The Magdalenian in Switzerland: Re-colonization of a newly accessible landscape

Denise Leesch a,*, Werner Müller a, Ebbe Nielsen b, Jérôme Bullinger c

a Université de Neuchâtel, Laboratoire d’archéozoologie, Avenue de Bellevaux 51, CP 158, CH-2009 Neuchâtel, Switzerland
b Archaeological Survey of the Canton of Lucerne, Libellennain 15, CH-6002 Luzern, Switzerland
c Musée cantonal d’archéologie et d’histoire, Place de la Riponne 6, CH-1014 Lausanne, Switzerland

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A B S T R A C T

During the Last Glacial Maximum, Switzerland was almost entirely covered with ice. However, in the ice-free region situated less than 50 km north of the glaciers, human occupation is confirmed as early as 23,000 cal BP. Numerous sedimentary sequences in lakes and mires have produced a wealth of proxy data indicating that environmental conditions improved rapidly after the melting of the glaciers that libered the Swiss Plateau at least at c. 17,500 cal BP, offering severe but possible life conditions to plant, animal and human communities. Contrary to what has long been the prevailing opinion, Magdalenian re-colonization of Switzerland did not start with the onset of the warming of Greenland Interstadial 1e, but well before. According to most of the recently obtained AMS dates, the Magdalenian occupation falls within the cold, treeless, environment of the Oldest Dryas period; it is even conceivable that it did not extend into Greenland Interstadial 1e. More than 50 sites, among which famous caves and rockshelters such as Kesslerloch and Schweizersbild, as well as large open-air campsites like Monruz and Moosbühl, have produced different techno-assemblages that find good comparisons in the rest of Europe. In contrast to the exploitation of mainly local and regional flint sources, the use of “exotic” ornamental/symbolic objects—fossil mollusks, amber and jet— shows widespread, multidirectional long-distance connections with the upper Danube basin, the Mainz basin, the Paris Basin, the Atlantic coast, the Mediterranean and even the Baltic regions.

1. Introduction

Before the discovery of the open-air sites Champréveyres and Monruz in the 1980s, it was generally accepted that Magdalenian colonization of Switzerland, expanding from southwest France, had taken place only in a late stadium of the Late Glacial, meaning the Bölling/Allerød Interstadial. This model was based on many erroneous conventional radiocarbon dates that were obtained during the 1970s and early 1980s (Sedlmeier, 1989, p. 196; Höniesen et al., 1993, p. 201) and on the assumption that resettlement would have had to be concurrent with climate warming. The problematic radiocarbon determinations also suggested that the different Magdalenian techno-assemblages were even partially contemporaneous with Azilian industries. At the present state of research, it has become clear that Magdalenian occupation can be correlated with the still cold period of Greenland Stadial GS-2 (GS-a and GS-b) and that this techno-complex probably ended with the climatic amelioration of the Greenland Interstadial GI-1e. Evidence from Champréveyres and Monruz demonstrates indeed that the Azilian was established on the Swiss Plateau from at least 12,300 BP (c. 14,400 cal BP) onwards (Leesch et al., 2004). The aim of this contribution is to present some of the new radiocarbon dates supporting the idea that Switzerland was colonized independently from temperature but in relation with the development of the vegetation cover and the density of horse and reindeer populations.

2. Topographical characteristics of Switzerland

Switzerland, with a surface area of c. 41,000 km², consists of three large topographical entities: the Alps, taking up the southern half of the country with the central chain exceeding 4000 m, the Jura mountain chain in the northwest with its highest peaks reaching 1600 m, and finally the Swiss Plateau, extending between these two mountain ranges from Lake Geneva to Lake Constance with an average altitude of 400–600 m (Fig. 1). As a consequence of these topographic features, the Swiss Plateau was filled with ice during periods of glaciations, for the most part from the Rhone–Aare and Rhone–Linth–Reuss glaciers (e.g. Ehlers and Gibbard, 2004). With the decay of the ice cover, the areas became

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available for resettlement. Thus, Switzerland may serve as a model for the process of re-colonization of temporarily inhabitable landscapes.

3. The Last Glacial Maximum

The exact extent of the glaciers during their last maximum expansions has been refined in a recent update of the LGM map of Switzerland by a group of researchers (Bini et al., 2009). While these data can be regarded as satisfactorily precise and are by and large accepted, the exact chronology of the LGM remains controversial (e.g. Schoeneich, 2003; Ivy-Ochs et al., 2004, 2008; Preusser, 2004; Svensson et al., 2006; Schoeneich et al., 2011). This might stem from the fact that some researchers define the LGM based solely on a temperature curve derived from different ocean or ice core drilling projects, while for others the LGM designates the time of the largest extent of the glaciers (either globally or locally, e.g. for the Alps), therefore a time period where several factors must coincide, including low temperatures, high amounts of precipitation, low snow line, etc. The present article follows Ivy-Ochs et al. (2004) who dated the largest extent of the Solothurn lobe of the Rhone piedmont glacier. According to these authors, “the maximum extent [...] was contemporaneous with the world wide ice maximum between 24 and 19 ka” and the “break down of the Rhone piedmont glacier system occurred between 21.1 and 19.1 ka”. It has to be visualized that e.g. in the Rhone valley at the location of present-day Martigny, ice thickness must have exceeded 2000 m (Kelly et al., 2004), and in the area of Lake Neuchâtel, the ice sheet had a thickness of over 600 m (Bini et al., 2009). Obviously, the expansion of the glaciers not only eradicated any signs of previous occupations in that area but also inhibited any form of life, be it plant or animal. However, away from the glaciers, living conditions might have been extreme but not impossible.

