# INTRODUCTION

Since the Club of Rome published its seminal study on »The limits of growth« (Meadows et al. 1972) in 1972, the interaction of the human population with its surrounding ecosystem and, in particular, the handling of finite resource supplies became a topic of major public debate. The publicity of this report fostered further studies on climate and environmental developments and the relation of these factors to human societies. These succeeding studies aimed to refine the data for simulation approaches to allow increasingly precise predictions of future developments. Subsequently, the simulations should provide maintainable solutions for political and social policy-makers concerning the most appropriate human behaviour in the future. Especially, the ability of past societies to adjust their policies of population growth and economic demands in response to climate and environmental change were investigated as examples of the ecological tolerance and resilience of social systems.

Many studies on past societies identified short-term shifts in the palaeoclimatic record as major causes of crisis which sometimes led to a collapse and/or reorganisation of societies during the Holocene (Weiss/Bradley 2001; Haug et al. 2003; Tainter 2008, 44-45). In contrast, Pleistocene social systems were frequently found to remain stable and unaltered across relatively long periods which could also encounter some marked shifts in the palaeoclimatic record (cf. Bettinger/Richerson/Boyd 2009). Perhaps, this inertia of Pleistocene societies is due to more flexible subsistence strategies of hunter-gatherer groups which were adapted to insecure environments and sustained stabilizing social security networks. Small alterations in the resource availability resulting from local environmental factors such as hydrological changes, vegetation development, variation in the behaviour of prey species, or natural disasters could be faced by these flexible, well-connected, and mobile groups with adaptation of single parts of the archaeologically observable record. These abilities formed the basis of the highly resilient social systems.

However, examples such as the changes in the subsistence strategies in northern German Mesolithic societies possibly related to the decline of hazelnut patches in response to a short cold episode in the Holocene (»8.2 kyrs event«; Holst 2010) suggested that the flexibility of such hunter-gatherer economies could lead to significant changes of the mobility and territorial patterns. Moreover, reorganisation of social systems was also observed in the Pleistocene record raising the question for the limits of resilience of these systems. For instance, the significant environmental changes provoked by abrupt climate shifts in the Weichselian Lateglacial (c. 16,200-11,700 years ago) and at the onset of the Holocene were discussed as a cause for the Neolithic revolution in the Levant (Hayden 1981; Bar-Yosef 1998; Maher/Banning/Chazan 2011; Simmons 2007; Rosen/Rivera-Collazoa 2012). This consecutive scenario suggested that confronted with regional to supra-regional changes flexible strategies of hunter-gatherers could fail to offer security and the necessity of a major reorganisation of the inert social system would arise. In addition, the stability and consequential predictability of the natural environment were suggested as important factors in the establishment of new behavioural patterns (Bettinger/Richerson/Boyd 2009).

These suggestions demonstrated the close connection to studies on strategies of hunter-gatherer groups to reduce risk and uncertainty. These strategies aimed to compensate for stress caused by minor variations of their environments (e. g. Halstead/O'Shea 1989a; Stein Mandryk 1993; Winterhalder/Leslie 2002). Natural disasters such as volcanic events form one example for these sometimes significant, but relatively short-termed variations of the environment. Although these short-lived events are useful as correlation points of the chronostratigraphic records, their impact on past social systems remained controversial (Grattan 2006; Weber/Grimm/Baales 2011; Cooper/Sheets 2012).

