2 °C possibly synchronous with the GI-1d, GI-1c2 ([Brauer et al., 2000](#)), and GI-1b oscillations. A comparison of temperature estimates obtained at Lake Lautrey with other quantitative reconstructions from neighbouring regions in west-central Europe show general agreement in identifying an identical succession of major warming (GI-1a, Preboreal) and cooling (GS-2a, GS-1) phases, but differences in the magnitude of the temperature changes reconstructed indicate difficulties concerning the methods of reconstruction and/or to the sensitivity or accuracy of the climatic indicators used ([Peyron et al., 2005](#); [Magny et al., 2006](#)).

Regarding the annual precipitation (PANN) and its seasonal distribution throughout the last Glacial–Interglacial transition at Lake Lautrey, the onset of GI-1 and Holocene coincided with a clear reactivation of the hydrological cycle with an increase in annual precipitation and available moisture, probably in connection with the retreat of sea ice and an increasing evaporation over the ice-free North Atlantic Ocean due to higher temperature ([Renssen and Isarin, 2001](#)). Given (1) that the abrupt warming in ca 14 700 and 11 700 cal BP corresponded to a major lowering of lake levels in the Jura Mountains ([Magny, 2001](#); [Magny et al., 2006](#)) and (2) that the sediment markers

## LAKE LE LOCLE (JURA MOUNTAINS)



## LAKE LAUTREY (JURA MOUNTAINS)



**Fig. 5.** Quantitative estimates of climatic parameters for the Lateglacial and early Holocene in the Jura Mountains using pollen, chironomidae, and lake-level data. Lower panel : the Lateglacial palaeoclimatic record from Lake Lautrey (from Heiri and Millet, 2005; Peyron et al., 2005; Magny et al., 2006). Upper panel: the early Holocene palaeoclimatic record from Lake Le Locle (from Magny et al., 2001). GDD5: growing degrees above 5 °C × days; PANN : annual rainfall; MTWA: mean temperature of the warmest month; E/PET: real evapotranspiration/potential evapotranspiration.

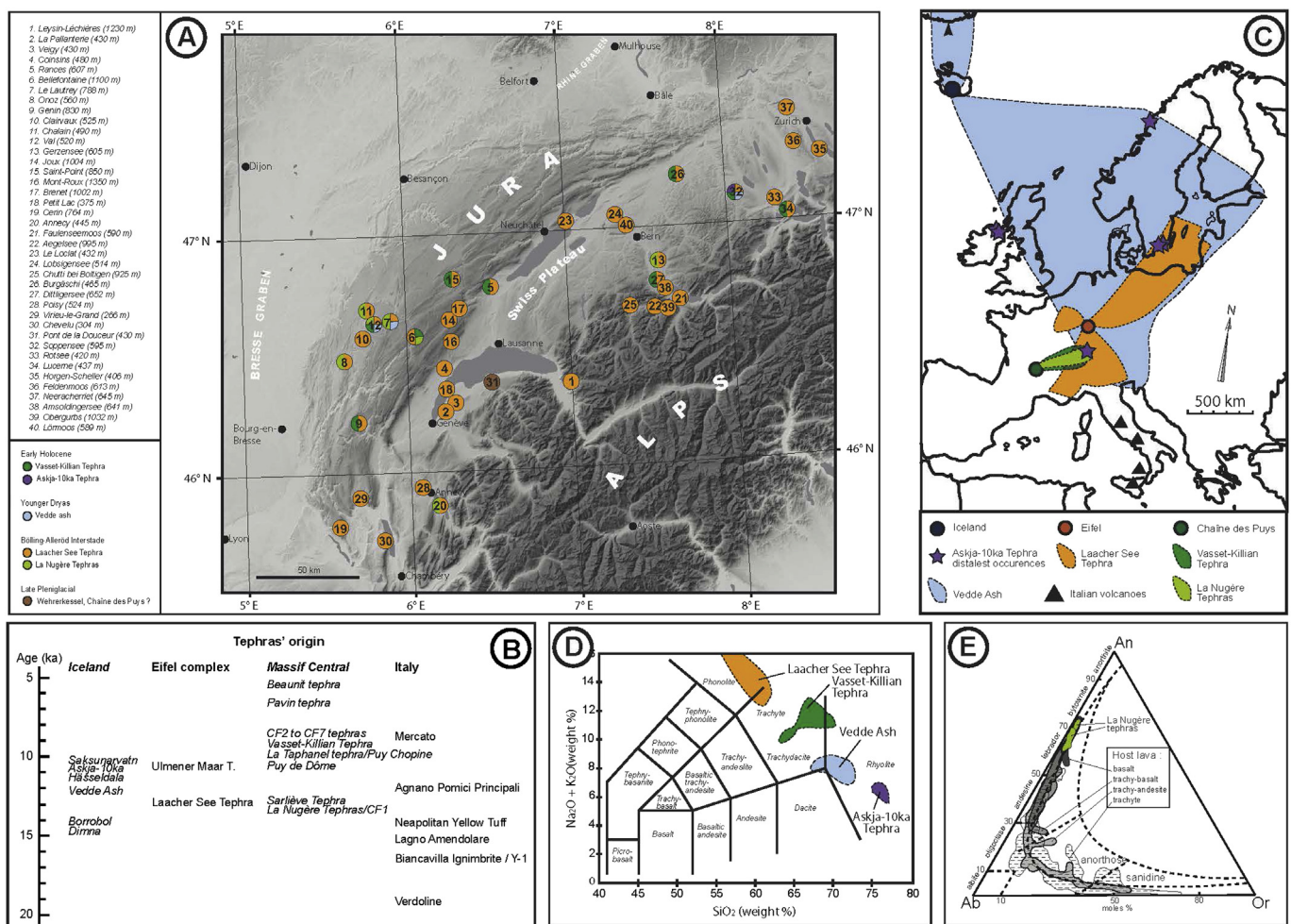
used for the reconstruction of past lake levels from during the warm season, quantitative estimates obtained at Lake Lautrey suggest dry summers and wet winters at the onset of the GI-1 and Holocene. GS-2a and GS-1 may have been characterised by

dry winters and wet summers. Such opposite patterns of seasonality may have reflected variations in the extension of the sea ice and the position of the storm track in agreement with AGCM experiments (Renssen and Isarin, 2001).

The early Holocene palaeoclimates in the Jura Mountains have been best documented by quantitative estimates obtained at Lake Le Locle, Swiss Jura, using pollen and lake-level data (Magny et al., 2001). Climatic parameters reconstructed here suggest that regional phases of higher lake-level conditions around 11 350–11 100 (Preboreal oscillation), 10 250–9900, 9550–9350 (Boreal oscillations), and 8400–8050 cal BP (8200 event) (Magny, 2013) coincided with an increase in annual precipitation by ~300 mm, a decrease in summer temperature by ~1.5°–2 °C, and a shortening of the growing season. This general pattern could have resulted from alternate southward–northward displacements of the Atlantic Westerly Jet Stream and its associated cyclonic track in response to both deglaciation events and variations in solar activity (Magny and Bégeot, 2004).

## 2.5. Tephrochronological data

In addition to data documenting palaeoenvironmental and palaeoclimatic changes, the sediment sequences studied in lakes and peat bogs of the Jura Mountains include tephra layers which offer key time-marker horizons for inter-regional correlations according to the INTIMATE strategy (Davies et al., 2002; Turney et al., 2006; Blockley et al., 2012). In this area and the Swiss Plateau, at least 40 sites have been studied since the Hofmann (1963) study carried out on Neeracherriet and Feldenmoos peatbogs (Switzerland) (Fig. 6-A). Some of the tephra described in lakes and peatbogs in French and Swiss Jura mountains are visible, usually observed as a greyish or dark layer depending on the host-sediment mineralogy, while the others are invisible to



**Fig. 6.** A – Lateglacial and Holocene tephra and cryptotephra layers in Jura Mountains, Northern Alps and Western Swiss Plateau. 1. Eicher (1979); 2,3. Martini and Duret (1966); 4, 40. Wegmüller and Welten (1973); 5. Martini (1970), Eicher (1987), van den Bogaard and Schminke (1985); 6, 9, 27, 28, 29, 30, 31. Martini (1970); 7. Bossuet et al. (1997), Vannièrre et al. (2004), Walter-Simonnet et al. (2008); 8. Magny and Ruffaldi (1994), Walter-Simonnet et al. (2008); 10. Unpublished data; 11. Duret and Martini (1965), and unpublished data; 12. Unpublished data; 13. Eicher and Siegenthaler (1976), Eicher (1987), Lotter et al. (1992), Lotter et al. (1992), Walter-Simonnet et al. (2008); 14. Creer et al. (1980); 15. Leroux (2010); 16. Bégeot (2000); 17. Fuchs (2008); 18. Moscariello and Costa (1997), Moscariello et al. (1998); 19. Ruffaldi (1993); 20. Brauer and Casanova (2001), Nomade (2005); 21. Eicher and Siegenthaler (1976), Lotter et al. (1992); 22. Wegmüller and Lotter (1990), Lotter et al. (1992); 23. Rollià et al. (1994), Hadorn (1992, 1994); 24. Amman and Tobolski (1983), Eicher and Siegenthaler (1983), van den Bogaard and Schminke (1985); 25. Eicher (1979, 1987), Welten (1982), van den Bogaard and Schminke (1985); 26. Martini (1970), van den Bogaard and Schminke (1985); 32. Lotter et al. (1992), Blockley et al. (2007), Lane et al. (2011a); 33. Eicher (1987), Lotter et al. (1992); 34. Schnellmann et al. (2006); 35. Magny (2001); 36, 37. Hofmann (1963); 38. van den Bogaard and Schminke (1985); 39. Juvigné (1980); B – Main tephra from Iceland, the Eifel complex, the French Massif Central and Italy; C – Continental dispersion of La Nugère Tephra, Laacher See Tephra, Vedde Ash, Askja-10 ka Tephra and Vasset-Killian Tephra; D – Silica vs alkaline elements diagram for Laacher See Tephra, Vedde Ash, Askja-10ka Tephra and Vasset-Killian Tephra; E – Chemical composition of plagioclase from the La Nugère Tephra.

the naked eye. Therefore, their detection is obtained either using magnetic susceptibility measurement with a 5 mm step along the cores (Jouannic, in prep.; Walter-Simonnet et al., 2008; Jouannic, in prep.), or by quantification of tephra glass shard concentration under an optical microscope in continuous (~1 cm<sup>3</sup>) samples of sediment prepared according to the process published by Blockley et al. (2004). Quantification under an optical microscope of the tephtras, especially acidic ones which cannot be detected by susceptibility measurement, is a long and exacting task. This is the reason why new rapid detection methods are currently being tested (Jouannic, in prep.; Caseldine et al., 1999; Kylander et al., 2012; Jouannic, in prep.). Assigning a tephra to a known eruption or a volcano can be made either by heavy mineral assemblage, phenocrystal chemistry, or chemical characterization of glass shards achieved by the analysis of major and minor elements using electron microprobe equipment. The latter method is now commonly used except when glass shards are too weathered for chemical analysis.

During the period 40–8 ka cal BP, many different volcanic complexes have been active in Europe (e.g. Iceland, the Eifel, the French Massif Central, Italy), generating a great number of tephtras deposited during the main eruptions (Fig. 6-B). North-west Europe, and especially eastern France and Switzerland, are in the centre of the area circumscribed by these points of eruption (Fig. 6-C). Six tephtra layers can be identified and characterized in lakes and peatbogs in the Jura Mountains and Swiss Plateau (Fig. 6-A).

The Icelandic volcanic complex is composed of two groups of volcanoes. Tholeiitic basalts are related to the Grimsvötn-Kverfjöll group situated in the Northern part of Iceland, when volcanoes from the southeast part of the island (Hekla and Katla) erupt alkaline basalts, olivine basalts and rhyolite (Jakobsson, 1979 in Davies et al., 2002). Some Icelandic tephtras have a wide dispersion (Davies et al., 2005; Pilcher et al., 2005; Blockley et al., 2007; Lane et al., 2011, 2012). In lakes and peatbogs of the Jura Mountains and Swiss Plateau two Icelandic tephtras were identified: the Vedde Ash (12 121 ± 114 a) and the Askja-10ka tephtra (10 702–10 991 cal BP) (Lane et al., 2011) (Fig. 6-C). The Vedde Ash is characterized by a bimodal basaltic-rhyolitic composition: in this area only the rhyolitic phase can be observed (Fig. 6-D). The Askja-10ka tephtra was described in only one site, the Soppensee (Lane et al., 2011). Its rhyolitic composition cannot be mistaken for the Vedde Ash's (Fig. 6-D).

The Eifel volcanic complex (near Bonn, Germany) generated two main tephtras (Fig. 6-B), but only the Laacher See Tephtra is observed as a visible layer in the region. It was dated to 12 880 ± 40 varve years (Brauer et al., 1999), 12 900 ± 560 years <sup>40</sup>Ar/<sup>39</sup>Ar (Van den Bogaard, 1995), and ca. 13 160 years from tree-ring analysis (Friedrich et al., 2004). This phonolitic tephtra (Fig. 6-D) is widespread in the North Atlantic region as well as in northern, southern, and continental Central Europe, where three phases with a different chemistry and manner of dispersion were identified (van den Bogaard and Schminke, 1985; Harms and Schminke, 2000) (Fig. 6-C).

The volcanoes of the Chaîne des Puys were very active during the Lateglacial and the Early Holocene (Fig. 6-B). Chemical analysis of tephtras and volcanic products from the Chaîne des Puys shows an evolution of basalts and trachy-basalts into trachytes (Maury et al., 1980; Boivin et al., 2004). Their dispersion is usually limited to Limagne and Monts du Forez (Etlicher et al., 1987; Juvigné and Gewalt, 1987; Vernet et al., 1990; Juvigné et al., 1992; Juvigné et al., 1996; Boivin et al., 2004), and their relative chronology was built by using four methods: pollen analysis, radiocarbon dating, thermoluminescence dating, and tephtric overlap (Vivent and Vernet, 2001; Vernet and Raynal,

2000; Boivin et al., 2004). In our region, the oldest tephtra occurrence corresponding to the Chaîne des Puys eruption was identified in only one site, Pont de la Douceur (Fig. 6-A), by Martini (1970). Martini related this tephtra layer to the Chaîne des Puys volcanoes owing to its late pleniglacial age (Blavoux and Brun, 1966) and its heavy mineral assemblage mostly composed of brown hornblende. Two very discrete tephtra layers have been deposited during the Allerød, before the Laacher See Tephtra (Walter-Simonnet et al., 2008). The chemical composition analysis of glass shards weathered into zeolites could not be carried out by using an electron microprobe. However, they have ages, mineral assemblages, and plagioclase chemical composition close to those of tephtras emitted by the Puy de la Nugère (ca 13 300 a) (Fig. 6-E).

The Vasset-Killian Tephtra (VKT), a trachytic tephtra (Fig. 6-A and D), was detected in nine sites, but chemically characterized only in Soppensee tephrostratigraphy by Lane et al. (2011). In the other sites, this tephtra was characterized only by its heavy mineral assemblage (Jouannic, in prep.; Martini, 1970; Eicher, 1987; Leroux et al., 2008; Jouannic, in prep.) or by correlation with magnetic susceptibility peaks (Schnellmann et al., 2006). However, the exact source volcano is unknown and the precise date of the eruption remains uncertain. In Soppensee, a new date of 9406–9265 cal BP for the VKT was proposed (Lane et al., 2011).

To sum up, with six different occurrences of tephtra layers deposited during the Late Glacial and Early Holocene, the Jura Mountains and Swiss Plateau area appear as an important tephrochronological bridge between northern and central Europe records and southern and western ones. These data outline the potential of tephtra layers as isochronous markers for developing more precise chronology and inter-site comparisons on common timescales. They also suggest the probable occurrence of other Lateglacial and Holocene cryptotephtras in eastern France records.