In the northwestern corner of Switzerland (close to Basel), two caves yield proof of human occupation: Kastelhöhle Nord and Y-Höhle (Fig. 2). The middle archaeological layer of Kastelhöhle Nord, excavated in 1948, has produced a small lithic assemblage of 228 objects assigned to the Badegoulian (Fig. 3). It is characterized by a large number of splintered pieces and no blade production. Raw material is diverse and mostly of regional origin (less than 40 km), except for 4 pieces that come from 100 km to the southwest (Affolter, in Sedlmeier, 2010). This composition shows that the people living in this area were exploiting the same resources that were used later during Magdalenian periods. From the faunal remains associated with the industry three reindeer bones from which two bear cut marks, have produced AMS 14C dates of 18,530 ± 150 BP, 19,200 ± 150 BP and 19,620 ± 140 BP (Terberger and Street, 2002; Sedlmeier, 2010). The second cave, “Y-Höhle”, yielded only a single reindeer bone with cut marks (Fig. 4); this bone has been dated to 18,875 ± 115 BP (Sedlmeier, 2010). Even though this element is in secondary position and was probably washed into the cave from the surface above, it is proof for human occupation at that time. Both occupations date therefore to a calibrated age between 22,100 and 23,400 years cal BP, which places them into or right after the end of the LGM, depending on the reference used. It has indeed been speculated that this early colonization of the area was made possible by or linked to the brief warming phase of the GI-2 (Terberger and Street, 2002; Sedlmeier, 2010); yet the contemporaneity of this relatively short phase of about 700 years with the obtained dates remains open to discussion. The caves are located at the northern border of the Jura Mountain in valleys facing away from the alpine glaciers so that the Jura mountain range might have had in a way a “protective effect” and allowed a milder microclimate as compared to the southern flank of the Jura. Nevertheless, with these two occupations in Switzerland and some other sites in Germany (Terberger and Street, 2002), it is established that the region north of the Alps was not completely depopulated at that time, even though population density was probably rather low.

4. The ice decay

The precise chronology of the ice decay is still debated, yet the rough time frame seems to be generally accepted: ice collapse was rather rapid, breakdown of the Rhone piedmont glacier system started possibly right at, or shortly after reaching its maximum extent at 21,000 cal BP, but no later than c. 19,100 cal BP (Ivy-Ochs et al., 2004, 2008). Already at 17,500 cal BP, the entire Alpine
foreland was ice-free and major environmental changes can be observed in many lakes and mires (Schoeneich, 2003). Records exist for example for Lake Constance (Wessels, 1998a, 1998b), Lake Zurich (Lister, 1988) and Lake Neuchâtel (Hadorn et al., 2002; Magny et al., 2003; Thew et al., 2009). The newly accessible, glacier-shaped landscape was characterized by many lakes and mires and by an absence of top soil, so that the re-colonization by plants must have been slow at the beginning and could only be achieved by pioneer vegetation capable of growing on mineral soils. Many sedimentary sequences preserved in those lakes, ponds and mires at various altitudes were analyzed for palaeoecological studies, thus making this region one of the best studied areas for the Late Glacial and Holocene in Europe (e.g. Lang, 1985; Burga and Perret, 1998; Richard and Bégeot, 2000).

5. Late Glacial vegetation and climate history

Some of the most detailed studied lakes and mires for the reconstruction of the Late Glacial vegetation and climate history of this area are (see Fig. 1): Lobsgensee (Elias and Wilkinson, 1983; Ammann, 1989), Grand-Marais (Gaillard, 1984; Gaillard and Lemdahl, 1994) Soppensee (Lotter et al., 1992a; Lotter, 1999), Rotsee (Ammann and Lotter, 1989; Lotter, 1991; Verbruggen et al., 2010), Aegelsee (Lotter et al., 1992b; Wehrli et al., 2007), Gerzensee (Lotter et al., 1992b, 2000; Schwaneder et al., 2000), Lake Chalain (Wegmüller, 1966), Lake Cerin (Ruffaldi, 1993, 1996) and Lake Lautrey (Heiri and Millet, 2005; Magny et al., 2006). In addition to pollen analysis, those investigations often include the study of plant macrofossils, diatoms, beetles, chironomids, mollusks and in several cases also annually laminated sediments. Moreover, stable-isotope investigations allow correlation of the major changes observed in the vegetation with the Greenland Ice Core Event Stratigraphy (Björck et al., 1998; Walker et al., 1999; Schoeneich, 2003; Lowe et al., 2008).

In respect to the Magdalenian, the palaeoenvironmental research conducted at Hauterive/Rouges-Terres is of particular importance. This study concerns a section of 150 m that has been documented during the construction of a motorway along Lake Neuchâtel and is situated only 500 m east of the Magdalenian campsite Champréveyres (Magny et al., 2003; Thew et al., 2009). The section allowed high resolution analyses of the pollen, plant macrofossil, insect, and mollusk record, notably for a well developed sedimentary sequence of the Oldest Dryas. Moreover, the sequence being rich in organic matter, 87 AMS radiocarbon dates were obtained from plant remains, and thus constitutes a major reference stratigraphy for the early phase of the Late Glacial. Interestingly, the radiocarbon dates show several $^{14}C$ plateaus of constant age, notably one at c. 12,600–12,400 BP, relevant for the Magdalenian–Azilian transition, and another one at c. 12,200–12,000 BP (Hajdas and Bonani, 2009).

Late Glacial vegetation history of the of the Swiss Plateau has been divided into four regional pollen assemblage zones (RPAZ) termed as CHb-1, CHb-2, CHb-3 and CHb-4 (Lotter et al., 1992a; Ammann et al., 1996). The first zone, CHb-1, equivalent to the Late Pleniglacial/Oldest Dryas biozone, is the most relevant stage for understanding the re-colonization process by Magdalenian populations and covers the time span from the decay of the glaciers to the onset of the Bølling biozone. Zone CHb-2 corresponds to the start of the Bølling biozone and is correlated with G1-1e. At the present state of research, it is not established whether the Magdalenian extends into this latter zone or whether the Azilian starts at that time. Zone CHb-3 corresponds to a later phase of the Bølling biozone and to the expansion of the Azilian. These three regional pollen assemblage zones and subzones can be characterized as follows (Fig. 5):

**RPAZ CHb-1, Artemisia-PAZ** (Late Pleniglacial/Late Glacial/Oldest Dryas biozone/Greenland Stadial GS-2a/b)

This zone is subdivided into three subzones termed as CHb-1a, CHb-1b and CHb-1c.