An important natural disaster affecting large parts of north-western Europe at the end of the Weichselian Lateglacial Interstadial was the Laacher See volcanic eruption (LSE; *c.* 13,000 years ago). Besides representing an important marker horizon, the Laacher See tephras (LST) covered and preserved mid-Weichselian Lateglacial horizons and numerous remains of hunter-gatherer groups on large areas in the vicinity of the volcano in the Central Rhineland. These remains were attributed to the *Federmesser-Gruppen* (FMG; see Material-Archaeology-Archaeological groups, p. 65-74) due to some characteristic artefact types. Thus far, near Bad Breisig a single concentration of archaeological remains still attributed to the mid-Weichselian Lateglacial represented the only assemblage recovered on top of the LST in this area (Baales/Grimm/Jöris 2001). These remains were still attributable to the FMG (see p. 163-168) suggesting that hunter-gatherer groups of this region could compensate this short-term natural disaster by relying on their widespread social system. In addition, a horizon which was stratigraphically lower than the mid-Weichselian Lateglacial horizon also yielded archaeological material. This material was well protected by a significant loess cover topped by the LST. These well preserved remains were classified as Late Magdalenian (see p. 56-65). Rich environmental records found in the two horizons below the LST allowed detailed reconstructions of the landscape inhabited by these hunter-gatherers and revealed very different habitats: A cold grass steppe landscape with horse, reindeer, arctic fox, and arctic hare in the loess covered period (Brunnacker 1978a; Street et al. 2006) and a temperate, light forest environment with red deer, aurochs, elk, and beaver immediately underneath the LST (Baales 2002; Baales 2006a). In addition to the landscape and differences in the archaeological material were apparent in the prey fauna, equipment, and settlement patterns as well as in exploitation strategies of lithic resources (Floss 1994; Baales/Street 1996; Street et al. 2006). According to the radiometric and chronostratigraphic results, the two different behavioural complexes prevailed during phases which lasted almost 1,000 years, whereas the intermediate period of change must be set from approximately 15,300 to 14,000 years ago. Significant climate and environmental changes of the Weichselian Lateglacial were recorded during this period in high-precision archives from Greenland and from north-western Europe (Steffensen et al. 2008; Litt et al. 2001). Occasionally, the terrestrial environment responded with some time lags to the climate changes (Jones et al. 2002; Litt/Schmincke/Kromer 2003). However, once a new stable ecosystem regime was established it lasted for several centuries. Thus, the hunter-gatherer communities inhabiting north-western Europe were confronted with important changes of their ecosystem during the Weichselian Lateglacial comparable to the groups in the Levant. In Northwest-Europe, long-term changes led to variations in the supply of essential resources. In consequence, climate and environment were assumed as triggers leading to the differences observed in the archaeological record (e. g. Bosinski 1989; Floss 2002).

However, although the chronological sequence is known in some detail for the Central Rhineland, only few comparative studies dealt with when and how exactly the differences between the Late Magdalenian and the FMG appeared. Yet, only comprehensive knowledge about tempo and mode of these changes makes causal assumptions of the precise triggers and a characterisation of the process possible. Probably, the small number of diagnostically conclusive assemblages which date to the intermediate period in Central Rhineland prohibited a more detailed study of the changing patterns. Nevertheless, comparable assemblages to the well stratified sites from the Central Rhineland were found from the middle-ranged mountain regions of Western and Central Europe up to the eastern border of Poland and in most parts of south-western Europe (e. g. Weniger 1989; Kozłowski/Kozłowski 1996, 81-84; Leesch/Cattin/Müller 2004; Ginter/Połtowicz 2007; Valentin 2008a). Thus, the occurrence of these patterns can be studied based on material from other regions such as northern France where more assemblages from the intermediate period were recovered (Fagnart 1997; Bridault/Bignon/Bemilli 2003; Valentin 2008a). In particular, the archaeological material from the adjacent western upland zone as well as the Paris Basin was considered to form a chronological and, perhaps, ethnic entity during the Late Magdalenian (Floss/Terberger 2002, 138;