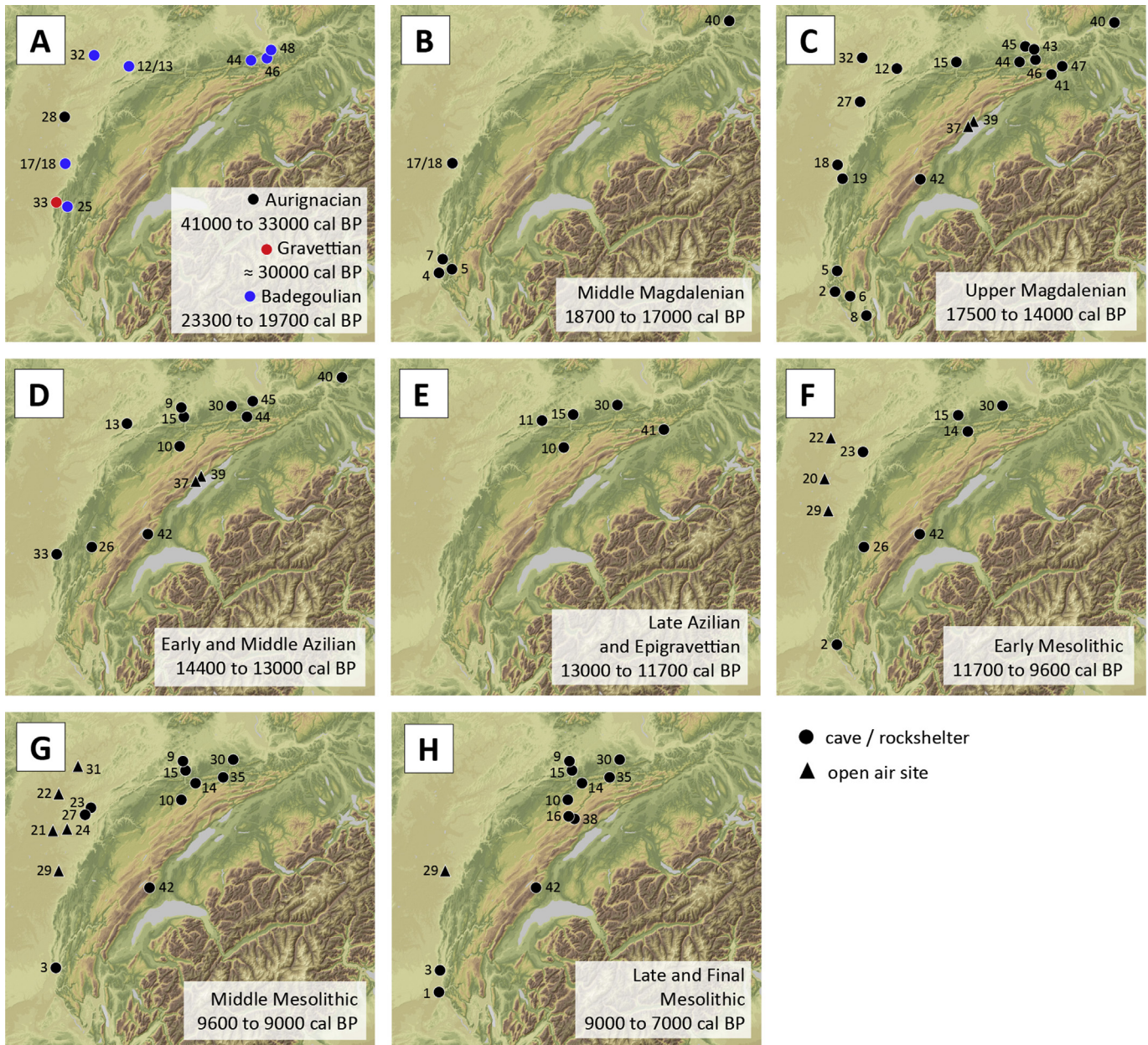
### 3. Archaeological data and cultural history

On both the French and Swiss sides of the Jura range during the last thirty years, the study of prehistoric sites has been greatly improved, firstly because of the achievements and the complete or partial publications of important rescue or programmed excavations, and secondly because new scientific research programmes have been undertaken to define the chronological framework of Upper Paleolithic, final Palaeolithic and Mesolithic cultures. This new research performed at 48 prehistoric sites (Table 1, Fig. 7) has yielded a huge set of environmental and archaeological data, and 256 new AMS dates which have been calibrated using the calibration software CALPAL (Danzeglocke et al., 2009; www.Cal.pal.de)(Appendix 1). This data now can be considered (at least as a first approximation) as representative of Palaeolithic and Mesolithic demography (Gamble et al., 2005; D'Errico et al., 2012) and indicates the main stages of human population between 40 000 and 8000 cal BP with cultural phases similar to those defined and radiocarbon-dated in neighbouring regions by Jaubert (2011), Leesch et al. (2012), and Gesquière and Marchand (2010). These well-dated sites constitute merely a sample of the recognised prehistoric sites, the number of which is not accurately known but is around seven hundred. The 256 AMS dates have mostly been already published but some of them are presented for the first time (Appendix 1). Half of them have been carried out on samples from excavations and the other half on samples from several investigations specifically aimed at chronology (Cupillard, 2008; Pion, 2000a; Pion and Mével, 2009; Szmjdt et al., 2010; Leesch et al., 2012, 2013; Drucker et al., 2011a, 2012; Cupillard et al., 2013).

**Table 1**

List of the Upper Palaeolithic, Final Palaeolithic and Mesolithic sites AMS dated in the French and Swiss Jura.

Number in Fig.7	Site	Locality	Country	District	Type	Altitude (m)	Excavation	Bibliography
1	Le Gardon	Ambérieu-en-Bugey	F	Ain	Cave	373	1985–2000	Voruz 2009
2	La Chênélaz	Hostias	F	Ain	Cave	900	1987–1997	Cartonnet and Naton 2000
3	Le Roseau	Neuville-sur-Ain	F	Ain	Rockshelter	275	1985–1987	Wittig and Guillet 2000
4	La Colombière	Neuville-sur-Ain	F	Ain	Rockshelter	275	1913–1915, 1948, 1975–1981	Pion 2000b, Paillet and Man-Estier 2010
5	Abri Gay	Poncin	F	Ain	Rockshelter	270	1970–1982	Pion 2000b, Paillet and Man-Estier 2010
6	Les Hoteaux	Rossillon	F	Ain	Rockshelter	250	1897, 1917–1919	Pion 2000b
7	La Croze	Saint-Martin-du Mont	F	Ain	Rockshelter	260	1913	Pion 2000b
8	Les Romains	Virignin	F	Ain	Rockshelter	278	1964–1969	Pion 2000b, Paillet and Man-Estier 2010
9	Sous Les Roches	Bavans	F	Doubs	Rockshelter	308	1977–1987	Aimé 1993
10	Gigot 1	Bretonvillers	F	Doubs	Rockshelter	457	1973–1982	Vuaillet et al., 1984, Cupillard 2008
11	Roche aux Gours	Longeville-sur-le-Doubs	F	Doubs	Rockshelter	302	1971	Vuaillet and Piningre, 1976, Cupillard 2008
12	Rigney 1	Rigney	F	Doubs	Cave	256	1950's	David 1996, Cupillard et al., 2013
13	Rigney 2	Rigney	F	Doubs	Rockshelter	256	1986–1987	David 1996, Cupillard 2008
14	Baume de Montandon	Saint-Hippolyte	F	Doubs	Rockshelter	590	1984–1985	Cupillard et al., 2000
15	Rochedane	Villars-sous-Dampjoux	F	Doubs	Rockshelter	355	1968–1976	Thévenin 1982, Fornage-Bontemps 2013
16	La Roche-aux-Pêcheurs	Villers-le-Lac	F	Doubs	Rockshelter	752	1992–1996	Cupillard 2010
17	Chaze II	Arlay	F	Jura	Cave	225	1992	Cupillard and Welté 2006, Cupillard 2008
18	Grappin	Arlay	F	Jura	Cave	225	1954, 1958–1960	Cupillard and Welté 2006, 2009
19	Chaumois-Boivin	Blois-sur-seille	F	Jura	Cave	450	1957	Cupillard 2008, Cupillard et al., 2013
20	Champins 1	Choisey	F	Jura	Open air site	196	1995	Séara et al., 2002
21	Champins 2	Choisey	F	Jura	Open air site	196	2004	Séara 2008
22	Sur la Prairie	Dammartin-Marpain	F	Jura	Open air site	192	2008–2009	Séara 2010
23	Châteauneuf	Dampierre	F	Jura	Rockshelter	220	1983	David 1993, Jaccotey and Milleville 2008
24	Aérodrome	Gevry	F	Jura	Open air site	197	1983	Séara 2008
25	La Baume	Gigny-sur-Suran	F	Jura	Cave	480	1966–1977	Campy et al., 1989, Cupillard et al., 2013
26	La Cimante	Meussia	F	Jura	Rockshelter	600	2003–2004	Cupillard 2012b
27	Les Cabônes	Ranchot	F	Jura	Rockshelter	216	1978–1989	Cupillard and David 1995, David 1996, Cupillard 2008
28	La Mère Clochette	Rochefort-sur-Nenon	F	Jura	Cave	225	1905–1908	Brou 2001, 2007; Szmidi et al., 2010
29	A Daupharde	Ruffey-sur-Seille	F	Jura	Open air site	215	1995–1996	Séara et al., 2002
30	Mannlefelden 1	Oberlarg	F	Jura	Rockshelter	550	1971–1980	Thévenin and Sainy 1980, Fornage-Bontemps 2013
31	Sur la Noue	Beaujeu	F	Haute-Saône	Open air site	189	1984–1985	Cupillard 2008
32	La Baume Noire	Frétingney-Velloreille	F	Haute-Saône	Rockshelter	240	1985–1987	David 1996, Cupillard et al., 2013
33	La Balme	Cuiseaux	F	Saône-et-Loire	Cave	240	1961–1963	Fornage-Bontemps 2010
34	Birseck-Ermitage	Arlesheim	Ch	BL	Cave	357	1910 and 1914	Le Tensorer, 1998, Leesch et al., 2012
35	Les Gripons	Saint-Ursanne	CH	JU	Rockshelter	496	1986–1989	Pousaz 1998
36	Le Bichon	La Chaux-de-Fonds	CH	NE	Cave	846	1956–1957, 1991–1992	Morel 1993, 1998; Chauvière 2009
37	Champréveyres	Hauterive	CH	NE	Open air site	428	1984–1986	Leesch 1994, Leesch et al., 2012
38	Col-des-Roches	Le Locle	Ch	NE	Rockshelter	935	1928	Cupillard 2010
49	Monruz	Neuchâtel	CH	NE	Open air site	428	1989–1992	Bullinger et al., 2006, Leesch et al., 2012
40	Kesslerloch	Thaygen	CH	SH	Cave	440	1873–1903; 1980	Le Tensorer, 1998, Leesch et al., 2012
41	Rislißberghöhle	Oensingen	CH	SO	Cave	488	1971–1973	Le Tensorer 1998, Leesch et al., 2012
42	Mollendruz	Mont-la-Ville	CH	VD	Rockshelter	1088	1982–1986, 1991	Pignat and Winiger 1998
43	Hollenberg-Höhle 3	Arlesheim	CH	BL	Cave	450	1950–1952; 1977	Le Tensorer 1998, Leesch et al., 2012
44	Köhlerhöhle	Brislach	CH	BE	Cave	378	1934–1937	Le Tensorer 1998, Leesch et al., 2012
45	Büttenloch	Etingen	CH	BL	Cave	380	1918–1919	Le Tensorer 1998, Leesch et al., 2012
46	Kastelhöhle Nord	Himmelried	CH	SO	Cave	397	1948–1950; 1959	Sedlmeier, 2010, Leesch et al., 2012, Leesch and Bullinger 2013
47	Käsloch	Winznau	CH	SO	Cave	420	1905	Leesch et al., 2012
48	Y-Höhle	Hofstetten-Flüh	CH	SO	Cave	462	Before 2010	Leesch et al., 2012, Leesch and Bullinger 2013



**Fig. 7.** Archaeological maps of AMS dated sites. For the site numbers, refer to [Table 1](#). **A** – Map of the Aurignacian, Gravettian, Badegoulian AMS dated sites **B** – Map of the Middle Magdalenian AMS dated sites **C** – Map of the Upper Magdalenian AMS dated sites **D** – Map of the Early and Middle Azilian AMS dated sites **E** – Map of Late Azilian/Epigravettian AMS dated sites **F** – Map of the Early Mesolithic AMS dated sites **G** – Map of the Middle Mesolithic AMS dated sites **H** – Map of the Late and Final Mesolithic AMS dated sites.

### 3.1. Aurignacian: from 41 000 to 33 000 cal BP (Fig. 7A)

As of 2013, evidence of Aurignacian culture is totally absent from Switzerland and from the Jura range (Leesch and Bullinger, 2013) and the only example of its kind is the Cave of La Mère Clochette at Rochefort-sur-Nenon located along the lower Doubs River on the western margins of the Jura range (Szmidi et al., 2010). On this site, excavated around 1900, five AMS dates have been made on bone or artefacts and fixed between 41 222–39 540 cal BP (OxA-19622) and 33 539–34 154 cal BP (Beta-150312). The results of greatest confidence seem to be those given by two samples treated by ultrafiltration, ie OxA-19622 : 41 222–39 540 cal BP and OxA-19621 : 40 464–38 120 cal BP (Szmidi et al., 2010). This occupation

corresponds to Proto-Aurignacian or Early Aurignacian culture, contemporary with MIS 3 and with a time range extending from GS-9 to GI-10 (Blockley et al., 2012). Close to this site, the Cave des Gorges at Amange (Jura) is a new, interesting stratigraphical sequence still being investigated, where the lowest layer US 4 provides few lithic artefacts and cold tolerant mammal fauna with 2 AMS dates of 40 666 to 38 641 cal BP (Bereiziat et al., 2012).

### 3.2. Middle Gravettian : around 30 000 cal BP (Fig. 7A)

Gravettian peopling is unknown in Switzerland and in the Jura range (Cupillard et al., 2013; Leesch and Bullinger, 2013). It seems to be present in the Prejurassic area, but recent TL dates between

17.6 and 10.1 ka do not fit with the Gravettian lithic industry (Lamotte et al., 2012). Nevertheless, the only one of its kind is the Cave of La Balme at Cuiseaux located on the western margins of the Central Jura range (Fornage-Bontemps, 2010; Cupillard et al., 2013; Leesch et al., 2013). On this site, excavated during the 1960s, faunal remains are very poor, and the lithic industry belongs to the Middle Gravettian, dated between 29 914 and 30 447 cal BP (Ly-3728 (GrA))(Fornage-Bontemps, 2010; Cupillard et al., 2013). Therefore, this occupation could be coeval with GS-5 and GI-4 (Lowe et al., 2008). This point shows that human peopling was possible along the western fringe of the range, 20 km from the front of the ice cap (Buoncristiani et al., 2002). Moreover, the study of the lithic industry shows that flints come mainly from local upper Cretaceous outcrops and seem to exclude an allochthonous occupation (Fornage-Bontemps, 2010).

### 3.3. Badegoulian or possible Early Magdalenian: from 23 300 to 19 700 cal BP (Fig. 7A)

Between 27 000 and 23 000 cal BP, the Jura range experienced a glacial advance and the climatic conditions must have been very harsh at its western margins (Buoncristiani et al., 2002). Solutrean culture, which in France, extends from 26 000 to 23 000 cal BP (Jaubert, 2011), is not present beyond the eastern part of the Saône River (Combiér and Montet-White, 2002; Tiffagom, 2006). The first stage of repopulation is dated between 23 300 and 21 400 cal BP at the end of the LGM during the glacial decay. Four sites produced 6 AMS dates. The best studied and documented site is Himmelried (Kastelhöhle-Nord), whose “middle layer” is attributed to the Badegoulian techno-complex, corresponding to the Type A Magdalenian techno-assemblage defined by Leesch (1993). At this site, 3 AMS dates performed on modified reindeer bones are placed between 23 051–23 775 and 21 788–22 468 cal BP (Sedlmeier, 2010; Leesch et al., 2012). In France, in the rock-shelter of Frétigny «La Baume Noire», two new AMS dates performed on reindeer bone of levels M4 et M5 are respectively placed at 22 804–23 338 cal BP and 21 454–22 172 cal BP (Drucker et al., 2012). They are contemporary with the Middle Kastelhöhle layer and Y-Höhle cave where a cut marked reindeer bone is dated between 22 466 and 23 021 cal BP (Leesch et al., 2012). These four sites lie in the time range corresponding to the extension of GI-2 and GS-2c. The second stage of peopling is dated between 21 000 and 19 700 cal BP during the second part of the deglaciation (GS-2b). Four sites with four reindeer and woolly rhinoceros skull AMS dates are involved: layer V of La Baume de Gigny (Jura) (Drucker et al., 2012), layer D of Rigney 1 (Cupillard and Welté, 2006), a part of layer C Grappin Cave in Arlay (Jura) (Drucker et al., 2012) and Kohler cave (Leesch et al., 2012). In these 4 cases, the cultural context is badly documented but we can suppose that they correspond to Late Badegoulian or Early Magdalenian short term occupations. The seven sites of these two stages are located in the Jura margins, at a low altitude between 220 and 462 m and between 20 and 50 km from the Jurassic or Alpine glacier fronts. They show that prehistoric groups can be found at the end of LGM, during ice melt. The well-identified and well-dated fauna remains show that the vegetation was sufficient to support these large species. On the other hand, lithic raw materials indicate regional origins which reflect regional sources of flint close to the Magdalenian ones, indicating that these prehistoric groups were not pioneers exploiting a new area, but were exploiting a familiar territory for a long time (Leesch et al., 2012). These new data obtained in the western part of Jura confirm as well the early recolonization of

Central Europe at the end of the LGM, already noted by several authors (Terberger and Street, 2002; Blockley et al., 2006).