CHb-1a (Artemisia-Pinus sub-PAZ; > 17,500 cal BP): The onset of this zone is not well defined because of the absence of vegetation during a certain time after the ice decay. First plant communities indicate sparse herbaceous pioneer vegetation including heliophilous taxa such as Artemisia, Helianthemum and Dryas octopetala. High values of Pinus in the pollen record are due to long-distance transport whereas significant numbers of pollen from Abies and Picea stem from reworked sediments indicating unstable conditions.
CHb-1b (Artemisia-Helianthemum sub-PAZ; c. 17,500–15,800 cal BP): The second subzone is characterized by more stabilized conditions (less reworked coniferous pollen of Abies and Picea). Pollen spectra are dominated by an arctic alpine heliophilous flora. Vegetation can be described as grassland with alpine and steppe herbs. A skull from a woolly rhinoceros dated to 13,980/C6 140 BP (17,236/C6 243 cal BP) that has been recovered from Lake Neuchâtel (Fig. 6; Morel and Hug, 1996) and a nearly complete skeleton of a mammoth dated to 13,705 ± 55 BP (16,845 ± 192 cal BP) discovered in the Jura mountain (Hajdas et al., 2007), at an altitude of 1045 m, demonstrate that the plant cover was sufficiently developed to allow large herbivorous animals to graze in this area.

CHb-1c (Artemisia-Betula nana sub-PAZ; c. 15,800–14,700 cal BP): This subzone is characterized by the expansion of dwarf shrubs such as B. nana and various low to the ground growing Salix species. During this phase species-rich grassland with dwarf shrub heaths covered the Swiss lowlands and alpine foreland. The campsites Monruz and Champréveyres (Gaillard, 2004) as well as

Fig. 3. Kastelhöhle Nord (middle archaeological layer): lithic industry assigned to the Badegoulian (from Sedlmeier, 2010).
certain occupation layers from the cave Kesslerloch (Ammann et al., 1988) are correlated with this vegetation phase on the basis of pollen analysis.

Palaeotemperatures inferred from coleopteran assemblages (notably in Hauterive/Rouges-Terres and Champréveyres; Coope and Elias, 2000; Coope and Lemdahl, 2009) indicate mean temperature of the warmest month slightly under 10 °C and mean temperature of the coldest month between −15 and −20 °C, sometimes even lower. Only towards the end of Oldest Dryas, the mean temperature of the warmest month rose to c. 11 °C and to c. −10 °C for the coldest month.

**RPAZ CHb-2, Juniperus-Hippophaë-PAZ** (c. 14,700–14,400 cal BP) (start of Late Glacial Interstadial/beginning of Bølling biozone/ Greenland Interstadial GI-1e, Meienendorf)

This pollen assemblage zone is marked by a rapid increase of *Juniperus communis* and *Hippophaë rhamnoides*. It corresponds to the onset of the Bølling biozone correlated to GI-1e and to what is also termed as Meienendorf interstadial in northern Germany. The vegetation consists of open shrub and grassland into which some tree birches (*Betula pendula* and *Betula pubescens*) are spread.

Temperature estimates reconstructed on the basis of coleopteran assemblages show a rapid rise corresponding to a major episode of warming in both summer and winter temperatures. The mean temperature of the warmest month rises to at least 15 °C and the mean temperature of the coldest month to c. 0 °C. At the present state of research, no archaeological assemblage in Switzerland is clearly correlated with this short and characteristic vegetation phase.

**RPAZ CHb-3, Betula-PAZ** (c.14,400–13,850 cal BP; Late Glacial Interstadial, Bølling biozone, Greenland Interstadial GI-1e/1d/1c)

CHB-3 is a long phase dominated by tree birch (*Betula sp.*) that can be divided into two subzones: a longer subzone CHB-3a rich in tree birch (*Betula sp.*), willow (*Salix sp.*) and characterized by increasing values of poplar (*Populus sp.*) suggesting still open birch woodland, and a short phase CHB-3b, not always well attested, showing a decrease in *Betula* associated with an increase in grasses. The latter phase is usually attributed to the classic Oldest Dryas and indicates still open birch woodland with *Juniperus and Salix* but no pine trees or only very few. During the later phase of CHB-3, temperature rises up to c. 18 °C means for the warmest month, while the mean temperature for the coldest month is situated around 0 °C–2 °C. The Azilian occupation in Champréveyres is correlated with subzone CHB-3a on the basis of palynological analysis (Gaillard, 2004).

**6. Geographic distribution of the Magdalenian sites**

Strikingly, only few Magdalenian sites have been discovered around the numerous lakes and mires in the morainal lowland areas of the Swiss Plateau and in the Alpine foreland. The same holds true for adjacent southwest Germany where occupations in caves and rockshelters are abundant in the Swabian Alb compared to only few open-air localities in the lowlands of Oberschwaben and in the Rhine valley (Weniger, 1982; Eriksen, 1991). As it is frequently the case in karst regions, Palaeolithic research in Switzerland has long concentrated on caves and rockshelters since they are much easier to locate than open-air sites. The distribution of the more than 50 Magdalenian sites recorded at present is thus largely attributable to reasons of history of research and does not reflect the primary occupation of the landscape (Fig. 7). As shown by the discovery of Monruz and Champréveyres, the absence of any other sites around Lake Neuchâtel, Lake Bienne and Lake Morat is probably due to the fact that most sites are situated below the present-day lake level of those water bodies. The two vast sites situated on the shore of Lake Neuchâtel were indeed discovered during the construction of a motorway at c. 2 m below the present-day lake level, a depth that can only rarely be investigated under normal circumstances.