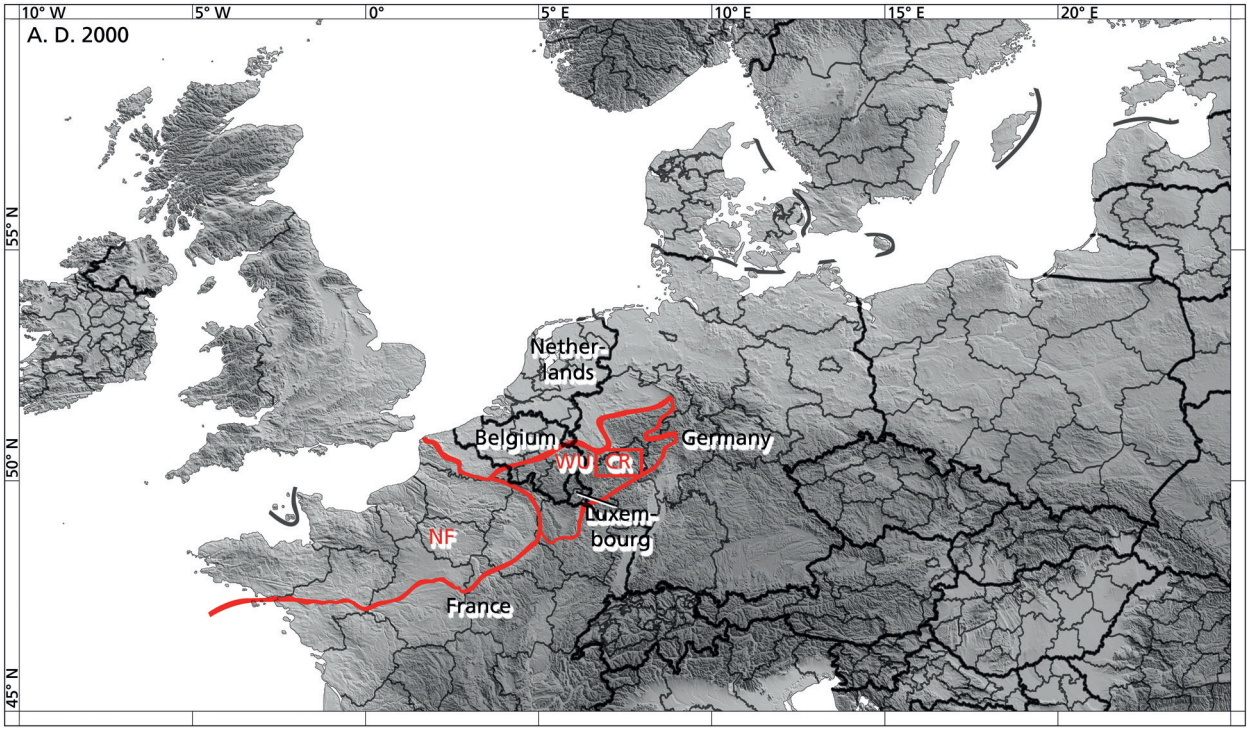


**Fig. 1** Map of study areas (red) in north-western Europe with modern national (dark grey) and regional borders (medium grey; data source: Global Administrative Areas, http://www.gadm.org/country; freely available for academic and other non-commercial use). **CR** Central Rhineland. – **WU** western upland zone. – **NF** northern France. – For further details see Material-Environment-Landscapes , p. 31-40, and text.

cf. Arts/Deeben 1987). Furthermore, FMG assemblages comparable to those from the Central Rhineland were also found in northern France (Bodu/Valentin 1997; Bodu 2000a) suggesting the continuity of connections among these regions. In consequence, a common transformation process for these regions can be assumed. Thus far, no unambiguous FMG site was recovered in the upland zone between the Central Rhineland and northern France (De Bie/Vermeersch 1998; cf. Arts 1988) but numerous FMG sites are known from the adjacent lowlands (De Bie/Van Gils 2006). This difference in the distribution of sites is possibly explicable by the lack of open air sites, which were clearly preferred by the FMG, in the western uplands. Moreover, the Upper/Final Palaeolithic and Mesolithic levels in the cave sites were often found disturbed by natural agents or undocumented human interference. Nevertheless, based on the similarity of the FMG assemblages in the surrounding of the western upland zone, the same development as in northern France and the Central Rhineland is also assumed for this region. Therefore, in addition to the Central Rhineland, the framing western upland zone and northern France (**fig. 1**; for further details see p. 38-40) were selected to form the study area.

In France, the process of change between the Late Magdalenian and the FMG was termed Azilianisation (Bordes/Sonneville-Bordes 1979). Modern studies from northern France treated the Azilianisation as an evolutionary development (Bodu/Valentin 1997; Valentin/Fosse/Billard 2004), whereas the abbot Henri Breuil regarded the Azilian as a revolutionary process (Breuil 1913). The issue if changes occur in a revolutionary or in an evolutionary process is not restricted to human social systems. Comparable models on the »tempo and mode in evolution« (Simpson 1944) were discussed in palaeobiology (Eldredge/Gould 1972; Gould 1994; Eldredge et al. 2005). The observed scales and, in particular, the temporal frame of reference were thereby identified as important aspects for the interpretation of the examined process (Thomson 1992).

Consequently, the difference between the two views on the Azilianisation process as understood in the present study consists in the appearance of the changes: An evolutionary process is assumed as a constant adaptation. Thus, the differences between the Late Magdalenian and the FMG would arise from the accumulation of several, small-scale adaptations of hunter-gatherers over the more than 1,000 years between the two periods. These gradual effects on the various parts of life allow for a distinction of a succession of changes in the behaviour of the past hunter-gatherers. In contrast, a revolutionary process is suggested as a concentration of adaptations in a major shift. This major shift could be explained by a chain-reaction of closely related spheres of hunter-gatherers' life. For example, in mobile hunter-gatherer groups subsistence strategies and mobility patterns are closely related (see above). Moreover, changes in the mobility pattern could subsequently affect social networks. The chain-reaction could have been started when a threshold or limit was passed. The abrupt climate and environmental changes formed a strong external stimulus which could have pushed the flexible adaptive system of hunter-gatherers to its limits. However, if changes of social systems occurred in this threshold-like manner the factor causing the overstepping of the limit could be identifiable at the onset of the shift. Nevertheless, considering isolated lines of evidence cannot produce a reliable distinction between the two process types because single parameters also switch rapidly in an evolutionary process. Furthermore, both types affect probably the complete way of life of hunter-gatherers in a long temporal study. In the present study, the two types of process (revolution and evolution) are therefore assumed to be distinguished by the tempo in which they affect large parts of human life.