### 3.4. Middle Magdalenian: from 18 700/18 000 cal BP to 17 000 cal BP (Fig. 7B)

The Middle Magdalenian is traditionally divided into different groups or ‘faciès’ (Leesch, 1993; Le Tensorer, 1998; Cupillard and Welté, 2006; Leesch et al., 2012). The first one is the Magdalenian “à navettes” only known in the French Jura at Arlay ‘Grappin’ (Cupillard et al., 2013). The second one is the Middle Magdalenian with triangles, “baguettes demi-rondes” and double bevelled antler points defining a Type B Magdalenian techno-assemblage on the basis of the lower layer at Birsek-Ermitage cave (Leesch, 1993). The third one is the Middle Magdalenian with points of Lussac-Angles and “baguettes demi-rondes à décor de tubérosités” corresponding to the Type C Magdalenian techno-assemblage defined at Kesslerloch (Leesch, 1993). At Arlay, the beginning of the first faciès is dated between 18 111–18 727 cal BP and 18 084–18 649 cal BP, i.e. the end of GS-2b, and its end might have occurred around 17 164–17 656 cal BP, i.e. the beginning of GS-2a. The Magdalenian with triangles is not well-dated at Birsek-Ermitage (Table 1), but in the cave of Chaze 2 in Arlay, which provides a triangle and a ‘baguette demi-ronde’, a woolly rhinoceros mandible is dated between 17 347 and 16 929 cal BP (Cupillard and Welté, 2006), i.e. the beginning of GS-2a (Table 1). On the site of Kesslerloch, the oldest new AMS dates could correspond to Middle Magdalenian, and in this case it would be fixed at least around 17 500 cal BP at the beginning of GS-2a (Leesch et al., 2012). All Middle Magdalenian sites are located on the margins of the Jura range and at low altitude. Although sites are mainly known in caves and rock-shelters, open-air sites of techno-assemblage B have been recognized in Switzerland and France (David, 1993; Leesch et al., 2012). The fauna is well-known and characterized with cold tolerant species including mammoth, woolly rhinoceros, reindeer, and horse. This shows that the vegetation could support these large herbivores. Moreover, some of these karst sites are very rich in lithic industries, bone and antler reindeer industries and portable art, such as the rock-shelter of la Colombière (Pion, 2000b; Paillet and Man-Estier, 2011), Grappin Cave (Cupillard and Welté, 2006, 2009) and Thaygen (Kesslerloch) cave (Höneisen, 1993; Le Tensorer, 1998). In Grappin Cave, the petrographic study of flints shows a large spectrum of flint resources which reflects a huge site catchment area along the Jura range (Cupillard and Welté, 2009).

### 3.5. Upper Magdalenian: From 17 500 to 14 000 cal BP (Fig. 7C)

Upper Magdalenian is undoubtedly the best known stage of the Upper Paleolithic because of the great number of caves and rock-shelters and because of the presence of two very well-preserved open-air sites in Neuchâtel (Monruz) and Hauterive (Champréveyres) where modern excavations have provided a very detailed palaeoenvironmental, chronological and palaeo-ethnological framework for Upper Magdalenian groups (Leesch, 1997; Morel and Müller, 1997; Bullinger et al., 2006). Today, 77 AMS dates have been obtained from 22 sites mainly located in lowlands under 600 m altitude, but two belong to the high range: Hostias ‘La Chênélaz’ (900 m) (Cartonnet and Naton, 2000) and Mont-la-Ville ‘Mollendruz’ (1088 m) (Pignat and Winiger, 1998). If the typology of Upper Magdalenian is well-established in the Swiss Jura range where Leesch et al. (1993, 2012) identified Types D and E Magdalenian techno-assemblages (Leesch 1993; Leesch et al., 2012), the chronological framework of these two techno-

assemblages is quite unequally documented. The Type D, characterised by “lithic industries dominated by backed bladelets, but not containing enough antler industry to distinguish them from techno-assemblage B” (Leesch et al., 2012, p. 7), is very well dated from the site of Monruz and Champréveyres, with 24 AMS dates from between 16 691–15 819 and 15 168–14 454 cal BP (Table 2). However, this chronological window could be reduced in time between 15 800 and 14 700 cal BP, a time range corresponding to the results of AMS dates from horse bone at Monruz and to the well-dated and very detailed pollen sub-zone CHb-1c in which Magdalenian levels are present (Leesch et al., 2012). On the other hand, the Type E Magdalenian assemblage, defined by “lithic industries with angle backed points, shouldered points, curve-backed points and backed bladelets”, known in a few rockshelters such as Kohlerhöhle and Kastelhöhle-Nord and in the open air site of Winznau-Köpfli, has not been recognised from open air lacustrine sites. New AMS dates from these latter 3 sites do not permit more precise data on the chronological stage of these industries. According to the chronological position of the Middle Magdalenian and of the Early Azilian occupations of Monruz and Champréveyres, the Upper Magdalenian would be theoretically dated between 17 000 and 14 000 cal BP, but we need to use reindeer AMS dates to check and detail this assertion on the basis of the best Upper Magdalenian assemblages. After the AMS dating from these sites, the Upper Magdalenian is placed between 17 419/16 792 cal BP and 14 189/13 819 cal BP, a time range which is coeval with GS-2a and GI-1d. Hence, its onset would overlap the end of the Middle Magdalenian and, on the other hand, its end would be contemporary with the Early Azilian. Some new AMS dates from Arlay (Grappin, layer C, pro parte), Kesslerloch pro parte and Mont-la-Ville (Mollendruz rockshelter, layer 5), indicate Upper Magdalenian occupation, but they need to be collaborated by further detailed studies. Generally, in the Jura area, the Upper Magdalenian is characterised by an increase of sites and by a large human dispersal enhanced by the development of large open air sites (Leesch and Bullinger, 2012), as well as the presence of the first human grave of Les Hoteaux (Pion, 2000b; Tillet, 2001). The majority of sites belong to GS-2a. Those of GI-1d are scarce and co-vary with a climatic improvement and the development of sparse forest coeval to the local disappearance of reindeer (Drucker et al., 2012).

### 3.6. Early Azilian and Middle Azilian : from 14 400 to 13 000 cal BP (Fig. 7D)

The first manifestations of Azilian culture, with its backed-curved points, were easily recognised at the open air sites of Champréveyres and Monruz along the Neuchâtel lake where they are dated between 14 400 and 14 000 cal BP, at the end of the Bölling, GI-1d (Leesch et al., 2004, 2012). Between 14 400 and 13 800 cal BP, well-dated occupations are scarce and lithic techno-assemblages are not typical and could be attributed to early Azilian. The sites in question are Thaygen (Kesslerloch, layer IIc pro parte), Mont-la-Ville (Mollendruz, layer C5 inf. pro parte), Büttenloch layer B, Meussia layer 3, (Cupillard, 2012b) and Cuiseaux (La Balme, Layer B). During the Alleröd, from the end of GI-1c to GI-1a, corresponding to the Middle Azilian, there is apparently a numerical increase of sites characterized by larger geographical dispersal (Cupillard and Bourgeois, 2008). Unfortunately, our data are unequally documented, as the well-dated sites are located in the northwestern part of the Jura. These sites are located below 550 m a.s.l., except Le Bichon (846 m). The 22 available radiocarbon dates from Alleröd belong mainly to the first part of this period, the end of GI-1c and GI-1b. Palynological studies show that all these sites were located below the treeline,

in an open pine-birch forest (Bégeot, 2000). Rochedane's layers C'1 and B show intensive occupations which provided a rich fauna dominated by red deer (Bridault, 1990), an abundant lithic industry (Thévenin, 1982), engraved and painted portable art (D'Errico, 1995) and scattered, well-dated human bones (Cupillard, 2008). In contrast, the other sites including Oberlag Layer S (Thévenin and Sainty, 1980), Rigney 2, and Bretonvillers (Cupillard, 2008) have smaller lithic and bone series and seem to be short-term occupations. The cave of Bichon is a very special case of a bear hunting accident (Morel, 1998; Chauvière, 2008). On the other hand, the study of lithic raw material shows the importance of regional flints, which indicate that the Jura range was no longer a barrier to exchanges (Cupillard and Bourgeois, 2008).

### 3.7. Late Azilian and Late Epigravettian: from 13 000 to 11 700 cal BP (Fig. 7E)

For the Younger Dryas, archaeological data are poor (Thévenin, 1982, 2002; Pion, 2004) and our precise knowledge is based only on four well-dated sites. These occupations in rockshelters are the layer R of Oberlag, the layer A4 of Rochedane (Drucker et al., 2011a), the layer D2 of Gigot at Bretonvillers and the layer III of Longeville (Cupillard, 2008). In addition, a part of layer II of Rislisberghöhle could be included in this small group of sites (Leesch et al., 2012). The lithic techno-assemblages from sites of Oberlag, Rochedane, Bretonvillers, and Longeville have been recently revised. Layers A4 of Rochedane and R of Oberlag may be attributed to the Late Epigravettian, while layers D2 of Bretonvillers and III of Longeville may be considered as belonging to the Late Azilian or to the Late Epigravettian (Fornage-Bontemps, 2013).

At Rochedane and Oberlag, the hunted fauna has been well studied : it is temperate and dominated by red deer (Bridault, 1990). Stone industries are made from local resources and the abundance of small geometric points at Rochedane (Fornage-Bontemps, 2013) reflects intensive hunting practices (Bridault, 1990) with the presence of engraved and painted portable art (D'Errico, 1995), whereas the three other sites are less documented (Fornage-Bontemps, 2013). These very late Final Palaeolithic occupations are all dated from the first part of GS-1 between 12 900 cal BP and 12 661 cal BP. The lack of <sup>14</sup>C dates between 12 600 and 11 700 cal BP must be emphasized. Could this situation be explained by climatic context or by changes in human use of landscape during the Younger Dryas? The latter hypothesis must be carefully examined, because palynological studies show a tripartite division of this biozone with a warmer phase between two colder phases (Bégeot, 2000).

### 3.8. Early Mesolithic: From 11 700 to 9600 cal BP (Fig. 7F)

The Preboreal saw the first appearance and the development of the Early Mesolithic, which corresponds to the first part of the First Mesolithic defined by Gesquière and Marchand (2010). This first Mesolithic settlement is characterised by a general increase of sites and of radiocarbon dates (Crotti and Cupillard, 2013). This period is marked as well by the appearance of important open air sites in the western lowlands, including Choisey les Champins, Ruffey a Daupharde, and Dammartin-Marpain sur la Prairie (Crotti and Cupillard, 2013). The rhythm of these occupations is not regular and varies with time. According to the calibrated <sup>14</sup>C dates, the oldest Mesolithic phase is isolated and is known only from the layer C2 at the open air site of Choisey les Champins 1 dated between 11 270 and 11 190 cal BP. The flint industry of this site shows northern influences, similar to Epi-ahrensbourgian traditions (Séara et al., 2002). Between this first occupation and the following



sites, there is a gap of several centuries. Most of the Early Mesolithic sites belong to the later part of the Preboreal and the beginning of the Boreal. This second phase of the Early Mesolithic is dated between 10 400 and 9600 cal BP in several open air sites including Dammartin-Marpain (Séara, 2010), Choisey Les Champins 1, and Ruffey A Daupharde (Séara et al., 2002) and in several rockshelters including Oberlag (Mannlefelden, layer Q), Mollendruz, layer 4<sup>e</sup> (Pignat and Winiger, 1998) and Hostias La Chênélaz, layer 2b (Cartonnet and Naton, 2000). As far as the Early Mesolithic is concerned, two main points must be emphasized. First, there is a chronological gap between the beginning of the Holocene and the earliest phase of the Early Mesolithic. Is there a link with the deterioration, the Remoray Phase, dated around 11 200 cal BP (Magny, 2004) and the Northern Mesolithic because of this climatic crisis? The second point is the consolidation phase of peopling at the end of Preboreal and the beginning of Boreal characterised by a wide dispersal of Beuronian and Sauveterrian groups, even in the Jura Range. This phenomenon is in conformity with the general climatic improvement demonstrated by palynology and climatic limnology (Magny, 2004).

### 3.9. Middle Mesolithic : from 9600 to 9000 cal BP (Fig. 7G)

The Middle Mesolithic corresponds to the second part of the First Mesolithic defined by Gesquière and Marchand (2010). During the main part of the Boreal, there is a wider dispersal of Middle Mesolithic sites. In the western lowlands, important open-air settlements of Dammartin-Marpain (Séara, 2010), Choisey Les Champins 1, and Ruffey A Daupharde (Séara et al., 2002) have been excavated and provide an important set of AMS dates showing a continuity of settlement during this period, despite “Boreal oscillations” dated between 9550 and 9350 cal BP (Magny, 2013). Many occupations are recognised as well in rockshelters as, for example, Bavans (Sous la Roche, layers 6 and 7), Ranchot (Les Cabônes, layer 3 pro parte), and Mollendruz, layer 4d (Pignat and Winiger, 1998). Beuronian and Sauveterrian groups exploited intensively all the altitudinal ecosystems, and base camps are found in the plains but also in the high ranges (Cupillard and Crotti, 2013). The discovery of scattered human bones at Ranchot layer 3 (Valentin, 1998) and of a very special grave at Ruffey-sur-Seille level R2 must also be emphasized (Valentin and Le Goff, 1998).

### 3.10. Late Mesolithic: from 9000 to 7000 cal BP (Fig. 7H)

This phase corresponds to the Second Mesolithic defined by Gesquière and Marchand (2010). The first part of the Early Atlantic and the beginning of the Late Mesolithic are characterised by the development of trapezes (Perrin et al., 2009). Only few sites are concerned; they are Oberlag « Mannlefelden I/J, Bretonvillers ‘Gigot, layer C2 pro parte’ (Cupillard, 2008), Ruffey ‘A Daupharde, layer R1 pro parte’ (Séara et al., 2002), Villers-le-Lac ‘Roche aux Pêcheurs, layer 5’ (Cupillard, 2010) and Mollendruz layer 4b (Pignat and Winiger, 1998). This first phase of the Late Mesolithic began around 9000 cal BP. The rareness of this initial stage of Second Mesolithic must be stressed, and the poor preservation of sites could be explained by destruction provoked by the 8200 cal BP event (Crotti and Cupillard, 2013).

The latter part of the Early Atlantic, between 8000 and 7000 cal BP, is the second stage of the Late Mesolithic. Sites are well-preserved and several of them are well-dated : this is the case with Villers-le-Lac ‘Roche-aux-Pêcheurs, layer C4’ (Cupillard, 2010), Bretonvillers ‘Gigot, layer C2 pro parte’ (Cupillard, 2008), Saint-Ursanne ‘Les Gripons, layer 3’ (Pousaz, 1991), Saint-Hippolyte ‘Montandon, layer 4’ (Cupillard, 2008), Ruffey-sur-Seille ‘A Daupharde, level R1’ (Séara et al., 2002), Neuville ‘Le Roseau, layer 3’

(Perrin, 2001) and Ambérieu-en-Bugey ‘Gardon cave, layers 57 and 54’ (Voruz, 2009).

From 8000 to 7300 cal BP, the economy of Mesolithic groups seems to have been based only on hunting and gathering. Since 7300 cal BP, few Final Mesolithic industries are contemporary with Early Neolithic industries, as in the Gardon cave where Final Mesolithic levels 54 and 57 are interstratified with Early Neolithic levels 56 and 58 (Voruz, 2009). This Early Neolithic presence is confirmed by palynological results which clearly show agricultural practices in lacustrine or peat-bog sequences at differing altitudes in the Jura range.