The distribution of the open-air sites however clearly indicates that open localities were commonly used alongside caves and rockshelters. Even the cave-free Swiss Plateau was intensively occupied, as shown by the site of Moosbühl, near Bern, the largest Magdalenian campsite known today in Switzerland (Bullinger et al., 1997). In addition to this major site, detailed studies of assemblages collected from surface locations have recently increased the number of known sites and changed the general picture of the Magdalenian occupation in this part of the country (von Burg, 1994; Nielsen, 1999, 2002, 2009). As an example: around the peat bog Wauwilermoos, Magdalenian artefacts are known from 11 locations, major sites being Kottwil-Station 11, Kottwil-Hubelweid and Mauensee-Moos. Another important site discovered only few kilometers northwest of the Wauwil bog is Reiden-Stumpen, located on a sandstone hill (c. 512 m asl), approximately 50 m above the present-day valley floor (Nielsen, 1994). The collections from those surface sites show the same techno-typological diversity than the assemblages excavated from caves and are thus likely to indicate different chronological Magdalenian occupation phases.

Contrary to the Mesolithic period, for which a large number of sites at high altitudes in the Alps above 1000 m (Crotti, 1993, 2008; Braillard et al., 2003; Bullinger and Huber, 2010) are documented, during the Magdalenian, altitudes above c. 600 m do not seem to have been occupied, or only in the latest phase. Ecological factors probably limited human expansion into these territories. The topographical setting of the Magdalenian sites thus seems to be essentially correlated with the possibilities for exploiting local vegetation and animal resources.
7. Diversity of the Magdalenian assemblages

Most Magdalenian sites of Switzerland have been excavated more than 50 years ago, except for Champréveyres (Leesch, 1997), Monruz (Bullinger et al., 2006), certain sectors of Moosbühl (Bullinger et al., 1997), Rislisberghöhle (Stampfl, 1983) and Ches-selgraben (Spycher and Sedlmeier, 1985; Sedlmeier, 1998, pp. 311–313). The cave site Rislisberghöhle and the rock shelter Ches-selgraben however have not yet been studied and published in detail, so that even for these sites that have been excavated quite recently it remains difficult to get a precise idea of the stratigraphic context of the material they contained. It has to be assumed that due to relatively coarse excavation techniques used before 1970, the stratigraphic integrity of most of the assemblages extracted from caves is questionable. Nevertheless, based upon several more or less well individualized archaeological layers and on some sites that yielded only one occupation horizon, a subdivision of the Late Upper Palaeolithic assemblages into five “techno-assemblages” has been proposed some twenty years ago (Leesch, 1993; Le Tensorer, 1998). Because no new stratified assemblages have been excavated since that time, no extra information can be added to the general scheme that was then proposed. For a reminder, the main characteristics of the five assemblages can be summarized as follows:

7.1. Techno-assemblage A

This assemblage is known from only one site in Switzerland, from Kastelhöhle Nord (middle layer), a cave that was excavated in 1948/1950. The small assemblage, already presented above...
contains 228 artefacts characterized by a great number of splintered pieces and does not contain any backed bladelets nor any bone or antler artefacts (Sedlmeier, 2010). Reindeer and arctic hare are represented among the rare faunal remains associated. The assemblage is assigned to the Badegoulian, a typo-technological attribution supported by three radiocarbon determinations around 23,000 cal BP.

7.2. Techno-assemblage B

The lower archaeological layer of cave Birseck–Ermitage, excavated in 1910, yielded a rich Magdalenian industry containing dihedral burins, scrapers on blades, piercers, backed bladelets and a series of 10 scalene triangles of the type that is usually associated with middle Magdalenian assemblages (Fig. 8; Höneisen et al., 1993, p. 158; Sedlmeier, 1998, p. 302). The bone industry also comprises several baguettes demi-rondes and two double bevelled antler points. Wild horse, reindeer, lemming, pika and ground squirrel are represented among the associated faunal remains. The open-air site Kottwil has also produced two scalene triangles associated with various other Magdalenian tools that may indicate the presence of a site belonging to this techno-assemblage on the central Swiss Plateau (Kottwil-Station 14; Nielsen, 2002, 191; Nielsen, 2009, fig. 635, 49).

7.3. Techno-assemblage C

Although the cave of Kesslerloch has certainly been re-occupied many times and the assemblage lacks stratigraphic integrity, it is clear from the typo-technological point of view that it contains artefacts belonging to an assemblage that is not represented in most of the other Swiss Magdalenian sites. This assemblage is characterized by a rich antler industry containing points of the Lussac-Angles type and by baguettes demi-rondes à décor de tubérosités, characteristic of the middle Magdalenian (Fig. 9; Höneisen, 1993). The presence of mammoth and woolly rhinoceros among the faunal remains, as well as a little sculpture representing a musk-ox (Figs. 9 and 10), also point to a relatively early stage of the Magdalenian, since those animals disappeared from the Swiss Plateau and from southwestern Germany before the end of the Magdalenian (Weniger, 1982). The assemblage of the nearby cave Freudenthal containing also a fragment of a baguette demi-ronde à décor de tubérosités, belongs to the same techno-assemblage. Palynological investigations performed on cores that were drilled in 1980 in front of the Kesslerloch tend to assign certain layers from the base of the sedimentary sequence to the vegetation phase of the expansion of B. nana, at c. 13,000 BP (Ammann et al., 1988). Several AMS radiocarbon dates however point to the existence of older occupation layers (see below).

7.4. Techno-assemblage D (D-a and D-b)

A large number of sites have produced lithic industries dominated by backed bladelets but do not contain enough antler industry to distinguish them from techno-assemblage C. However, all are devoid of angle-backed, curve-backed and shouldered points, distinguishing them also from techno-assemblage E. These industries concern for example Sächlihöhe Oben, Heidenküche, Hollenberg-Höhle 3, Rheinfelden-Ermitage, Reiden-Stumpen, Champpréveyres, Monruz and Moosbühl. Possibly this type of industry must be subdivided into two sub-assemblages D-a and D-b. The assemblages of Champpréveyres and Monruz containing more than 50% of backed bladelets can be taken as the reference assemblages of techno-assemblage D-a (Fig. 10), whereas the assemblage of Moosbühl containing significant proportions of truncated backed bladelets, rectangles and longborers is taken as a reference for techno-assemblage D-b (Fig. 11). The beads made from jet found at Moosbühl also differ slightly in shape from those found at Monruz, the former being rather thick and one of them with a bi-conical cross-section (Fig. 11, 53), whereas the latter ones are thin and flat (at Gönnersdorf, however, both types occur together). None of the faunal spectra associated with these
assemblages contain mammoth, woolly rhinoceros or musk-ox, and therefore probably post-date the retreat of these species from the Swiss Plateau. Palaeoenvironmental data and radiocarbon ages from Champréveyres and Monruz date these assemblages to the Oldest Dryas, RPAZ CHb-1c, whereas palynological investigations at Moosbühl tend to place the techno-assemblage from that site either to RPAZ CHb-1c or CHb-2 (Bullinger et al., 1997).