To reveal the tempo and mode of changes from the Late Magdalenian to the FMG as a case study and to examine these changes in regard to climate and environment as potential triggers, different lines of evidence (climate, environment, archaeology) need to be set in a common frame of reference. Thus, relevant material for the climate, environmental, and archaeological development from the relevant period are assembled in the present study. The relevant period spans the time from the Late Magdalenian to the FMG in Central Rhineland which approximates 16,200-12,800 years before 2000 A.D. (b2k). In the Lateglacial, the radiocarbon timescale is also commonly used due to the absolute dating of organic remains being essential for the construction of chronologies. On this timescale, the study period correlates to *c.* 13,200-10,800 $^{14}$C years before present ($^{14}$C-BP) which refers to 1950 A.D. The material assembled in the present study includes Late Weichselian climate records (see Material-Climate, p. 7-30), environmental archives (see Material-Environment, p. 30-48), and radiocarbon databases (see Material-Databases, p. 49-53) as well as archaeological inventories (see Material-Archaeology, p. 53-244). In the present study, climate records form the chronostratigraphic baseline against which the environmental change and the process of human adaptation are examined to clarify the chronological succession. The environmental records as well as the archaeological assemblages are qualitatively examined concerning their precise chronostratigraphic position and the reliability as a high-resolution record. Then the material is correlated by the use of annually laminated archives and radiocarbon dating and set in the same high-precision time frame. Radiocarbon dates require a reliable calibration to be related to the chronostratigraphy of climate and environmental archives. Thus, the calibration records are also reviewed and a generally applied calibration curve (Weninger/Jöris 2008) is further refined for the Weichselian Lateglacial. By the use of pollen stratigraphies and directly dated macro-remains as well as directly dated faunal remains the progress of environmental change is modelled on regional scales. Furthermore, to identify the differences between the Late Magdalenian and the FMG, the archaeological material of the Central Rhineland is introduced per assemblage and with several standard values of the assemblages collected to equalise the data sets. The assemblages are grouped according to the resource exploitation strategies including subsistence but also indications of site function and mobility. The sorting into the groups is based on the attribution to predefined classes and the formation of indices. The material from northern France is presented in a comparable manner to locate changes in several lines

of evidence. These lines of evidence and the changes therein are set in relation to the high-resolution chronostratigraphy by radiocarbon dating of the archaeological assemblages. This multi-linear approach is chosen because, as stated previously, small alterations are probable to occur in the behaviour of hunter-gatherers as buffering mechanism to perhaps local changes. Nevertheless, a major reorganisation is reflected by changes of numerous patterns in several lines of evidence occurring in a short time period. If this shift is observed a major trigger such as climate amelioration or forest development can be sought shortly before or at the onset of changing patterns. However, if indications for a major reorganisation are absent in the archaeological record small adjusting alterations were sufficient to cope the climate and environmental changes of the Weichselian Lateglacial. In this case, the resilience of the Late Magdalenian would have caused an adaptive process leading to the transformation into the FMG. Thus, the present study aims to characterise whether the change from the Late Magdalenian to the FMG reflected a revolutionary or an evolutionary process.

Studying this process of change in the Weichselian Lateglacial and, in particular, in north-western Europe is furthermore advantageous because adoption effects can be neglected. During the Last Glacial Maximum (LGM) most parts of Central Europe were de-populated (cf. Terberger/Street 2002; Verpoorte 2009) and only resettled by a major Magdalenian expansion coming from a south-western European refugium. This expansion direction was further supported by genetic data (Pereira et al. 2005). Thus far, no significant influence from people and/or ideas coming from the south-eastern refugium was observed in the archaeological record*. Hence, by the onset of the studied period the Late Magdalenian is the only archaeological group observable in Northwest-Europe. Furthermore, by the end of the studied period the known groups in north-western Europe descended directly from this Late Magdalenian. Changes occurred consequently within a single genetic inheritance and social transmission system. Therefore, the process of change without interfering adoption processes reflects an adaptive cycle of a Pleistocene social system. Increasing differentiation of groups occurred during the Weichselian Lateglacial and the more so during the Holocene. As a result, studying the process of change in the form of an undisturbed adaptive cycle is no longer possible afterwards.

Since further acculturation inputs are therefore excluded, understanding the process of change in the Weichselian Lateglacial represents a paragon for the behaviour of social systems under severe ecological stress. This knowledge contributes to the formation of general patterns of human behaviour under stress and is indispensable as an elementary component in creating future scenarios for a globalised world.

* In contrast, aDNA data meanwhile suggests a population turnover during the studied period by people coming from south- to south-eastern areas (Posth et al. 2016; Fu et al. 2016).