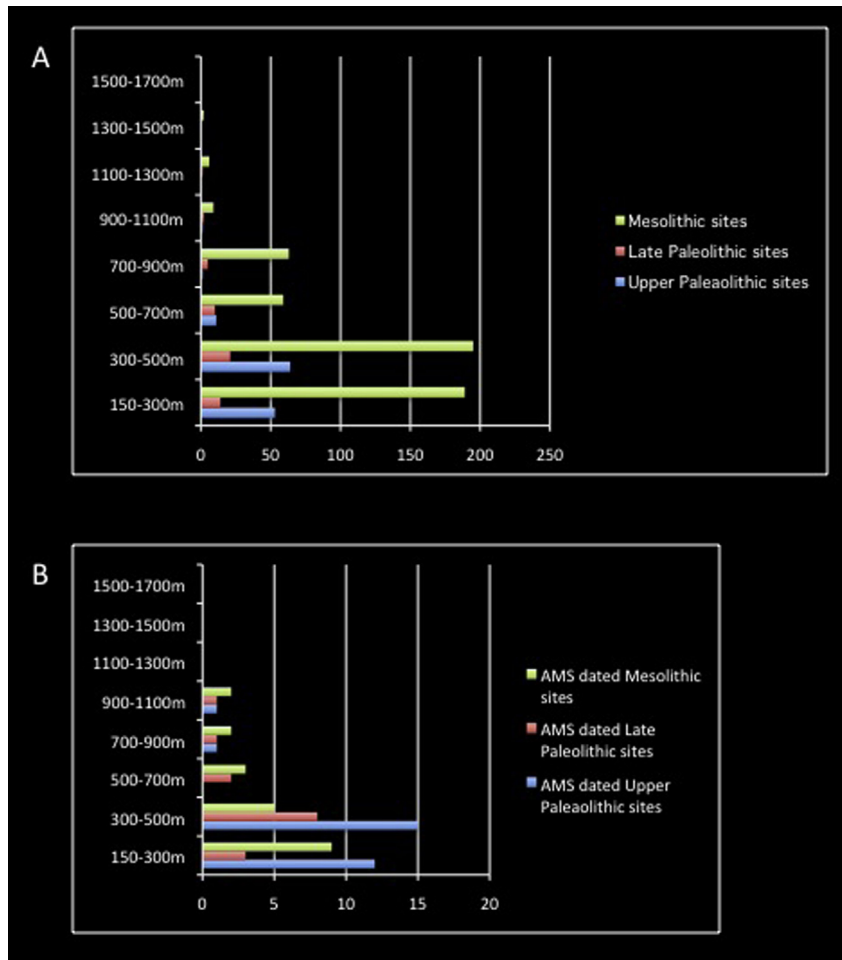
## 4. Discussion and conclusions

The French and Swiss Jura range, between 40 000 and 8000 cal BP, provides an abundance of palaeoclimatic/palaeoenvironmental and archaeological data which have been produced separately for a few decades. In this work, we have attempted to give a general overview of the all this data with a special focus on archaeology. At this point, although it is not yet possible to present a general integrated synthesis, we can nevertheless point out possible correlations between cultural evolution and palaeoclimatic and palaeoenvironmental changes. However, before attempting to compare palaeoclimatic and palaeoenvironmental records with archaeological data for a regional synthesis, it is important to point out some problems in order to reach this integrated view.

The first problem deals with the representativeness of the 48 archaeological sites which have been selected for this study and the 256 available AMS dates used for the reconstruction of the general cultural evolution. In the Jura range and its margins, according to our recent and unpublished archaeological inventories, around 700 Upper/Final Palaeolithic and Mesolithic sites (caves, rockshelters, open air sites and scatter areas) have been found. They compose 130 Upper Paleolithic sites (18%) with 2 Aurignacian sites, 3 Gravettian sites and 7 Badegoulian sites; 53 Final Palaeolithic sites (8%), with 38 Early and Middle Azilian sites, and 15 Late Azilian/Epigravettian sites; and 523 Mesolithic sites (74%), with 78 Early Mesolithic sites, 162 middle Mesolithic sites and 283 Late Mesolithic sites.

Fig. 8a presents the altitudes of these 700 archaeological sites. It shows (i) that Aurignacian, Gravettian and Badegoulian sites are scarce and are located below 500 m a.s.l.; (ii) that Magdalenian sites are relatively abundant and located mainly between 190 and 500 m a.s.l., whereas only rare occupations are located above 900 m a.s.l.; (iii) that Azilian and Epigravettian sites are less numerous than the Upper Magdalenian sites, but with elevated occupations between 700 and 1000 m a.s.l. particularly during the early and middle Azilian. The late Azilian and the late Epigravettian are less numerous and located below ca 500 m a.s.l.; and (iv) that Mesolithic sites are very abundant, located between 190 and 1500 m, but mainly between 190 m and 900 m, with an increasing number of sites from the early to the recent Mesolithic.

Among these 700 sites, only 63 (9%) have been radiocarbon-dated and give 397 dates, with 141 conventional results obtained from 41 sites (5% of the total sites and 36% of the dates), and 256 AMS results from 48 sites (7% of the total of sites and 64% of the dates), with 29 Upper Palaeolithic sites (22% of the Upper Palaeolithic sites), 15 Late Palaeolithic sites (28% of Final Palaeolithic sites) and 21 Mesolithic sites (4% of the Mesolithic sites). Therefore, the Upper and Final Paleolithic are better radiocarbon-dated than the Mesolithic. This situation is illustrated by Fig. 8b which shows the altitude distribution of the 48 AMS radiocarbon-dated sites. This picture mainly reflects the present state of the research and



**Fig. 8.** A. Number and elevation (in m a.s.l.) of all the archaeological sites (radiocarbon-dated or not, i.e. 700 sites): Aurignacian (ca 45 000–34 000 cal BP), Gravettian (ca 34 500–25 000 cal BP), Badegoulian/early Magdalenian (ca 23 000–18 700 cal BP), middle Magdalenian (ca 18 700–17 000 cal BP), late Magdalenian (ca 17 500–14 000 cal BP), early and middle Azilian (ca 14 500–13 000 cal BP), late Azilian and late Epigravettian (ca 13 000–11 700 cal BP), early Mesolithic (ca 11 700–9600 cal BP), middle Mesolithic (ca 9600–9000 cal BP), and late Mesolithic (ca 9000–7000 cal BP). From [Cupillard et al. \(2013\)](#), [Leesch et al. \(2013\)](#), [Crotti and Cupillard \(2013\)](#), Cupillard and Perrenoud-Cupillard (unpublished data). The chronology is in agreement with and refers to cultural phases defined and radiocarbon-dated in neighbouring regions by [Jaubert \(2011\)](#) and [Leesch et al. \(2012\)](#). B. Number and elevation (in m a.s.l.) of the archaeological sites discussed in the paper and dated by the AMS-radiocarbon method (48 sites, 256 AMS dates).

has still to be improved, particularly for the Mesolithic period, by increasing the number of AMS dates.

The second difficulty arises from the chronological and spatial heterogeneity of the sequences used for the reconstruction of palaeoclimatic and paleoenvironmental evolution. Because of the LGM, the Jura mountains do not deliver continuous natural or archaeological sequences covering the period 40 000 to 8000 cal BP. The closest continuous natural ones are located beyond the extent of the LGM, with Les Echets and La Grande Pile, located on the southwestern and northwestern margins of the range. Moreover, continuous karst sequences are absent because of erosion or sedimentation gaps observed in several infillings ([Campy and Chaline, 1993](#)) whereas loessic sequences are incomplete in the northern part of Switzerland. On the other hand, in the extent of LGM, pre-LGM natural sequences are very scarce and truncated, whereas post-LGM sequences from lakes and mires up to 400 m a.s.l. are abundant, and their multi-proxy studies can establish high-resolution palaeoenvironmental and palaeoclimatic records. Unfortunately, only a few provide well-preserved archaeological layers, such as the Magdalenian and Azilian open-air sites of Neuchâtel “Monruz” and Hauterive “Champréveyres”. Between 17 000 and

8000 cal BP, the archaeological sites are included mainly in karst sequences and secondarily in Holocene alluvial sequences. Although they are rarely continuous (but there are exceptions), these sequences give large sets of well-preserved organic materials such as bones, nut shells and charcoal, which facilitate archaeozoological studies, AMS dating and isotope geochemical analyses. These types of data are often the only tools available for reconstructing the palaeoenvironmental and palaeoclimatic context of human settlements. Therefore, defining the palaeoenvironmental and paleoclimatic context of the cultural changes consists of establishing correlations, on the basis of AMS dates, between (i) the data obtained from archaeological sites and (ii) the multi-proxy records provided by lake and mire sediment sequences.

A third difficulty deals with the taphonomy which appears to be particularly evident for archaeological sites as shown by the sites of Hauterive-Champréveyres and of Neuchâtel-Monruz, recently investigated on the shore of Lake Neuchâtel ([Leesch et al., 2012](#)). As noted by [Leesch et al. \(2012\)](#), [Cupillard et al. \(2013\)](#), and [Crotti and Cupillard \(2013\)](#), Palaeolithic and Mesolithic research has long concentrated on caves and rockshelters since they are easier to locate than open air sites. The fortuitous discovery of

Champréveyres and Monruz or Choisey “Les Champins”, Ruffey “A Daupharde” and Dammartin-Marpain “Sur la Prairie”, hints strongly at the possibility of many other well-preserved archaeological sites below the present-day lake water-levels, in alluvial deposits, or even in peat bogs. In contrast, the above compilation of regional lake sediment sequences document the period 40–8 ka. The lack of data for the LGM is due to a local ice cap preventing sediment accumulation in lake basins in elevated areas of the Jura Mountains up to the deglaciation. This points out the need to develop systematic investigations in lower areas (even if geomorphological conditions were not favourable to the formation of lacustrine basins) and/or in more elevated but ice-free areas close to the regional icecap border. This appears to be a pre-requisite to establish a continuous palaeoclimatic-palaeoenvironmental record as well as a solid chronology for the LGM in the Jura range.

A fourth difficulty arises from discrepancies between palaeoclimatic/palaeoenvironmental and archaeological data. Thus, even if several archaeological sites provided key stratigraphic sequences giving evidence of well-dated successive occupations from distinct cultural periods, the available archaeological data most often represent discontinuous cultural sequences from a chronological and spatial point of view. Systematic and extensive investigations are needed and are at work to establish a solid pattern of the regional history of human settlement in terms of changes in culture, spatial extension of occupation in the region, and demography (Leesch et al., 2012; Cupillard et al., 2013; Crotti and Cupillard, 2013). In contrast, strategically selected lake-sediment sequences may relatively easily provide continuous records to identify past changes in climatic and environmental conditions (Wegmüller, 1966; Bégeot, 2006; Magny et al., 2006).

In addition to these first methodological problems dealing with the representativeness of the palaeoenvironmental records and the archaeological data, we have also to consider questions about the economic and social structures of the Upper Palaeolithic and Mesolithic groups (and their possible variations). In this domain, our knowledge has still to be improved: this appears to be particularly evident in comparison with the richness of data collected in the Jurassian range from the Neolithic and Bronze age lake-dwellings sites (Pétrequin et al., 2005). This is a crucial point in evaluating the possible sensitivity of the last hunter-gatherer societies to climatic changes. Nevertheless, during the last decades many improvements have been made which help to define more precisely the subsistence strategies and their variations especially during the Upper Magdalenian and the Mesolithic (Leesch, 2000; Cupillard, 2010; Leesch et al., 2013; Crotti and Cupillard, 2013).

A last difficulty may arise from an estimation of the population density and human dispersal from the number of sites recognised in the region for prehistoric stages characterised by nomadic hunter-gatherer groups (Bocquet-Appel et al., 2005). Studies on lithic raw material and exotic artefacts help to outline exploited territories and exchange networks (Affolter, 2002; Leesch et al., 2013; Séara et al., 2002; Cattin et al., 2009; Cupillard, 2010) and archaeozoological studies coupled with stable isotope analyses provide useful data on the palaeoenvironment and the territories exploited (Drucker et al., 2011a, 2012). However, even if important, these palaeoenvironmental data appear still to be limited to best documented periods, i.e. those after 18 700 cal BP. Similarly, regarding our knowledge about settlements, spatial investigations have been developed only for sites of the Upper Magdalenian and Mesolithic, which give a good data set for a deeper understanding of the organization of hunter-gatherer settlements and help to develop functional models of societies such as those proposed by Leesch and Bullinger (2012) and Séara et al. (2002). In contrast, the data about the habitat appear more deficient for the Upper

Paleolithic before 17 500 cal BP. These types of studies are obviously crucial and need to be developed for a better understanding of the sensitivity of the last hunter-gatherer groups to climatic and environmental changes. As illustrated by Fig. 9, it is clear that the available documentation displays a discontinuity of settlement which supports previous observations (Campy and Richard, 1988). This may reflect a possible impact of the Jurassian LGM ice cap and its consequences on the preservation and the possible discovery of archaeological sites (Cupillard, 2012a; Leesch et al., 2012; Cupillard et al., 2013). According to the apparent timing of the human settlement shown in Fig. 8, three main stages can be distinguished:

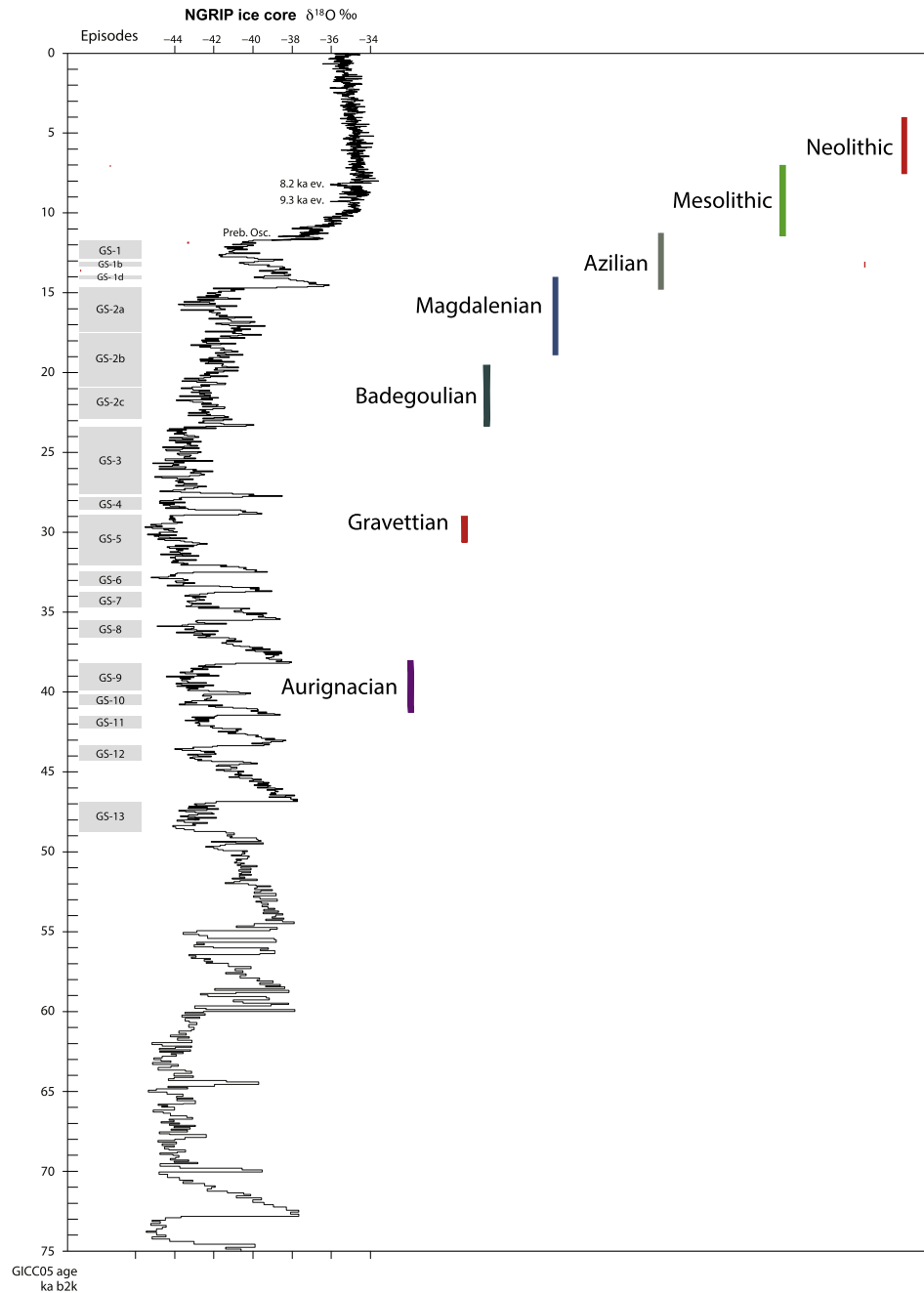
- 1) The first stage spans the period 40 000–18 700 cal BP and it is strongly influenced by the LGM. From an archaeological and palaeoclimatological point of view, it is poorly documented because the Jurassian lakes were ice-covered during this phase and because only a few well-dated Aurignacian, Gravettian and Badegoulian occupations have been studied in the western Jurassian lowlands.

Aurignacian and Gravettian settlements, between 40 000 et 30 000 cal BP, predate the LGM. They are very few, and located outside the Jura range. They also seem to be intermittent occupations. The complete absence of Upper Palaeolithic sites before 27 000 cal BP in the Jura mountains as well as on the Swiss Plateau may be explained by their possible destruction by the LGM ice cap. Their regional rareness outside the LGM ice-cap extent is more problematic in comparison with the neighbouring settlement centers recognised in the Swabian Jura (South-western Germany) and in Burgundy in eastern France (Otte, 2010; Floss et al., 2013). This suggests that the western Jura range could have been occasionally frequented by Aurignacian and Gravettian groups. Such a hypothesis has still to be examined on the basis of systematic investigations between the valleys of the Saône and Doubs rivers.