7.5. Techno-assemblage E

This assemblage is characterized by industries containing angle-backed points, shouldered points and few curve-backed points, associated with backed bladelets. Industries of this type are recorded in cave sites such as Kohlerhöhle (Sedlmeier, 1993, 1998, Fig. 12) and Kastelhöhle Nord (Swiss et al., 1959) as well as in
open-air sites like Winznau-Köpfli (Zürcher, 1969), Kottwil-Hubelweid (Nielsen, 1999) and possibly Einsiedeln-Langrüti, a site located at the edge of Lake Sihlsee at an altitude of nearly 900 m in the Alps (Leuzinger-Piccand, 1996). In the sites where bone is preserved, the fauna comprises horse and reindeer besides various other cold adapted species. The two important cave sites Kohlerhöhle and Kastelhöhle have also produced single- and double beveled antler points, but since the layers containing the Magdalenian occupation horizons are quite thick, it is impossible to determine with what stone industry these elements were precisely associated.

8. The reference sites Monruz and Champréveyres

At the present state of research, only the Magdalenian and Azilian industries of Monruz and Champréveyres can be considered being accurately integrated in the palaeobotanical reference sequence established for the Swiss Plateau and may therefore serve as reference assemblages (Fig. 5). The occupation horizons were interstratified within well developed sedimentary sequences containing pollen, macrorests, insects, mollusks, etc. (Moulin, 1991; Leesch, 1997; Coope and Elias, 2000; Leesch et al., 2004; Bullinger et al., 2006). Moreover, the Magdalenian and Azilian layers were rich in faunal and botanical remains. Of particular interest are the abundant charcoal fragments and diverse other charred plant macrofossils that were extracted from the combustion residues preserved in the hearths (Figs. 13 and 14). The anthracological determinations show that, besides low quantities of Betula, more than 96% of the charcoal fragments analyzed from the Magdalenian hearths is Salix (probably the low to the ground growing species Salix retusa), whereas the wood spectra from the Azilian hearths are more diverse, including Juniperus as the dominant species, together with Betula and Salix, but neither Pinus nor Populus. In terms of relative chronology, the Magdalenian occupation horizons are

Fig. 9. Techno-assemblage C. Kesslerloch (from Höneisen, 1993).
therefore correlated with the regional PAZ CHb-1c, before the onset of the expansion of *Juniperus* on the Swiss Plateau. Since *Juniperus* develops only at the beginning of the climatic warming correlated with Greenland Interstadial GI-1e, the Azilian horizons fall either within the regional PAZ CHb-2 or at the beginning of the following PAZ CHb-3 in which juniper is still well represented. The radiocarbon dates obtained from charcoal and bone material date the Magdalenian occupations to c. 13,000 BP (c. 15,500 cal BP), confirming their relative chronological position within the palaeobotanical frame. The dates obtained on charcoal from the Azilian layers of Monruz and Champréveyres situate these occupations to c. 12,300 BP (c. 14,400 cal BP) either still within CHb-2 dominated by *Juniperus* or within the succeeding pollen assemblage zone CHb-3a.

The Magdalenian occupation horizons from the other sites in Switzerland having not produced any botanical remains, it is impossible to correlate the techno-assemblages B, C and E with one
of the defined regional pollen assemblage zones. The chronological position of these assemblages can therefore be inferred only from the radiocarbon dates. However, this type of correlation based solely on radiocarbon ages remains unsatisfying because the accuracy of the radiocarbon dates cannot be verified by the botanical data (Leesch, 2000).

9. New AMS radiocarbon determinations from different Magdalenian sites

In the course of the last two decades, more than 40 AMS radiocarbon measurements were performed on bone/antler material from different Magdalenian sites (Leesch and Müller 2012) in addition to the 22 existing ones performed on charcoal from Champréveyres and Monruz (Leesch, 1997; Bullinger et al., 2006). These measurements were undertaken in order to verify the results obtained in earlier years by the conventional method and to refine the chronological position of the various assemblages (Fig. 15). However, the bones collected from caves and rockshelters do not usually result from a single occupation but from a succession of an unknown number of stays. Moreover, due to the rather approximate excavation techniques prior to the 1970s the finds could usually not be attributed to one single or thin occupation layer. Therefore, these remains do not fulfill the required archaeological evaluation criteria (Pettitt et al., 2003) and are unsuitable for reliable correlation of the obtained dates with specific industries. In most cases the results merely give a rough indication as to the date of certain occupation episodes.

The AMS dates were performed on bone samples originating from eight caves and three open-air sites: Kesslerloch (16 dates), 

Fig. 11. Techno-assemblage D-b, Moosbühl (from Schwab, 1985; Bullinger et al., 1997).
Hollenberg-Höhle (4 dates), Büttlenoch (4 dates), Birseck-Ermitage (1 date), Kohlerhöhle (5 dates), Kasloch (3 dates), Kisliberghöhle (5 dates), Kastelhöhle Nord (3 dates), Moosbühl (1 date), Champréveyres (2 dates) and Monruz (1 date). The three new dates obtained for Monruz and Champréveyres were undertaken in order to compare the results gained from bone material with those previously obtained on charcoal and to compare them with the dates obtained on bones from the Magdalenian sites in the Paris Basin (Bodu et al., 2009). The results of the measurements are presented in Fig. 15, together with the calibrated dates expressed in cal BC with a confidence interval of 94.5%. However, in the text section only the BP dates are used for better readability.