Between 27 000 and 18 700 cal BP, the absence of Solutrean sites and the scarceness of Badegoulian sites in the Jura region may be explained by the presence of an ice cap and unfavourable environmental conditions in its surroundings. Markers of a first re-occupation by Palaeolithic groups appear only at the end of the LGM in the northern and northwestern parts of the Jura region. They suggest only short-term occupations in the vicinity of recently deglaciated zones, marked by presence of reindeers, probably in relation to the existence of refuge areas in margin lowlands around the Jura range (Drucker et al. 2012).

- 2) The second stage from 18 700/18 000 to 11 700 cal BP corresponds to the time window between the end of the ice melt in the Jura Mountains and the end of the Late Glacial. Since ca 17 000 cal BP, climate and paleoenvironment are well revealed by Jurassian lake sediment-sequences, while archaeological sites are numerous and well investigated. Human dispersal suggests different successive sub-stages.

The first one, between 18 700 and 17 000 cal BP, corresponds to the onset of the true Magdalenian settlement (Middle Magdalenian) which is limited to the periphery of the Jura. The absence of Magdalenian sites in the highest parts of the Jura Mountains probably reflects the presence of a residual ice cap. On the less-elevated plateaus, the absence of Magdalenian sites may be explained by particular characteristics of territories exploited by Magdalenian hunters with an apparent preference for raw material originating from lowland areas as suggested by lithic artefacts from Grappin cave in Arlay (Cupillard and Welté, 2009).



**Fig. 9.** Chronology of Upper Palaeolithic, Final Palaeolithic, Mesolithic and Neolithic of the French and Swiss Jura sites AMS dated compared to the Greenland ice sheet climate (NGRIP). The NGRIP oxygen isotopes curve is based on the INTIMATE event stratigraphy (Blockley et al., 2012) for the period 48–0 ka, and the NGRIP Project data (NGRIP Members, 2004) for the period 75–48 ka.

The second phase, corresponding to the Upper Magdalenian and the Early/Middle Azilian between 17 500 and 13 000 cal BP, can be considered as a consolidation phase of settlement. For the first time, settlements are found in the Jura range from 15 000 cal BP. During this phase, after the complete deglaciation of the Jura range at ca 17 000/16 600 cal BP, the Magdalenian sites (ca 17 000–14 000 cal BP) are mainly located below 500 m a.s.l., while only short-term occupations are present in the more elevated areas during the last part of the period, i.e. during the late Oldest Dryas or early Bölling pollen zones at sites of La Chênélaz (900 m a.s.l.) and Mollendruz (1088 m a.s.l.). Available data suggest that Late Magdalenian hunters have preferentially exploited territories

located at low altitude around the Jura range (Swiss Plateau, Rhone Valley, lowland zone to the west of the Jura Mountains, Rhin Valley), with a penetration into the main Jurassian valleys and only short-term occupations in the western plateaus and the high-elevated areas (Leesch et al., 2012). This is supported by studies of the origins of the lithic raw material found in archaeological sites (Leesch et al., 2013; Mével, 2013).

During the Oldest Dryas pollen zone, the preference of Magdalenian groups for lowland areas may have been in relation to a more abundant vegetation cover, which favoured reindeer and horse populations particularly appreciated by the Magdalenian hunters (Leesch et al., 2012). In addition, the extension of forested areas at

the beginning of the Bölling pollen zone favoured the development of new species such as deer and probably provoked changes in cynegetic practices. This led to a diversification of hunting territories which may explain the first Magdalenian occupations in the highest parts of the Jura range, which were followed between 14 000 and 13 000 cal BP by a large altitude range of the Azilian sites.

During the third sub-stage, between 13 000 and 11 700 cal BP (i.e. during the Younger Dryas cold event), Late Palaeolithic sites are rare, and only few well-dated sites are located below 500 m a.s.l. This suggests a contraction of the population density probably linked to cooler climatic conditions during the GS-1 cold event which strongly affected the ecosystems and provoked a decrease in available natural resources. This period is coeval with the apparition of Late Epigravettian groups. It is important to note the synchronicity between changes in climatic/environmental conditions and cultures (northern extension of Epigravettian culture).

3) The third stage between 11 700 and 7000 cal BP corresponds to the early Holocene. An important corpus of palaeoenvironmental and archaeological data record this phase characterised by warmer climatic conditions, an extension of the forest and a recolonisation of the Jura range by Mesolithic groups. Nevertheless, AMS dating shows that this phenomenon was not regular and that the rhythm of these occupations underwent variations during the period.

The first occurrence of the Mesolithic has been radiocarbon dated to ca 11 270–11 190 cal BP. It seems to have been geographically limited to the western lowlands of the Jura range and lithic industries could indicate a northern cultural influence close to the Epi-Ahrensbourgian. This delay of the Mesolithic recolonization, whereas climatic and environmental conditions are quite favourable, could have been explained by a previous strong impact of the more than 1000 year-long Younger Dryas cold event on the Late Azilian/Late Epigravettian groups (strong decrease in natural resources associated with hard climatic and environmental conditions) resulting in a marked decrease in the regional population density.

The true development of the Mesolithic dispersal of the Jura range occurred around 10 400 cal BP during the second part of the Preboreal pollen zone, reinforced during the Boreal pollen zone.

Dating from the second part of the Preboreal, after ca 11 200 cal BP, large Mesolithic open-air sites have been recognized in lowland areas to the west and east of the Jura range, while more elevated areas in the Jura Mountains are characterized by the first Early Mesolithic occupations in the Upper part of the Jura range. The Boreal pollen zone, between ca 10 200 and 9000 cal BP, corresponds to a reinforcement of the Mesolithic settlement in lowland as well in more elevated areas with intensification of occupations to ~1100 m a.s.l. This time interval is also characterised by the possible appearance of a first human impact on the vegetation.

The first part of the Old Atlantic pollen zone before ca 8000 cal BP is characterised by the development of the second phase of the Mesolithic with regular blade debitage and trapezes (Perrin et al., 2010). In the Jura range, this period is marked by a clear decrease in the number of Mesolithic sites which suggests a strong decrease in the population probably affected by unfavourable climatic and environmental conditions (with a reduction in natural resources) characteristic for the 8.2 ka event in the Jura region (Magny et al., 2001). However, the rapid re-expansion of the Mesolithic occupations on the whole Jura range after 8000 cal BP indicates that, in addition to the dynamics of the last Mesolithic societies and the development of the first Neolithic groups, around 7300 cal BP

(Gauthier and Richard, 2008), the impact of the ca 200 years-long 8.2 ka cold event was less strong on both the ecosystems and societies than that of the millennial-scale Younger Dryas cold event.

In conclusion, study of the Jura range has supplied a large data set about climate, paleoenvironment and prehistory for the period 40–8 ka cal BP. Considered as a whole, the data gathered in this synthesis invite further investigations for a better understanding of the response of environment and societies to climate changes as follows:

1. There is a need to develop further systematic exploration of the Jura range to find archaeological sites and sediment sequences containing a record the time window 40 000–17 000 cal BP.
2. Made of calcareous rock, the Jura Mountains have hundreds of caves at different altitudes, inside or outside of the maximal extent of the LGM ice cap. These sites can be ideal for the study of speleothems and fauna (above all bones of bears such as *Ursus spelaeus* and *Ursus arctos*) which will provide highly significant data for the understanding of the regional climatic conditions during the period 40–17 ka cal BP not documented by lake sediment sequences.
3. There is a need to establish a solid chronology for the disappearance of the Jurassian ice cap during the transition between the late Pleniglacial and the early Lateglacial.
4. Another important requirement is to develop systematic extensive archaeological surveys of all the available Upper Paleolithic, Late Paleolithic and Mesolithic sites in order to establish improved chronological, typo-technological and paleoenvironmental records and detailed archaeological maps (Cupillard, 2012a). It is necessary to continue surveys about human impact on environment in pollen profiles (developing studies of anthropogenic pollen indicators and charcoal, and more AMS dates) in order to confirm possible Mesolithic land clearance(s) and to refine the chronology, the intensity and the rhythm of the earliest stages of agriculture.

## Acknowledgements

Financial support for the regional studies synthesized in this paper was provided by (1) the French CNRS (UMR-6249 Chrono-Environment), (2) the CNRS-programme ECLIPSE “*Cervus*” (dir. A. Bridault), (3) the Collective Research Program (PCR-1997–2003) « *The Late Glacial at the North of the Alps and at the South of Jura range* » (dir. G. Pion, 1997–2003), (4) the PCR (2005–2008) « *The Late Glacial and the beginning of Holocene in the Jura range and its margins* » (dir. Christophe Cupillard, 2005–2008), (5) the Program n° 124457 of the Swiss National Science Foundation Fonds: « Dynamics of land use pattern of lateglacial hunter populations throughout the seasonal cycle: the mobility of Magdalenian groups of the Swiss Plateau and Jura mountain » (dir. D. Leesch and W. Muller), (6) a PCR directed by P. Bodu, F. Bon and L. Brou, (2001–2009), (7) the PCR « *Raw material's gestion and human peopling around the Serre range* » (dir. L. Jaccottey et A. Milleville; 2007–2009), (8) the PCR « *Final Paleolithic and Mesolithic in the Parisian Bassin and its margins* » (dir. P. Bodu and B. Valentin; 2010–2012), and (9) and the programme IFB-INRA « *Global change, animal biodiversity and societies since 16000 years ago in northern France* » (dir. A. Bridault). We would like to thank our colleagues Pierre Bodu, Jérôme Bullinger, Luc Jaccottey, Denise Leesch, Annabelle Milleville, Werner Müller, Gilbert Pion, Frédéric Séara, Caroline Szmids and Boris Valentin for fruitful collaborations. Many thanks are due to Beryl Sandoz and Jim H. Dickson for their review of the English language. We thank two anonymous reviewers for their constructive comments, which helped us to improve the quality of the paper.

## Appendix 1

**Table 2**

List of the AMS dates of the Upper Palaeolithic, Final Palaeolithic and Mesolithic sites in the French and Swiss Jura. These 256 new AMS dates have been calibrated using the calibration software CALPAL ([Danzeglocke et al., 2009](#); [www.Cal.pal.de](http://www.Cal.pal.de))

Number	District	Site	Locality	Altitude (m)	Layer or level	Sample material	Laboratory	BP	Ecart-type	Cal BP	Ecart type	Mini	Maxi	Reference	Typo-chronological attribution
1	1	Le Gardon	Ambérieu-en-Bugey	373	Layer 58	Charcoal	Ly-5515	5982	96	6835	118	6717	6953	<a href="#">Voruz 2009</a>	Early Neolithic/Final Mesolithic
2	1	Le Gardon	Ambérieu-en-Bugey	373	Layer 58	Charcoal	Ly-5513	6124	42	7044	85	6958	7129	<a href="#">Voruz 2009</a>	Early Neolithic/Final Mesolithic
3	1	La Chênélaz	Hostias	900	Layer 2b	Bone (indet.)	Ly-5498	9528	140	10,860	213	10646	11073	<a href="#">Cartonnet and Naton 2000</a>	Early Mesolithic
4	1	La Chênélaz	Hostias	900	Layer 2	<i>Rangifer</i>	OxA-8027 (Ly-703)	12460	65	14,737	320	14416	15057	<a href="#">Bridault et al., 2000</a>	Upper Magdalenian
5	1	La Chênélaz	Hostias	900	Layer 2c	Bone (indet.)	Ly-4790	12610	200	14,945	429	14516	15374	<a href="#">Cartonnet and Naton 2000</a>	Upper Magdalenian
6	1	La Chênélaz	Hostias	900	Layer 2c	Bone (indet.)	Ly-743/OxA-8068	12780	75	13,291	278	14962	15519	<a href="#">Cartonnet and Naton 2000</a>	Upper Magdalenian
7	1	Le Roseau	Neuville-sur-Ain	275	Layer 3	Bone (indet.)	Ly-5923	6140	70	7043	98	6944	7141	<a href="#">Wittig and Guillet 2000</a>	Early Neolithic/Final Mesolithic
8	1	Le Roseau	Neuville-sur-Ain	275	Layer 3	Bone (indet.)	GrA-16351	6720	40	7588	33	7554	7621	<a href="#">Perrin 2001</a>	Late Mesolithic
9	1	Le Roseau	Neuville-sur-Ain	275	Layer 4	Bone (indet.)	GrA-13649	7600	40	8405	20	8385	8425	<a href="#">Perrin 2001</a>	Late Mesolithic
10	1	Le Roseau	Neuville-sur-Ain	275	Layer 4	Bone (indet.)	GrA-13648	8050	40	8916	95	8821	9011	<a href="#">Perrin 2001</a>	Middle Mesolithic
11	1	La Colombière	Neuville-sur-Ain	275	E7-6/27.7	<i>Rangifer</i> /antler	Ly-644/GrA-9713	14390	70	17,542	253	17289	17795	<a href="#">Bridault et al., 2000</a>	Middle Magdalenian
12	1	Abri Gay	Poncin	270	CF2b M13/909	<i>Rangifer</i>	Ly-640 (Gr-9705)	12160	60	14,193	233	13960	14426	<a href="#">Bridault et al., 2000</a>	Upper Magdalenian
13	1	Abri Gay	Poncin	270	C? - 430/P13	<i>Alces</i>	Ly-1454(OxA)	12505	65	14,821	303	14518	15124	<a href="#">Drucker et al., 2009</a>	Upper Magdalenian
14	1	Abri Gay	Poncin	270	CF2d G18/123	<i>Rangifer</i>	Ly-639 (GrA-9720)	12980	70	15,822	409	15412	16231	<a href="#">Drucker et al., 2009</a>	Upper Magdalenian
15	1	Abri Gay	Poncin	270	81-1 15	<i>Gulo</i>	Ly-1543 (OxA)	13795	100	16,972	192	16780	17164	<a href="#">Bridault and Chaix 2009</a>	Upper Magdalenian
16	1	Les Hoteaux	Rosillon	250	Human grave	<i>Rangifer</i> /antler bâton percé	OxA-9457(Ly-1132)	12830	75	15,352	269	15082	15621	<a href="#">Oberlin and Pion 2009</a>	Upper Magdalenian
17	1	La Croze	Saint-Martin-du-Mont	260	R7	<i>Rangifer</i>	GrA-9704(Ly-638)	14260	70	17,463	254	17209	17717	<a href="#">Bridault et al., 2000</a>	Middle Magdalenian
18	1	Les Romains	Virignin	278	Layer C II b	<i>Rangifer</i>	GrA-9710 (Ly-432)	12830	60	15,350	250	15099	15600	<a href="#">Bridault et al., 2000</a>	Upper Magdalenian
19	1	Les Romains	Virignin	278	Layer C III	<i>Rangifer</i>	GrA-9709(Ly-642)	12690	60	15,076	307	14768	15383	<a href="#">Bridault et al., 2000</a>	Upper Magdalenian
20	1	Les Romains	Virignin	278	Layer 4 ?	<i>Mammuthus</i>	Ly-1772	13140	80	16,062	396	15665	16458	<a href="#">Oberlin and Pion 2009</a>	Upper Magdalenian
21	25	Sous Les Roches	Bavans	308	Layer 5	<i>Cervus</i>	GrA-22131	6000	60	6848	75	6772	6923	<a href="#">Drucker et al., 2009</a>	Early Neolithic/Final Mesolithic
22	25	Sous Les Roches	Bavans	308	Layer 6	<i>Cervus</i>	GrA-23126	8590	60	9582	52	9529	9634	<a href="#">Drucker et al., 2009</a>	Middle Mesolithic
23	25	Sous Les Roches	Bavans	308	Layer 7	<i>Cervus</i>	GrA-23127	6935	40	7769	49	7719	7818	<a href="#">Drucker et al., 2009</a>	Late Mesolithic
24	25	Sous Les Roches	Bavans	308	Layer 8	<i>Cervus</i>	GrA-23129	12170	60	14,204	232	13972	14436	<a href="#">Drucker et al., 2009</a>	Azilian
25	25	Gigot 1	Bretonvillers	457	Layer C2	<i>Cervus</i>	Ly-6511(OxA)	6130	35	7053	80	6972	7133	This work	Late Mesolithic
26	25	Gigot 1	Bretonvillers	457	Layer C2	<i>Sus</i>	Ly-6512(OxA)	7705	45	8493	47	8445	8540	This work	Late Mesolithic
27	25	Gigot 1	Bretonvillers	457	Layer C3	<i>Sus</i>	Ly-6514(OxA)	8640	45	9608	49	9558	9657	This work	Middle Mesolithic
28	25	Gigot 1	Bretonvillers	457	Layer C3	<i>Cervus</i>	Ly-6513 (OxA)	8735	40	9716	88	9628	9804	This work	Middle Mesolithic
29	25	Gigot1	Bretonvillers	457	Layer C4	<i>Cervus</i>	GrA-43939	8645	40	9607	46	9560	9653	<a href="#">Drucker et al., 2011a</a>	Middle Mesolithic
30	25	Gigot 1	Bretonvillers	457	Layer D2 zone 2	<i>Cervus</i>	Ly-4716 (OxA)	10840	50	12,810	78	12732	12888	<a href="#">Drucker et al., 2009</a>	Late Azilian
31	25	Gigot 1	Bretonvillers	457	Layer D8 zone 3	<i>Cervus</i>	Ly-4715 (OxA)	11560	55	13,448	113	13334	13561	<a href="#">Drucker et al., 2009</a>	Azilian
32	25	Roche aux Gours		302	Layer III	Bone indet.	Ly-4549(GrA)	10720	40	12,703	42	12661	12745	This work	Late Azilian

33	25	Rigney 1	Longeville-sur-le-Doubs Rigney	256	Out of stratigraphy	<i>Homo sapiens, ochred mandibule</i>	Ly-6515(OxA)	12930	55	15,716	389	15326	16105	This work	Upper Magdalenian
34	25	Rigney 1	Rigney	256	Layer D	<i>Coelodonta</i>	GrA-21036 (Ly-1925)	16880	80	20,111	267	19843	20378	Cupillard and Welté 2006	Bagedoulian
35	25	Rigney 2	Rigney	256	Layer 2	Bone (indet.)	Ly-4872(GrA)	11805	50	13,713	123	13590	13836	Cupillard et al., 2013	Azilian
36	25	Rigney 2	Rigney	256	Layer 2	Bone (indet.)	Ly-4873(GrA)	11775	50	13,669	117	13552	13786	Cupillard et al., 2013	Azilian
37	25	Montandon	Saint-Hippolyte	590	Layer IV	<i>Cervus</i>	Ly-3734(GrA)	6445	40	7371	41	7329	7412	Drucker et al., 2009	Late Mesolithic
38	25	Montandon	Saint-Hippolyte	590	Layer VI	<i>Cervus</i>	Ly-3733(GrA)	8680	45	9634	56	9577	9690	This work	Middle Mesolithic
39	25	Montandon	Saint-Hippolyte	590	Layer VI	<i>Cervus</i>	Ly-3732(GrA)	9255	40	10,422	78	10343	10500	Drucker et al., 2009	Middle Mesolithic
40	25	Rochedane	Villars-sous-Dampjoux	355	Level A1	<i>Cervus</i>	GrA-21522	6230	60	7136	92	7043	7228	Drucker et al., 2009	Early Neolithic/Final Mesolithic
41	25	Rochedane	Villars-sous-Dampjoux	355	Level A2	<i>Cervus</i>	GrA-21520	6730	60	7592	54	7538	7646	Drucker et al., 2009	Late Mesolithic
42	25	Rochedane	Villars-sous-Dampjoux	355	Level A3	<i>Cervus</i>	GrA-21519	8640	60	9621	61	9559	9682	Drucker et al., 2009	Middle Mesolithic
43	25	Rochedane	Villars-sous-Dampjoux	355	Level A3	<i>Cervus</i>	GrA-23150	10880	50	12,842	82	12760	12924	Drucker et al., 2009	Late Azilian
44	25	Rochedane	Villars-sous-Dampjoux	355	Level A4	<i>Cervus</i>	GrA-23147	10880	50	12,842	82	12760	12924	Drucker et al., 2009	Late Azilian
45	25	Rochedane	Villars-sous-Dampjoux	355	Level A4	<i>Cervus</i>	GrA-23518	10830	70	12,811	87	12723	12898	Drucker et al., 2009	Late Azilian
46	25	Rochedane	Villars-sous-Dampjoux	355	Level A'	<i>Homo sapiens</i>	GrA-41739	11120	50	13,017	120	12896	13137	Drucker et al., 2011a	Azilian
47	25	Rochedane	Villars-sous-Dampjoux	355	Level B	<i>Homo sapiens</i>	GrA-41740	11560	50	13,448	111	13336	13559	Drucker et al., 2011a	Azilian
48	25	Rochedane	Villars-sous-Dampjoux	355	Level B	<i>Cervus</i>	GrA-21516	11600	80	13,486	133	13352	13619	Drucker et al., 2009	Azilian
49	25	Rochedane	Villars-sous-Dampjoux	355	Level B	<i>Homo sapiens</i>	GrA-41741	11920	50	13,820	149	13670	13969	Drucker et al., 2011a	Azilian
50	25	Rochedane	Villars-sous-Dampjoux	355	Level C'1	<i>Capreolus</i>	GrA-45669	11370	50	13,265	123	13142	13388	Drucker et al., 2011a	Azilian
51	25	Rochedane	Villars-sous-Dampjoux	355	Level C'1	<i>Cervus</i>	GrA-21514	11570	70	13,454	119	13335	13573	Drucker et al., 2009	Azilian
52	25	Rochedane	Villars-sous-Dampjoux	355	Level D1	<i>Cervus</i>	GrA-45781	12230	50	14,287	245	14041	14532	Drucker et al., 2009	Upper Magdalenian
53	25	Rochedane	Villars-sous-Dampjoux	355	Level D1	<i>Cervus</i>	GrA-21512	12250	70	14,333	276	14057	14609	Drucker et al., 2009	Upper Magdalenian
54	25	Rochedane	Villars-sous-Dampjoux	355	Level D1	<i>Rangifer</i>	OxA –8030 (Ly-709)	12420	75	14,653	346	14306	14999	Bridault et al., 2000	Upper Magdalenian
55	25	La Roche-aux-Pêcheurs	Villers-le-Lac	752	Layer 4	<i>Sus scrofa</i>	ETH-11831	6530	70	7434	71	7363	7505	Cupillard 2010	Late Mesolithic
56	25	La Roche-aux-Pêcheurs	Villers-le-Lac	752	Layer 4b	Charcoal	Ly-606 (Oxa)	6590	70	7500	53	7446	7553	Cupillard 2010	Late Mesolithic
57	25	La Roche-aux-Pêcheurs	Villers-le-Lac	752	Layer 4c	Charcoal	Ly-1926 (GrA-21038)	6680	45	7551	36	7515	7587	Cupillard 2010	Late Mesolithic
58	25	La Roche-aux-Pêcheurs	Villers-le-Lac	752	Layer 5	<i>Vulpes</i>	Ly-1927(GrA-21039)	7740	45	8517	52	8465	8569	Cupillard 2010	Late Mesolithic
59	39	Chaze II	Arlay	225	Out of stratigraphy	<i>Coelodonta</i>	Ly-3291 (Poz)	13890	80	17,138	209	16929	17347	Cupillard et al. in press	Middle Magdalenian
60	39	Grappin	Arlay	225	Layer C	<i>Rangifer</i>	Ly- 4865 (GrA)	13450	50	16,404	410	15994	16814	Drucker et al., 2012	Upper Magdalenian
61	39	Grappin	Arlay	225	Layer C	<i>Rangifer</i>	Ly- 3878 (GrA)	13640	60	16,734	252	16482	16986	Drucker et al., 2012	Upper Magdalenian
62	39	Grappin	Arlay	225	Layer C	<i>Rangifer</i>	Ly- 4868 (GrA)	14180	50	17,410	246	17164	17656	Drucker et al., 2012	Middle Magdalenian
63	39	Grappin	Arlay	225	Layer C	<i>Equus</i>	Ly- 4866 (GrA)	14220	50	17,438	250	17188	17688	Cupillard et al. in press	Middle Magdalenian
64	39	Grappin	Arlay	225	Layer C	<i>Rangifer</i>	Ly- 4871 (GrA)	14520	50	17,666	234	17431	17900	Drucker et al., 2012	Middle Magdalenian

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Table 2 (continued)

Number	District	Site	Locality	Altitude (m)	Layer or level	Sample material	Laboratory	BP	Ecart-type	Cal BP	Ecart type	Mini	Maxi	Reference	Typo-chronological attribution
65	39	Grappin	Arlay	225	Layer C	<i>Rangifer</i>	Ly- 4869 (GrA)	14850	50	18,182	258	17924	18440	Drucker et al., 2012	Middle Magdalenian
66	39	Grappin	Arlay	225	Layer C	<i>Rangifer</i>	Ly- 4865 (GrA)	14940	60	18,226	240	17985	18466	Drucker et al., 2012	Middle Magdalenian
67	39	Grappin	Arlay	225	Layer C	<i>Rangifer</i>	Ly- 4865 (GrA)	15260	70	18,367	282	18084	18649	Drucker et al., 2012	Middle Magdalenian
68	39	Grappin	Arlay	225	Layer C	<i>Equus</i>	Ly- 3161 (GrA)	15335	100	18,418	304	18113	18722	Cupillard and Welté 2006	Middle Magdalenian
68	39	Grappin	Arlay	225	Layer C	<i>Rangifer</i>	Ly- 3162 (GrA)	15335	115	18,419	308	18111	18727	Cupillard and Welté 2006	Middle Magdalenian
70	39	Grappin	Arlay	225	Layer C	<i>Rangifer</i>	Ly- 3160 (GrA)	16840	100	20,062	285	19776	20347	Cupillard and Welté 2006	Middle Magdalenian
71	39	Grappin	Arlay	225	Layer C	<i>Ursus</i>	Ly- 4870 (GrA)	23400	90	28,167	162	28004	28329	Cupillard and Welté 2009	Animal occupation
72	39	Grappin	Arlay	225	Layer C	<i>Bos/Bison</i>	Ly- 3879 (GrA)	24960	130	29,942	277	29664	30219	Cupillard and Welté 2009	Animal occupation
73	39	Grappin	Arlay	225	Layer D	<i>Crocota</i>	OxA-19633	28570	150	31,045	355	32639	33350	Stuart 2008	Animal occupation
74	39	Chaumois-Boivin	Blois-sur-seille	450	Upper paleolithic level	<i>Rangifer</i>	Ly-3280 (Poz) renne	12530	120	14,844	344	14499	15188	Drucker et al., 2012	Upper Magdalenian
75	39	Les Champins 1	Choisey	196	Level C1	Hazelnut shell	Ly-244 (Oxa)	9175	70	10,366	91	10275	10457	Séara et al., 2002	Early Mesolithic
76	39	Les Champins 1	Choisey	196	Level C2	Hazelnut shell	Ly-2803 (Poz)	9805	65	11,230	40	11189	11270	Séara 2008	Early Mesolithic
77	39	Les Champins 2	Choisey	196	Unique level	<i>Bos</i> , engraved metacarpial	Ly-3125 (Poz)	8700	55	9676	85	9590	9761	Séara 2008	Middle Mesolithic
78	39	Sur la Prairie	Dammartin-Marpain	192	Locus 1	Hazelnut shell	Poz-32793	8130	50	9090	61	9028	9151	Séara 2010	Middle Mesolithic
79	39	Sur la Prairie	Dammartin-Marpain	192	Locus 9	Hazelnut shell	Poz-32833	8170	50	9137	85	9052	9222	Séara 2010	Middle Mesolithic
80	39	Sur la Prairie	Dammartin-Marpain	192	Locus 2	Hazelnut shell	Poz-32826	8170	50	9137	85	9052	9222	Séara 2010	Middle Mesolithic
81	39	Sur la Prairie	Dammartin-Marpain	192	Locus 3	Hazelnut shell	Poz-32828	8180	50	9145	86	9058	9231	Séara 2010	Middle Mesolithic
82	39	Sur la Prairie	Dammartin-Marpain	192	Locus 1	Hazelnut shell	Poz-35483	8190	50	9153	87	9066	9240	Séara 2010	Middle Mesolithic
83	39	Sur la Prairie	Dammartin-Marpain	192	Locus 7	Hazelnut shell	Poz-35492	8210	50	9174	84	9090	9258	Séara 2010	Middle Mesolithic
84	39	Sur la Prairie	Dammartin-Marpain	192	Locus 5	Hazelnut shell	Poz-32830	8230	50	9202	82	9120	9284	Séara 2010	Middle Mesolithic
85	39	Sur la Prairie	Dammartin-Marpain	192	Locus 8	Hazelnut shell	Poz-32832	8230	50	9202	82	9120	9284	Séara 2010	Middle Mesolithic
86	39	Sur la Prairie	Dammartin-Marpain	192	Locus 11	Hazelnut shell	Poz-32794	8420	50	9446	48	9397	9494	Séara 2010	Middle Mesolithic
87	39	Sur la Prairie	Dammartin-Marpain	192	Locus 7	Hazelnut shell	Poz-32791	8500	50	9506	24	9482	9530	Séara 2010	Middle Mesolithic
88	39	Sur la Prairie	Dammartin-Marpain	192	Locus 11	Hazelnut shell	Poz-32795	8540	60	9522	27	9494	9549	Séara 2010	Middle Mesolithic
89	39	Sur la Prairie	Dammartin-Marpain	192	Locus 11	Hazelnut shell	Poz-32824	8600	50	9583	43	9540	9626	Séara 2010	Middle Mesolithic
90	39	Sur la Prairie	Dammartin-Marpain	192	Locus 7	Hazelnut shell	Poz-32797	8830	50	9938	152	9786	10090	Séara 2010	Middle Mesolithic
91	39	Sur la Prairie	Dammartin-Marpain	192	Locus 2	Hazelnut shell	Poz-35486	8830	50	9938	152	9786	10090	Séara 2010	Early Mesolithic
92	39	Sur la Prairie	Dammartin-Marpain	192	Locus 2	Hazelnut shell	Poz-35485	8850	50	9964	142	9822	10106	Séara 2010	Early Mesolithic
93	39	Sur la Prairie	Dammartin-Marpain	192	Locus 7	Hazelnut shell	Poz-35493	8890	50	10,030	104	9926	10134	Séara 2010	Early Mesolithic
94	39	Sur la Prairie	Dammartin-Marpain	192	Locus 14	Hazelnut shell	Poz-32825	8890	50	10,030	104	9926	10134	Séara 2010	Early Mesolithic
95	39	Sur la Prairie	Dammartin-Marpain	192	Locus 1	Hazelnut shell	Poz-35482	8890	50	10,030	104	9926	10134	Séara 2010	Early Mesolithic
96	39	Sur la Prairie	Dammartin-Marpain	192	Locus 1	Hazelnut shell	Poz-32823	8990	50	10,030	104	9926	10134	Séara 2010	Early Mesolithic