On the whole, the dates obtained by using AMS technique are older by several hundred years than those previously obtained by the conventional method. They tend to demonstrate that most Magdalenian sites pre-date the Greenland Interstadial 1e. The oldest date, 16,205 ± 55 BP, stems from a metacarpus of reindeer from Kohlerhöhle, a cave excavated between 1934 and 1938 that yielded an upper layer up to 60 cm thick, containing a very rich Magdalenian assemblage, and a lower layer containing only a few objects that cannot be assigned to a specific culture but associated with bones of mammoth, cave bear and lion (Lüdin, 1963; Sedlmeier, 1993). As the cave is situated some 50 km north of the maximum extension of the ice during the LGM, it appears that

![Techno-assemblage F, Kohlerhöhle (from Sedlmeier, 1998).](image-url)
human groups were occupying this area at an early stage of the Magdalenian expansion. Moreover, this date is close to the oldest date obtained for the large open-air site Munzingen (Pasda, 1994, 1998), situated in the Rhine valley some 50 km north of the Kohlerhöle. Caves that were occupied during the middle Magdalenian are also known in France, north of the Jura Mountains, for example in Arlay (Cupillard and Welté, 2006; Leesch et al., in press). A Magdalenian occupation as early as 16,000 BP does therefore seem possible, especially since this region had already been populated during the Badegoulian, at around 19,000 BP. However, Kohlerhöle having also produced four younger dates (12,790 ± 45 BP, 12,465 ± 40 BP, 12,460 ± 45 BP, 11,525 ± 60 BP), it can however not be ruled out that this old date represents a statistical outlier. Taking into account the thickness of the archaeological layer, it is also likely that the assemblage contains a mixture of elements from different techno-assemblages; the presence of some angle-backed points, curve-backed points and backed bladelets (Fig. 13) points to late Magdalenian and Azilian occupation phases.

The oldest date from Kesslerloch, around 15,000 BP, may be not reliable because the mammoth bone on which the determination was performed had bad collagen preservation (Napierala, 2008, p. 16). Four other dates are situated around 14,000 BP. They have been obtained on bones of ibex, deer and reindeer and contained a rich Magdalenian assemblage (116 cores) and contained a rich Magdalenian assemblage (116 cores) probably belonging to different techno-assemblages, most likely to D-a and E (Scheu and D. Leesch, 1959, 1959; Pflügl and Sedlmeier, 1989). One bone from Bos/Bison has produced a date of 13,435 ± 45 BP. The latter results would better correspond to an occupation by Azilian groups; however, none of the few associated artefacts with this layer can be accurately attributed to this culture.

Four consistent dates situated between 13,114 ± 71 BP and 12,798 ± 70 BP have been obtained for the cave Hollenberg-Höhle. This small cavity excavated in 1950, contained a small assemblage, possibly stemming from only one occupation (Sedlmeier, 1982; Müller and Leesch, 2011). It is famous for having produced a complete rondelle perforée made from jet (Alvarez Fernández, 2005) and another one made from a thin bone plate, together
### Table 1: AMS radiocarbon measurements from Magdalenian sites in Switzerland