248 and 249



97	39	Sur la Prairie	Dammartin-Marpain	192	Locus 2	Hazelnut shell	Poz-35487	9060	50	10,227	23	10203	10250	<a href="#">Séara 2010</a>	Early Mesolithic
98	39	Sur la Prairie	Dammartin-Marpain	192	Locus 6	Hazelnut shell	Poz-32831	9110	50	10,296	60	10236	10356	<a href="#">Séara 2010</a>	Early Mesolithic
99	39	Sur la Prairie	Dammartin-Marpain	192	Locus 2	Hazelnut shell	Poz-32827	9140	50	10,320	65	10254	10385	<a href="#">Séara 2010</a>	Early Mesolithic
100	39	Sur la Prairie	Dammartin-Marpain	192	Locus 6	Hazelnut shell	Poz-35489	9170	50	10,343	69	10273	10412	<a href="#">Séara 2010</a>	Early Mesolithic
101	39	Sur la Prairie	Dammartin-Marpain	192	Locus 6	Hazelnut shell	Poz-32796	9180	50	10,351	72	10279	10423	<a href="#">Séara 2010</a>	Early Mesolithic
102	39	Sur la Prairie	Dammartin-Marpain	192	Locus 6	Hazelnut shell	Poz-35490	9210	50	10,382	84	10298	10466	<a href="#">Séara 2010</a>	Early Mesolithic
103	39	Châteauneuf	Dampierre	220	Hors stratigraphie	<i>Cervus</i>	Ly-4743(OxA)	8100	40	9051	40	9011	9091	<a href="#">Séara 2010</a>	Middle Mesolithic
104	39	Châteauneuf	Dampierre	220	Hors stratigraphie	Hazelnut shell	Ly-4743(OxA)	8815	40	9908	136	9772	10044	<a href="#">Séara 2010</a>	Middle Mesolithic
105	39	Châteauneuf	Dampierre	220	Hors stratigraphie	Hazelnut shell	Ly-4741(OxA)	9110	45	10,290	52	10237	10342	<a href="#">Séara 2010</a>	Early Mesolithic
106	39	Aérodrome	Gevry	197	Unique Layer	Charcoals	Ly-412 (Oxa)	8765	75	9810	154	9656	9964	<a href="#">Séara 2010</a>	Middle Mesolithic
107	39	La Baume	Gigny-sur-Suran	480	Layer IV	<i>Cervus</i>	Ly-3289 (Poz)	6280	45	7216	39	7176	7255	<a href="#">Drucker et al., 2009</a>	Early Neolithic/Final Mesolithic ?
108	39	La Baume	Gigny-sur-Suran	480	Layer VI	<i>Rangifer</i>	Ly-3290 (Poz)	17645	110	21047	329	20718	21376	<a href="#">Drucker et al., 2012</a>	Badegoulian ?
109	39	La Cimante	Meussia	600	Layer 2	Charcoal	Ly-2739(OxA)	9590	50	10,946	129	10946	11075	<a href="#">Cupillard 2012b</a>	Early Mesolithic
110	39	La Cimante	Meussia	600	Layer 5	Bone indet.	Ly-2738	12240	55	14,305	254	14050	14559	<a href="#">Cupillard 2012b</a>	Azilian ?
111	39	Les Cabônes	Ranchot	216	Layer 3	<i>Cervus</i>	GrA-23149 Cerf	8380	45	9399	62	9337	9461	<a href="#">Drucker et al., 2008</a>	Middle Mesolithic
112	39	Les Cabônes	Ranchot	216	Layer 3	<i>Cervus</i>	GrA-21524	8570	60	9557	45	9511	9602	<a href="#">Drucker et al., 2008</a>	Middle Mesolithic
113	39	Les Cabônes	Ranchot	216	Layer 3	<i>Cervus</i>	GrA-21529	8840	60	9945	154	9790	10099	<a href="#">Drucker et al., 2008</a>	Middle Mesolithic
114	39	Les Cabônes	Ranchot	216	Layer 4	<i>Panthera spelea</i>	OxA-12021	12565	50	14,911	290	14620	15201	<a href="#">Stuart and Lister, 2011</a>	Upper Magdalenian
115	39	Les Cabônes	Ranchot	216	Layer 4	<i>Rangifer</i>	ErL-9392	13965	101	17,219	224	16995	17443	<a href="#">Drucker et al., 2012</a>	Upper Magdalenian
116	39	La Mère Clochette	Rochefort-sur-Nenon	225	Aurignacian level	Ochred split-based point	Beta-150312	29490	190	33,847	190	33539	34154	<a href="#">Szmids et al., 2010</a>	Aurignacian
117	39	La Mère Clochette	Rochefort-sur-Nenon	225	Aurignacian level	Ochred awl	Beta-150311	29920	220	34,204	203	34000	34407	<a href="#">Szmids et al., 2010</a>	Aurignacian
118	39	La Mère Clochette	Rochefort-sur-Nenon	225	Aurignacian level	Ochred compact bone fragment	Beta-150314	30800	220	34,935	365	34569	35300	<a href="#">Szmids et al., 2010</a>	Aurignacian
119	39	La Mère Clochette	Rochefort-sur-Nenon	225	Aurignacian level	Split -based point (Wing)	OxA-19621	33750	350	39,292	1172	38120	40464	<a href="#">Szmids et al., 2010</a>	Aurignacian
120	39	La Mère Clochette	Rochefort-sur-Nenon	225	Aurignacian level	Split -based point (Wing)	OxA-19622	35460	250	40,381	841	39540	41222	<a href="#">Szmids et al., 2010</a>	Aurignacian
121	39	A Daupharde	Ruffey-sur-Seille	215	Level R1	Bone indet.	Ly-380 (Oxa-6777)	6560	75	7476	64	7411	7540	<a href="#">Séara et al., 2002</a>	Late Mesolithic
122	39	A Daupharde	Ruffey-sur-Seille	215	Level R1	Bone indet.	Ly-172 (Oxa-5642)	6760	80	7617	60	7556	7677	<a href="#">Séara et al., 2002</a>	Late Mesolithic
123	39	A Daupharde	Ruffey-sur-Seille	215	Level R1	Bone indet.	Ly-381 (Oxa-6776)	7650	160	8479	171	8308	8650	<a href="#">Séara et al., 2002</a>	Late Mesolithic
124	39	A Daupharde	Ruffey-sur-Seille	215	Level R2	Charcoal	Ly-7352	8230	95	9221	137	9083	9358	<a href="#">Séara et al., 2002</a>	Middle Mesolithic
125	39	A Daupharde	Ruffey-sur-Seille	215	Level R2	Hazelnut shell	Ly-218 (Oxa)	8515	65	9508	31	9477	9539	<a href="#">Séara et al., 2002</a>	Middle Mesolithic
126	39	A Daupharde	Ruffey-sur-Seille	215	Level R2	Hazelnut shell	Ly-240 (Oxa)	8690	80	9712	124	9588	9836	<a href="#">Séara et al., 2002</a>	Middle Mesolithic
127	39	A Daupharde	Ruffey-sur-Seille	215	Level R2	Hazelnut shell	Ly-217 (Oxa)	8655	130	9733	172	9560	9905	<a href="#">Séara et al., 2002</a>	Middle Mesolithic
128	39	A Daupharde	Ruffey-sur-Seille	215	Level R2	Hazelnut shell	Ly-238 (Oxa)	8735	85	9766	145	9621	9911	<a href="#">Séara et al., 2002</a>	Middle Mesolithic
129	39	A Daupharde	Ruffey-sur-Seille	215	Level R2	Hazelnut shell	Ly-213 (Oxa)	8765	65	9786	125	9661	9911	<a href="#">Séara et al., 2002</a>	Middle Mesolithic
130	39	A Daupharde	Ruffey-sur-Seille	215	Level R2	Hazelnut shell	Ly-214 (Oxa)	8795	65	9876	163	9712	10039	<a href="#">Séara et al., 2002</a>	Middle Mesolithic
131	39	A Daupharde	Ruffey-sur-Seille	215	Level R3	Hazelnut shell	Ly-7353	8710	110	9776	172	9603	9948	<a href="#">Séara et al., 2002</a>	Early Mesolithic
132	39	A Daupharde	Ruffey-sur-Seille	215	Level R3	Hazelnut shell	Ly-410/AA-23362	8855	65	9959	151	9807	10110	<a href="#">Séara et al., 2002</a>	Early Mesolithic
133	39	A Daupharde	Ruffey-sur-Seille	215	Level R3	Hazelnut shell	Ly-241 (Oxa)	8980	80	10,083	124	9958	10207	<a href="#">Séara et al., 2002</a>	Early Mesolithic

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Table 2 (continued)

Number	District	Site	Locality	Altitude (m)	Layer or level	Sample material	Laboratory	BP	Ecart-type	Cal BP	Ecart type	Mini	Maxi	Reference	Typo-chronological attribution
134	39	A Daupharde	Ruffey-sur-Seille	215	Level R3	Hazelnut shell	Ly-411/AA-23363	9055	65	10,226	44	10181	10270	Séara et al., 2002	Early Mesolithic
135	39	A Daupharde	Ruffey-sur-Seille	215	Level R3	Hazelnut shell	Ly-215 (Oxa)	9210	70	10,390	94	10295	10484	Séara et al., 2002	Early Mesolithic
136	39	A Daupharde	Ruffey-sur-Seille	215	Level R4	Hazelnut shell	Ly-242 (Oxa.)	9005	85	10,100	129	9970	10229	Séara et al., 2002	Early Mesolithic
137	39	A Daupharde	Ruffey-sur-Seille	215	Level R4	Hazelnut shell	Ly-216 (Oxa.)	9135	75	10,335	85	10249	10420	Séara et al., 2002	Early Mesolithic
138	39	A Daupharde	Ruffey-sur-Seille	215	Level R4	Hazelnut shell	Ly-239 (Oxa.)	9210	85	10,396	104	10292	10500	Séara et al., 2002	Early Mesolithic
139	68	Mannlefelden 1	Oberlarg	550	Layer H	<i>Cervus</i>	GrA-35604	6600	45	7505	45	7460	7550	Drucker et al., 2011a	Late Mesolithic
140	68	Mannlefelden 1	Oberlarg	550	Layer I	<i>Cervus</i>	GrA-35603	7215	45	8054	65	7989	8119	Drucker et al., 2011a	Late Mesolithic
141	68	Mannlefelden 1	Oberlarg	550	Layer L	<i>Cervus</i>	GrA-35595	8040	45	8907	96	8811	9003	Drucker et al., 2011a	Middle Mesolithic ?
142	68	Mannlefelden 1	Oberlarg	550	Layer Q	<i>Cervus</i>	GrA-35594	9365	45	10,596	60	10536	10656	Drucker et al., 2011a	Early Mesolithic
143	68	Mannlefelden 1	Oberlarg	550	Layer R	<i>Cervus</i>	GrA-35592	10770	50	12,750	52	12697	12802	Drucker et al., 2011a	Late Azilian
144	68	Mannlefelden 1	Oberlarg	550	Layer S	<i>Cervus</i>	GrA-35571	11530	50	13,429	112	13316	13541	Drucker et al., 2011a	Azilian
145	70	Sur la Noue La Lande	Beaujeu	189	Unique Layer	Hazelnut shell	Ly-3293 (Poz)	8925	55	10,056	106	9950	10162	This work	Middle Mesolithic
146	70	La Baume Noire	Frétingney-Velloreille	240	Level M3	<i>Rangifer tarandus</i>	Ly-3292(Poz)	13045	75	15,932	401	15530	16333	Drucker et al., 2012	Upper Magdalenian
147	70	La Baume Noire	Frétingney-Velloreille	240	Level M4	<i>Rangifer tarandus</i>	Ly-5217(GrA)	19310	80	23,071	267	22804	23338	Drucker et al., 2012	Badegoulian ?
148	70	La Baume Noire	Frétingney-Velloreille	240	Level M5	<i>Rangifer tarandus</i>	Ly-5218(GrA)	18070	80	21,813	359	21454	22172	Drucker et al., 2012	Badegoulian ?
149	71	La Balme	Cuiseaux	240	Layer B	<i>Vulpes/Alopex</i>	Ly-3727(GrA)	11990	50	13,963	201	13762	14164	Cupillard et al., 2013	Azilian
150	71	La Balme	Cuiseaux	240	Layer C	<i>Bos/bison</i>	Ly-3728 (GrA)	43120	490	46,759	1588	45170	48347	Cupillard et al., 2013	Animal occupation
151	71	La Balme	Cuiseaux	240	Layer D	<i>Marmota marmota</i>	Ly-3729 (GrA)	24030	110	28,854	380	28473	29234	Cupillard et al., 2013	Animal occupation
152	71	La Balme	Cuiseaux	240	Layer F	<i>Lepus</i>	Ly-3728 (GrA)	25340	120	30,181	266	29914	30447	Cupillard et al., 2013	Gravettian
153	JU	Les Gripons	Saint-Ursanne	496	Layer 3	Charcoal	UZ-2597/ETH-6217	6540	80	7444	79	7365	7523	Pousaz 1991	Late Mesolithic
154	JU	Les Gripons	Saint-Ursanne	496	Layer 4	Charcoal	UZ-2599/ETH-6219	7205	80	8051	82	7968	8133	Pousaz 1991	Middle Mesolithic
155	JU	Les Gripons	Saint-Ursanne	496	Layer 4	Charcoal	UZ-2478/ETH-4713	8405	90	9395	93	9301	9488	Pousaz 1991	Middle Mesolithic
156	JU	Les Gripons	Saint-Ursanne	496	Layer 4	Charcoal	UZ-2477/ETH-4712	8660	100	9709	139	9570	9848	Pousaz 1991	Middle Mesolithic
157	JU	Les Gripons	Saint-Ursanne	496	Layer 4	Charcoal	UZ-2598/ETH-6218	8850	85	9940	169	9770	10109	Pousaz 1991	Middle Mesolithic
158	JU	Les Gripons	Saint-Ursanne	496	Layer 4	Charcoal	UZ-2370/ETH-3694	8960	125	10,025	184	9841	10209	Pousaz 1991	Middle Mesolithic
159	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	Charcoal ( <i>Salix</i> )	ETH-4245	10950	180	12,911	154	12756	13065	Egloff and Le Tensorer 1989	Azilian
160	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	Charcoal ( <i>Pinus</i> )	ETH-17831	11200	110	13,092	142	12950	13234	Chauvière 2008	Azilian
161	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	Charcoal ( <i>Pinus</i> )	ETH-17835	11220	100	13,112	134	12977	13246	Chauvière 2008	Azilian
162	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	Charcoal ( <i>Salix</i> )	ETH-17833	11250	100	13,146	134	13011	13280	Chauvière 2008	Azilian
163	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	Charcoal ( <i>Salix</i> )	ETH-17830	11290	110	13,193	137	13056	13330	Chauvière 2008	Azilian