<table>
<thead>
<tr>
<th>Site</th>
<th>Lab. number</th>
<th>^14C yr BP</th>
<th>cal BC 2σ</th>
<th>δ ^13C</th>
<th>Species</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>Birseck-Ermitage, lower layer</td>
<td>ETH-43307</td>
<td>11900 ± 55</td>
<td>11975 - 11553</td>
<td>-14.9</td>
<td>Rangifer</td>
<td>Leesch &amp; Müller 2012</td>
</tr>
<tr>
<td>Hollenberg-Höhle 3</td>
<td>Erl-13569</td>
<td>12846 ± 63</td>
<td>13950 - 13000</td>
<td>-18.9</td>
<td>Rangifer</td>
<td>Müller &amp; Leesch 2011</td>
</tr>
<tr>
<td></td>
<td>Erl-13570</td>
<td>12798 ± 70</td>
<td>13950 - 12900</td>
<td>-18.3</td>
<td>Rangifer</td>
<td>Müller &amp; Leesch 2011</td>
</tr>
<tr>
<td></td>
<td>Erl-13571</td>
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<td>-19.2</td>
<td>Rangifer</td>
<td>Müller &amp; Leesch 2011</td>
</tr>
<tr>
<td></td>
<td>Erl-13572</td>
<td>13077 ± 71</td>
<td>14500 - 13200</td>
<td>-18.6</td>
<td>Rangifer</td>
<td>Müller &amp; Leesch 2011</td>
</tr>
<tr>
<td>Kohlerhöhle, upper layer</td>
<td>ETH-39760</td>
<td>11525 ± 60</td>
<td>11590 - 11290</td>
<td>-36.0</td>
<td>Equus</td>
<td>Leesch &amp; Müller 2012</td>
</tr>
<tr>
<td></td>
<td>ETH-39761</td>
<td>12790 ± 45</td>
<td>13700 - 12950</td>
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<td></td>
<td>ETH-39762</td>
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<td></td>
<td>ETH-43309</td>
<td>12460 ± 45</td>
<td>13100 - 12200</td>
<td>-21.6</td>
<td>Rangifer</td>
<td>Leesch &amp; Müller 2012</td>
</tr>
<tr>
<td></td>
<td>ETH-43310</td>
<td>16205 ± 55</td>
<td>17650 - 16950</td>
<td>-21.1</td>
<td>Rangifer</td>
<td>Leesch &amp; Müller 2012</td>
</tr>
<tr>
<td>Büttenloch, layer B</td>
<td>UtC-12576</td>
<td>12170 ± 80</td>
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<td>-17.6</td>
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<td>Leesch &amp; Müller 2012</td>
</tr>
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<td></td>
<td>UtC-12577</td>
<td>12180 ± 90</td>
<td>12600 - 11800</td>
<td>-19.4</td>
<td>Lagopus</td>
<td>Leesch &amp; Müller 2012</td>
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<td>Büttenloch, layer A</td>
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<td>12870 ± 80</td>
<td>14200 - 13000</td>
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<td>Lepus</td>
<td>Leesch &amp; Müller 2012</td>
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<td></td>
<td>UtC-12575</td>
<td>12750 ± 80</td>
<td>13700 - 12650</td>
<td>-19.9</td>
<td>Lepus</td>
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<td>Moosbühl, sector VI</td>
<td>ETH-40929</td>
<td>7590 ± 40</td>
<td>6510 - 6380</td>
<td>-31.2</td>
<td>Rangifer, antler modif.</td>
<td>Leesch &amp; Müller 2012</td>
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<td>Equus</td>
<td>Bodu et al. 2009</td>
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<tr>
<td></td>
<td>OxA-20701</td>
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<tr>
<td>Monruz, sector 1</td>
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<td>13055 ± 60</td>
<td>14500 - 13200</td>
<td>-20.3</td>
<td>Equus</td>
<td>Bodu et al. 2009</td>
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<td>Kastelhöhle Nord, upper layer</td>
<td>ETH-45024</td>
<td>13435 ± 50</td>
<td>14950 - 14250</td>
<td>-18.8</td>
<td>Bos/Bison</td>
<td>Leesch &amp; Müller 2012</td>
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<td></td>
<td>ETH-45025</td>
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<td>-18.9</td>
<td>Rangifer</td>
<td>Leesch &amp; Müller 2012</td>
</tr>
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<td></td>
<td>ETH-45026</td>
<td>12215 ± 45</td>
<td>12550 - 11900</td>
<td>-19.8</td>
<td>Rangifer</td>
<td>Leesch &amp; Müller 2012</td>
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<tr>
<td>Rislisberghöhle</td>
<td>ETH-39768</td>
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<td>10840 - 10610</td>
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<td>Equus</td>
<td>Leesch &amp; Müller 2012</td>
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<tr>
<td></td>
<td>ETH-42514</td>
<td>12235 ± 45</td>
<td>12600 - 11900</td>
<td>-22.2</td>
<td>cf. Equus</td>
<td>Leesch &amp; Müller 2012</td>
</tr>
<tr>
<td></td>
<td>ETH-42515</td>
<td>12710 ± 45</td>
<td>13600 - 12700</td>
<td>-20.5</td>
<td>Capra ibex</td>
<td>Leesch &amp; Müller 2012</td>
</tr>
<tr>
<td></td>
<td>ETH-42516</td>
<td>12680 ± 45</td>
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<td></td>
<td>ETH-42517</td>
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<td>Kesslerloch</td>
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<td>12774 ± 54</td>
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<td>Equus</td>
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<td>Canis</td>
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<td></td>
<td>OxA-10238</td>
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<td>-20.0</td>
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<td></td>
<td>OxA-10239</td>
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<td>15500 - 14850</td>
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<td>Mammuthus</td>
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<tr>
<td></td>
<td>OxA-10298</td>
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<td>Mammuthus</td>
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</tr>
<tr>
<td></td>
<td>OxA-5746</td>
<td>14150 ± 100</td>
<td>14950 - 13950</td>
<td>-18.9</td>
<td>Rangifer</td>
<td>Housley et al. 1997</td>
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<td>OxA-5748</td>
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<td>14000 - 12600</td>
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<td>Bone, modified</td>
<td>Housley et al. 1997</td>
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<td></td>
<td>OxA-5750</td>
<td>13500 ± 100</td>
<td>14700 - 13000</td>
<td>-19.6</td>
<td>Rangifer</td>
<td>Albrecht 1982</td>
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<td></td>
<td>B-3329</td>
<td>12890 ± 90</td>
<td>14300 - 13000</td>
<td>bones indet.</td>
<td>Geyh &amp; Schreiner 1984</td>
<td></td>
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</table>

**Fig. 15.** AMS radiocarbon measurements performed on bone, antler, and teeth from Magdalenian sites in Switzerland. The ^14C dates are calibrated with the program OxCal v3.10 (Bronk Ramsey, 2005), using the Intcal09 curve (Reimer et al., 2009); 2σ confidence interval, 95.4%.

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with 34 mollusk shells. The industry, although not numerous, can be attributed to techno-assemblage D-a, while the radiocarbon dates, indicate a position within the Oldest Dryas.

Three dates obtained from horse bones sampled at Champréveyres and Monruz (12,815 ± 65 BP, 12,805 ± 75 BP, 13,055 ± 60 BP) are in good agreement with the AMS dates obtained in earlier years from wood charcoal (Leesch, 1997; Bullinger et al., 2006). They confirm the dating of both sites to c. 13,000 BP (c. 15,500 cal BP). They also demonstrate that, when sampling is operated under good stratigraphic control, there is no significant difference between dates obtained from bone material and dates from plant remains.

The new AMS measurements performed at Birseck–Ermitage and Moosbühl do not help to better date the assemblages from these sites. Birseck–Ermitage, a vast rock shelter that has been excavated from 1910 to 1914 (Sarasin, 1918; Sedelmeier, 1998), has produced a characteristic assemblage comprising scalene triangles and baguettes *demi-rondes* attributed to techno-assemblage B (Fig. 8), whose chronological position is still debated. The new AMS measurement performed on a reindeer bone has produced a date of 11,900 ± 55 BP. This result is similar to two dates obtained in earlier years by the conventional method. However, these dates do not correspond to the effective age of this assemblage, as it would signify that Magdalenian groups would have consisted in the same area with Azilian groups, the former hunting reindeer, the latter hunting red deer. Similarly, a new measurement performed on a worked reindeer antler from Moosbühl has produced a date of 7590 ± 40 BP which is doubtless an outlier and therefore does not help to determine the absolute age of the particular assemblage designated as techno-assemblage D-b (Fig. 11). These too young dates remind us that obviously erroneous dates, i.e., results that are too young by several thousand years, are easily identifiable as such, but that dates that are “wrong” by only 500 or 1000 years are not recognizable as incorrect because they fall within a plausible time span.