164	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	Charcaol (Pinus)	ETH-17834	11380	110	13,287	157	13129	13444	<a href="#">Chauvière 2008</a>	Azilian
165	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	<i>Ursus arctos</i> , tibia	ETH-8775	11360	120	13,269	161	13108	13430	<a href="#">Morel 1993</a>	Azilian
166	Morel	Le Bichon	La Chaux-de-Fonds	846	Unique layer	<i>Homo sapiens</i> , fémur	ETH-8774	11610	110	13,504	159	13345	13663	<a href="#">Morel 1993</a>	Azilian
167	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	Charcoal ( <i>Pinus</i> )	ETH-17836	11670	100	13,557	158	13399	13715	<a href="#">Chauvière 2008</a>	Azilian
168	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	<i>Ursus arctos</i> , phalanx 1	ETH- 8301	11680	90	13,566	153	13413	13719	<a href="#">Morel 1993</a>	Azilian
169	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	Charcoal ( <i>Salix</i> )	ETH-4246	11680	120	13,566	169	13397	13735	Egloff and Le Tensorer 1989	Azilian
170	NE	Le Bichon	La Chaux-de-Fonds	846	Unique layer	<i>Homo sapiens</i> , tibia	ETH-8773	11760	110	13,648	169	13479	13817	<a href="#">Morel 1993</a>	Azilian
171	NE	Champréveyres	Hauterive	428	Hearth L23	Charcoal	UZ-2284	12120	170	14,190	333	13857	14523	<a href="#">Leesch 1997</a>	Azilian
172	NE	Champréveyres	Hauterive	428	Hearth E18	Charcoal	UZ-2170	12550	130	14,870	350	14519	15220	<a href="#">Leesch 1997</a>	Azilian
173	NE	Champréveyres	Hauterive	428	Hearth K12	Charcoal	UZ-2174	12510	130	14,811	357	14454	15168	<a href="#">Leesch 1997</a>	Upper Magdalenian
174	NE	Champréveyres	Hauterive	428	Hearth O 39	Charcoal	UZ-2287	12500	145	14,778	387	14391	15165	<a href="#">Leesch 1997</a>	Upper Magdalenian
175	NE	Champréveyres	Hauterive	428	Hearth A12	Charcoal	UZ-2173	12540	140	14,852	362	14489	15214	<a href="#">Leesch 1997</a>	Upper Magdalenian
176	NE	Champréveyres	Hauterive	428	Hearth H16	Charcoal	UZ-2177	12600	145	14,939	361	14577	15300	<a href="#">Leesch 1997</a>	Upper Magdalenian
177	NE	Champréveyres	Hauterive	428	HearthE21	Charcoal	UZ-2172	12620	145	14,967	362	14604	15329	<a href="#">Leesch 1997</a>	Upper Magdalenian
178	NE	Champréveyres	Hauterive	428	Hearth L13	Charcoal	UZ-2175	12630	130	14,983	349	14634	15332	<a href="#">Leesch 1997</a>	Upper Magdalenian
179	NE	Champréveyres	Hauterive	428	Hearth M17	Charcoal	UZ-2171	12730	135	15,126	361	14765	15487	<a href="#">Leesch 1997</a>	Upper Magdalenian
180	NE	Champréveyres	Hauterive	428	Hearth D11	Charcoal	UZ-2282	12825	155	15,414	462	14951	15876	<a href="#">Leesch 1997</a>	Upper Magdalenian
181	NE	Champréveyres	Hauterive	428	Hearth X10	Charcoal	UZ-2286	12870	135	15,559	459	15100	16018	<a href="#">Leesch 1997</a>	Upper Magdalenian
182	NE	Champréveyres	Hauterive	428	Hearth A12	Charcoal	UZ-2283	12950	155	15,766	490	15276	16256	<a href="#">Leesch 1997</a>	Upper Magdalenian
183	NE	Champréveyres	Hauterive	428	Hearth N16	Charcoal	UZ-2285	13050	155	15,937	460	15477	16397	<a href="#">Leesch 1997</a>	Upper Magdalenian
184	NE	Champréveyres	Hauterive	428	Hearth A12	Charbon	UCLA-2760	17690	210	21,121	400	20721	21521	<a href="#">Leesch 1997</a>	Upper Magdalenian
185	NE	Champréveyres	Hauterive	428	Sector 1	<i>Equus</i>	OxA-20700	12815	65	15,315	257	15058	15572	<a href="#">Bodu et al., 2009</a>	Upper Magdalenian
186	NE	Champréveyres	Hauterive	428	Sector 1	<i>Equus</i>	OxA-20701	12805	75	15,293	269	15023	15562	<a href="#">Bodu et al., 2009</a>	Upper Magdalenian
187	NE	Col-des-Roches	Le Locle	935	Layer III	Bones indet.	ETH-11356	6885	65	7734	64	7670	7798	<a href="#">Cupillard 2010</a>	Late Mesolithic
188	NE	Monruz	Neuchâtel	428	Level C2 hearth Y50	Charcoal ( <i>Juniperus</i> )	ETH-17973	12165	130	14,230	296	13934	14526	<a href="#">Leesch et al., 2004</a>	Azilian
189	NE	Monruz	Neuchâtel	428	Level C2 hearth Y50	Charcoal ( <i>Juniperus</i> )	ETH-17974	12370	110	14,575	372	14203	14947	<a href="#">Leesch et al., 2004</a>	Azilian
190	NE	Monruz	Neuchâtel	428	Hearth P49	Charcoal (indet.)	ETH-20727	12800	85	15,281	282	14998	15563	<a href="#">Bullinger et al., 2006</a>	Upper Magdalenian
191	NE	Monruz	Neuchâtel	428	Hearth V 57	Charcoal ( <i>Salix</i> sp.)	ETH- 6414	12840	120	15,444	397	15046	15841	<a href="#">Bullinger et al., 2006</a>	Upper Magdalenian
192	NE	Monruz	Neuchâtel	428	Hearth R54	Charcoal ( <i>Salix</i> sp.)	ETH- 6419	12880	120	15,586	436	15149	16022	<a href="#">Bullinger et al., 2006</a>	Upper Magdalenian
193	NE	Monruz	Neuchâtel	428	Hearth S50	Charcoal ( <i>Salix</i> sp.)	ETH-6415	12900	120	15,654	452	15201	16106	<a href="#">Bullinger et al., 2006</a>	Upper Magdalenian
194	NE	Monruz	Neuchâtel	428	Hearth V 57	Charcoal( <i>Salix</i> sp.)	ETH-6412	12970	110	15,807	440	15367	16247	<a href="#">Bullinger et al., 2006</a>	Upper Magdalenian
195	NE	Monruz	Neuchâtel	428	Hearth S 50	Charcoal	ETH-6417	13030	120	15,910	435	15474	16345	<a href="#">Höneisen, 1993</a>	Upper Magdalenian
196	NE	Monruz	Neuchâtel	428	Level C2 Sector 1	<i>Equus</i>	OxA-20699	13055	60	15,946	392	15553	16338	<a href="#">Bodu et al., 2009</a>	Upper Magdalenian
197	NE	Monruz	Neuchâtel	428	Hearth S50	Charcoal ( <i>Salix</i> sp.)	ETH-6416	13070	130	15,970	433	15537	16403	<a href="#">Bullinger et al., 2006</a>	Upper Magdalenian
198	NE	Monruz	Neuchâtel	428	Hearth R 57	Charcoal (indet.)	ETH-6418	13110	120	16,026	420	15606	16446	<a href="#">Bullinger et al., 2006</a>	Upper Magdalenian
199	NE	Monruz	Neuchâtel	428	Hearth S49	Charcoal ( <i>Salix</i> sp.)	ETH-6420	13120	120	16,040	419	15620	16459	<a href="#">Bullinger et al., 2006</a>	Upper Magdalenian
200	NE	Monruz	Neuchâtel	428	Hearth C13	Charcoal	ETH-6421	13140	120	16,064	419	15645	16483	<a href="#">Housley et al., 1997</a>	Upper Magdalenian
201	NE	Monruz	Neuchâtel	428	Hearth V 50	Charcoal ( <i>Salix</i> sp.)	ETH-6413	13330	110	16,255	436	15819	16691	<a href="#">Bullinger et al., 2006</a>	Upper Magdalenian
202	SH	Kesslerloch	Thaygen	440	ind.layer	<i>Equus</i>	KIA-11825	12774	54	15,237	262	14974	15499	<a href="#">Napierala, 2008</a>	Upper Magdalenian
203	SH	Kesslerloch	Thaygen	440	ind.layer	<i>Equus</i>	KIA-11826	12502	52	14,819	295	14524	15114	<a href="#">Napierala, 2008</a>	Upper Magdalenian
204	SH	Kesslerloch	Thaygen	440	Layer In	<i>Equus</i>	KIA-11827	13052	53	15,941	390	15550	16331	<a href="#">Napierala, 2008</a>	Upper Magdalenian

(continued on next page)

Table 2 (continued)

Number	District	Site	Locality	Altitude (m)	Layer or level	Sample material	Laboratory	BP	Ecart-type	Cal BP	Ecart type	Mini	Maxi	Reference	Typo-chronological attribution
205	SH	Kesslerloch	Thaygen	430	Layer III n	<i>Equus</i>	KIA-11828	13858	55	17,085	180	16904	17265	<a href="#">Napierala, 2008</a>	Upper Magdalenian
206	g	Kesslerloch	Thaygen	440	Layer II c	<i>Equus</i>	KIA-11829	12897	53	15,591	329	15262	15920	<a href="#">Napierala, 2008</a>	Upper Magdalenian
207	SH	Kesslerloch	Thaygen	440	Layer II c	<i>Canis</i>	KIA-33350	12225	45	14,277	239	14037	14516	<a href="#">Napierala, 2008</a>	Azilian ?
208	SH	Kesslerloch	Thaygen	440	Layer II c	<i>Cervus</i>	KIA-33351	12335	45	14,502	338	14163	14840	<a href="#">Napierala, 2008</a>	Azilian ?
209	SH	Kesslerloch	Thaygen	440	Layer II c	<i>Coelodonta</i>	OxA-10238	14330	110	17,505	261	17243	17766	<a href="#">Napierala, 2008</a>	Middle Magdalenian
210	SH	Kesslerloch	Thaygen	440	Layer II c	<i>Mammuthus</i>	OxA-10239	13980	110	17,234	228	17006	17462	<a href="#">Napierala, 2008</a>	Middle Magdalenian
211	SH	Kesslerloch	Thaygen	440	Layer II c	<i>Mammuthus</i>	OxA-10298	15020	180	18,254	263	17990	18517	<a href="#">Napierala, 2008</a>	Middle Magdalenian
212	SH	Kesslerloch	Thaygen	440	Layer II c	<i>Rangifer</i> , antler point	OxA-5746	13120	90	16,038	401	15636	16439	<a href="#">Housley et al., 1997</a>	Upper Magdalenian
213	SH	Kesslerloch	Thaygen	440	Layer III Bc	<i>Rangifer</i>	OxA-5747	13430	100	16,367	427	15939	16794	<a href="#">Housley et al., 1997</a>	Upper Magdalenian
214	SH	Kesslerloch	Thaygen	440	Layer III Bc	Bone modif.	OxA-5748	12770	90	15,213	302	14911	15515	<a href="#">Housley et al., 1997</a>	Upper Magdalenian
215	SH	Kesslerloch	Thaygen	440	Layer III Ac	<i>Rangifer</i> , antler modif.	OxA-5749	14150	100	17,392	254	17138	17646	<a href="#">Housley et al., 1997</a>	Upper Magdalenian
216	SH	Kesslerloch	Thaygen	440	Layer III Ac	<i>Rangifer</i> , antler modif.	OxA-5750	13670	100	16,745	270	16475	17015	<a href="#">Housley et al., 1997</a>	Upper Magdalenian
217	SH	Kesslerloch	Thaygen	440	Layer III Ac	<i>Rangifer</i>	B-3329	12970	180	15,798	512	15285	16310	Albrecht 1982	Upper Magdalenian
218	SH	Kesslerloch	Thaygen	440	Layer III Ac	Bone (indet.)	Hv-10652	12890	90	15,595	380	15214	15975	Geyh and Schreiner 1984	Upper Magdalenian
219	SO	Risliberghöhle	Oensingen	488	Layer II	<i>Equus</i>	ETH-39678	10770	45	12,749	50	12699	12799	<a href="#">Leesch and Müller, 2012</a>	Late Azilian ?
220	SO	Risliberghöhle	Oensingen	488	Layer II	<i>Cf. Equus</i>	ETH-42514	12235	45	14,292	245	14047	14537	<a href="#">Leesch and Muller 2012</a>	Upper Magdalenian
221	SO	Risliberghöhle	Oensingen	488	Layer II	<i>Capra ibex</i>	ETH-42515	12710	45	15,112	296	14815	15408	<a href="#">Leesch and Muller 2012</a>	Upper Magdalenian
222	SO	Risliberghöhle	Oensingen	488	Layer II	<i>Cervus</i>	ETH-42516	12680	45	15,064	301	14762	15365	<a href="#">Leesch and Muller 2012</a>	Upper Magdalenian
223	SO	Risliberghöhle	Oensingen	488	Layer II	<i>Rangifer</i>	ETH-42517	13000	50	15,856	398	15457	16254	<a href="#">Leesch and Muller 2012</a>	Upper Magdalenian
224	VD	Mollendruz	Mont-la-Ville	1088	Layer 4b	Charcoals	CRG-579	7190	140	8022	141	7880	8163	<a href="#">Pignat and Winiger 1998</a>	Late Mesolithic
225	VD	Mollendruz	Mont-la-Ville	1088	Layer 4b	Charcoals	ETH-9570	7745	85	8609	173	8436	8782	<a href="#">Pignat and Winiger 1998</a>	Middle Mesolithic
226	VD	Mollendruz	Mont-la-Ville	1088	Layer 4d	Charcoals	ETH-5597	8175	100	9158	130	9027	9288	<a href="#">Pignat and Winiger 1998</a>	Middle Mesolithic
227	VD	Mollendruz	Mont-la-Ville	1088	Layer 4d	Charcoals	CRG-431	8207	206	9113	275	8837	9388	<a href="#">Pignat and Winiger 1998</a>	Middle Mesolithic
228	VD	Mollendruz	Mont-la-Ville	1088	Layer 4e	Charcoals	ETH-5598	9505	105	10,853	192	10661	11045	<a href="#">Pignat and Winiger 1998</a>	Early Mesolithic
229	VD	Mollendruz	Mont-la-Ville	1088	Layer 4e	Charcoals	ETH-9572	9265	85	10,442	118	10324	10560	<a href="#">Pignat and Winiger 1998</a>	Early Mesolithic
230	VD	Mollendruz	Mont-la-Ville	1088	Layer 5a	Charcoals	ETH-9571	8920	90	10,009	150	9859	10159	<a href="#">Pignat and Winiger 1998</a>	Early Mesolithic
231	VD	Mollendruz	Mont-la-Ville	1088	Layer 5 inf	Bone (indet.)	ETH-5600	11760	145	13,662	203	13459	13865	<a href="#">Pignat and Winiger 1998</a>	Azilian ?
232	VD	Mollendruz	Mont-la-Ville	1088	Layer 5 inf	Bone (indet.)	ETH-5601	12020	120	14,040	268	13771	14308	<a href="#">Pignat and Winiger 1998</a>	Azilian ?
233	VD	Mollendruz	Mont-la-Ville	1088	Layer 5 inf	<i>Rangifer</i>	OxA-9460 (Ly-1135)	12780	80	15,239	284	14954	15523	<a href="#">Oberlin and Pion 2009</a>	Upper Magdalenian
234	BL	Hollenberg-Höhle 3	Arlsheim	450	Layer D	<i>Rangifer</i>	Erl-13569	12846	63	15,397	263	15134	15660	Müller and Leesch 2011	Upper Magdalenian
235	BL	Hollenberg-Höhle 3	Arlsheim	450	Layer D	<i>Rangifer</i>	Erl-13570	12798	70	15,279	266	15013	15545	Müller and Leesch 2011	Upper Magdalenian
236	BL	Hollenberg-Höhle 3	Arlsheim	450	Layer D	<i>Rangifer</i>	Erl-13571	13114	71	16,028	392	15636	16420	Müller and Leesch 2011	Upper Magdalenian
237	BL	Hollenberg-Höhle 3	Arlsheim	450	Layer D	<i>Rangifer</i>	Erl-13572	13077	71	15,978	394	15584	16372	Müller and Leesch 2011	Upper Magdalenian

238	BE	Kohlerhöhle	Brislach	378	Upper layer	<i>Equus</i>	ETH-39760	11525	60	13,423	117	13306	13540	Leesch and Müller 2012	Azilian
239	BE	Kohlerhöhle	Brislach	378	Unique layer	<i>Equus</i>	ETH-39761	12790	45	15,270	248	15021	15518	Leesch and Müller 2012	Upper Magdalenian
240	BE	Kohlerhöhle	Brislach	378	Unique layer	<i>Equus</i>	ETH-39762	12465	40	14,761	293	14468	15054	Leesch and Müller 2012	Upper Magdalenian
241	BE	Kohlerhöhle	Brislach	378	Unique layer	<i>Rangifer</i>	ETH-43309	12460	45	14,751	297	14454	15048	Leesch and Müller 2012	Upper Magdalenian
242	BE	Kohlerhöhle	Brislach	378	Unique layer	<i>Rangifer</i>	ETH-43310	16205	55	19,350	289	19061	19639	Leesch and Müller 2012	Badegoulian ?
243	BL	Büttenloch	Ettingen	380	Layer B upper unit	<i>Lagopus</i>	UtC-12576	12170	80	14,208	242	13965	14450	Leesch and Müller 2012	Azilian ?
244	BL	Büttenloch	Ettingen	380	Layer B upper unit	<i>Lagopus</i>	UtC-12577	12180	90	14,227	254	13973	14481	Leesch and Müller 2012	Azilian
245	BL	Büttenloch	Ettingen	380	Layer A	<i>Lepus</i>	UtC-12575	12750	80	15,174	303	14871	15477	Leesch and Müller 2012	Upper Magdalenian
246	BL	Büttenloch	Ettingen	380	Layer A lower unit	<i>Lepus</i>	UtC-12574	12870	80	15,520	344	15175	15864	Leesch and Müller 2012	Upper Magdalenian
247	SO	Kastelhöhle Nord	Himmelried	397	Upper layer	<i>Bos/Bison</i>	ETH-45024	13435	50	16,388	410	15977	16798	Leesch and Müller 2012	Upper Magdalenian
248	SO	Kastelhöhle Nord	Himmelried	397	Upper layer	<i>Rangifer</i>	ETH-45025	12395	45	14,611	332	14278	14943	Leesch and Müller 2012	Upper Magdalenian
249	SO	Kastelhöhle Nord	Himmelried	397	Upper layer	<i>Rangifer</i>	ETH-45026	12215	45	14,261	235	14026	14496	Leesch and Müller 2012	Upper Magdalenian
250	SO	Kastelhöhle Nord	Himmelried	397	Middle layer	<i>Rangifer</i>	OxA-9737	18530	150	22,128	340	21788	22468	<a href="#">Bronk Ramsey et al., 2002</a>	Badegoulian
251	SO	Kastelhöhle Nord	Himmelried	397	Middle layer	<i>Rangifer</i>	OxA-9739	19200	150	22,981	301	22680	23282	<a href="#">Bronk Ramsey et al., 2002</a>	Badegoulian
252	SO	Kastelhöhle Nord	Himmelried	397	Middle layer	<i>Rangifer</i>	OxA-9738	19620	140	23,413	362	23051	23775	<a href="#">Bronk Ramsey et al., 2002</a>	Badegoulian
253	SO	Käsloch	Winznau	420	Unique layer	<i>Equus</i>	ETH-39769	12505	45	14,825	291	14534	15116	Leesch and Muller 2012	Upper Magdalenian
254	SO	Käsloch	Winznau	420	Unique layer	<i>Equus</i>	ETH-39770	13760	45	16,931	154	16776	17085	Leesch and Muller 2012	Upper Magdalenian
255	SO	Käsloch	Winznau	420	Unique layer	<i>Equus</i>	ETH-39771	12450	45	14,719	313	14405	15032	Leesch and Muller 2012	Upper Magdalenian
256	SO	Y-Höhle	Hofstetten-Flüh	462 ?	Out of stratigraphy	<i>Tarandus</i> , bone with cut marks	ETH-34750	18875	115	22,744	277	22466	23021	<a href="#">Sedlmeier, 2010</a>	Badegoulian ?

Upper Palaeolithic, Final Palaeolithic, Mesolithic and Early Neolithic AMS dates of French and Swiss Jura Range and its margins.

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