10. A well established Magdalenian population before GI-1e

The spatial, temporal and causal aspects of the re-colonization of the area of Switzerland after the Last Glacial Maximum can be reconstructed at present in the following details. As proven by two sites, the area north of the Jura Mountains was populated already during at least the final phase of the LGM, so that for the re-colonization of the Swiss Plateau, one must not a priori invoke an “immigration” of people from distant refugia. The melting of the glaciers is described as a rapid collapse rather than a slow melt down (Ivy-Ochs et al., 2004), however, the meaning of “rapid” has to be put in a geologist’s perspective. Between the onset of the melt down and the time the glaciers had completely liberated the Swiss Plateau lie probably at least some 2000 years. This means that the areas towards the farthest extent of the glaciers could be re-colonized much earlier than those closer towards the Alps. However, this succession cannot be retraced by the archaeological record since there are too few sites known today on the Swiss Plateau. At the same time, it might not be complete coincidence that the earliest date for a Magdalenian site in Switzerland south of the Jura Mountains comes from Kesslerloch close to Schaffhausen, at the ice margin during the LGM and must, therefore, have been liberated from ice right after the onset of the ice decay.

Human colonization of a newly accessible area should be set in relation to the colonization of the landscape by plant and animal communities and not primarily to climatic events. As the plant cover develops, it will eventually be productive enough to sustain large herbivores like reindeer and wild horse. If the snow cover in winter is low enough that these animals can access the vegetation they will be present in the area all year round. As soon as these herbivores are present in an area one can assume that human groups are capable of surviving as well. As demonstrated by the radiocarbon dates, most sites fall within the Oldest Dryas, essentially the stage that is correlated with GS-2a, a phase that was probably even colder than the preceding phase GS-2b (Schoeneich, 2003). Obviously, from at least 17,000 cal BP the ice-free zones at low altitudes were sufficiently re-colonized by vegetation to allow large animals to sustain themselves. Though the Magdalenian occupation was certainly not as dense as in the core area of southern France and Cantabria, there is no proof for a substantial time lag between occupation of the “classical” region and more “peripheral” zones.

In all assemblages known at the present state of research, local and regional flint sources are dominant. The distance of procurement generally does not exceed 40 km. None of the assemblages, not even the Badegoulian assemblage of Kastelholhe Nord, is composed of raw materials originating from long distances that would show links to a territory from which “pioneers” would have emigrated. The distance to the raw material sources is only longer when the sites are situated in a “flint-less” area such as the central Swiss Plateau, or when they are located in a region offering only low quality raw material not well adapted to the production of handed implements. In this case, the distances of transport may be up to 120 km; however, they do not indicate a favored direction as would be the case for pioneer settlements still attached to their home-region. In all the cases, the exploited raw materials show multidirectional provenance (Affolter, 2002, pp. 171–180), proving a well established population living in an environment most familiar to them. This behavior also demonstrates that occurrence or absence of flint in a region is of minor or of no importance at all. High mobility and/or a well functioning network with neighboring groups allowed colonization of all territories where vegetation was sufficiently developed to allow large herbivorous animals to graze and where the topography of the landscape permitted to set up successful hunting strategies.

Reindeer and wild horse are the main big game species in all sites, whereas bison is only attested in small numbers. Usually the faunal assemblages are dominated by either one of the two species, reindeer or horse, which might be due to seasonal or geographic/topographic factors. However, when bone preservation is good and when excavation techniques include wet-sieving of the sediments, the diversity of the faunal assemblages is high and contains also animals of small and medium size such as ibex, marmot, alpine hare, arctic fox, ground squirrel and pika, together with various birds and fishes. Seasonal determinations are currently investigated for all sites that have produced animal remains in order to reconstruct the dynamics of land use by the Magdalenian groups throughout the seasonal cycle. While this work is still in progress, it has already become clear that Switzerland was not only occupied during the “warm” (spring–autumn) season but all year round. High residential mobility characterizes the behavior of the groups during the warm season, especially when horses were hunted. As could be demonstrated from the archaeozoological study of the open-air sites Champréveyres and Monruz, it was indeed more efficient to move the camp to the kill-site of the horses than to carry the carcasses several kilometers back to a “base camp” (Müller et al., 2006). Thus, the kill-butchering site was transformed into a temporary campsite where the whole group stayed for a few weeks according to the number of horses that were killed (usually one to a maximum of three animals), before moving to another kill-site.

No significant changes in subsistence behavior can be observed between the Middle and the Upper Magdalenian. As far as can be reconstructed from the provenance of the flint materials that were used, the territories did not change notably (Affolter, 2009). These
were well established regional groups maintaining multidirectional contacts, however circulating along certain axes determined by topographical features and river systems (Cattin et al., 2009). As shown by the mollusks and by the feminine figures that were found in the cave of Petersfels (southwest Germany) and in Monruz, the Magdalenian groups living at the Jura foothill had particularly strong ties to the upper Danube basin, while those living north of the Jura chain, in the region of the Birse River, were more specifically oriented towards the Rhine valley. Most of the latter sites have indeed produced fossil mollusks originating from the Mainz basin (Sedimeyer, 1988; Eriksen, 2002; Alvarez Fernández, 2005) and/or from the Paris basin, while only one of them (Kohlerhöhle) has produced a shell from the upper Danube basin. The shells from the upper Danube basin are distributed over a distance of c. 250 km and may indicate the extension of the territory inhabited by members of the same group. A few Mediterranean shells, and even amber from the Baltic Sea (Beck, in Schwab, 1985; Beck, 1997), indicate the existence of an even farther reaching network of social relationships that permitted the diffusion of these exotic elements over more than 500 km.

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The authors would like to thank Lawrence Straus for initiating the session on the Magdalenian at the INQUA Congress in Bern. We are grateful to Jörg Schibler and Jürg Sedimeyer for providing unpublished radiocarbon dates from Büttenloch, Kohlerhöhle and Käslöch. Thanks are also due to Reto Marti (director of the cantonal survey of Solothurn) for
Käsloch. Thanks are also due to Reto Marti (director of the cantonal
unpublished radiocarbon dates from Büttenloch, Kohlerhöhle and
the session on the Magdalenian at the INQUA Congress in Bern. We
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