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Bridging prehistoric caves with buried landscapes in the Swabian Jura (southwestern Germany)

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ABSTRACT

The Ach and Lone valleys of the Swabian Jura represent two key areas for the study of the dispersal of modern humans into central Europe, owing to the presence of numerous cave sites in the region that contain stratigraphic sequences spanning the Middle and Upper Paleolithic. However, despite the relatively complete sequences contained within these caves, previous studies hypothesize that phases of erosion have influenced the preservation of Upper Paleolithic deposits, particularly those dating to the Gravettian. Furthermore, these same studies suggest that during the Late Glacial and Holocene, colluvial sediments subsequently covered these unconformities. In this paper we present a dataset that helps us evaluate how geomorphological processes active at the regional scale around the Last Glacial Maximum (LGM) have impacted the preservation of the archaeological record within the cave sites of the Ach and Lone valleys. To this end we applied and integrated a variety of methods, including geophysical prospection, coring, micromorphology, Fourier Transform infrared (FTIR) spectroscopy, and radiocarbon dating. Our results show that alternating phases of soil formation, hillside denudation, river valley incision and floodplain aggradation have been the major processes active in Lone and Ach valleys throughout the Pleistocene and Holocene. These processes impacted the formation histories of the caves in the two valleys, thereby significantly influencing how we interpret the archaeological record of the region. In particular our data support the hypothesis arguing for the erosion of Gravettian-aged deposits (which are dated between 29.000 and 27.000 ^{14}C BP) from the caves of Bockstein, Hohle Fels and possibly Hohlenstein-Stadel. Shortly after this erosive phase, increased depositional rates of loess nearly free of gravel and reworked soils marked in both the Ach and Lone valleys a shift towards colder and drier conditions corresponding with the LGM. Deteriorating climate likely forced Gravettian groups to abandon the Swabian Jura. The Magdalenian recolonization of the region took place in a cool interstadial (13.500–12.500 ^{14}C BP) that was followed by a period of climate deterioration with minor phases of erosion in the caves and bedrock denudation. Towards the beginning of the Holocene the accumulation of frost debris (*Bergkies*) at the cave entrances marked the cessation of erosion within the caves.

1. Introduction

1.1. Linking caves with the landscape

Caves and rockshelters play a significant if outsized role in Paleolithic research. Humans preferentially selected these types of sites for habitation since the lower Paleolithic (e.g., Wonderwerk Cave, South Africa. Malan and Cooke, 1941; Beaumont and Vogel,

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2006; Chazan et al., 2008) and their rich assemblages of archaeological materials—often found within well-stratified and datable deposits—have attracted the attention of archaeologists since at least the 19th century. However, despite the importance of caves for Paleolithic humans (and the scientists who investigate them), much, if not most, of the daily lives of foragers was carried out in the open air, and not in the confines of a natural shelter. By only focusing on the archaeological record of caves and rockshelters, we run the risk of forming biased views of the activities and behaviors of Paleolithic humans. Archaeologists recognize this bias (Conard, 2001) and have addressed these concerns through a wide range of methodological approaches that provide a link between activities conducted in the open air and the material remains recovered from excavations in caves (Castel et al., 1998; Çep and Waiblinger, 2001; Faith, 2007; Niven, 2007; Saladié et al., 2011; Starkovich, 2014; Yeshurun et al., 2007). Geoarchaeologists who study Palaeolithic cave sites have similar concerns about linking data collected within a cave to processes that occur outside of a cave. Since the late 1970s (Goldberg, 1979), numerous micromorphological investigations have shown that paleoenvironmental changes influence the formation of cave deposits (Courty and Vallverdu, 2001; Goldberg et al., 2015; Karkanas, 2010; Mentzer, 2011; Sherwood et al., 2004). However, it is not always possible to form a link between micromorphological observations made at the microscopic or site scale with specific environmental processes (Courty and Vallverdu, 2001). This problem is exacerbated by the fact that researchers working in caves and those working in the open air often make observations at different scales and with different techniques: cave geoarchaeologists rely on micromorphology and field observations made over tens of centimeters and meters; landscape geoarchaeologists and quaternary geoscientists often focus on observations made over tens of meters or kilometers and study geomorphic features such as loess sequences (e.g. Terhorst et al., 2014), lake deposits (e.g. Litt et al., 2001) and river terraces (e.g. Vanderberghe, 2015). As a result, research focusing on “inside” deposits and “outside” deposits is often designed to answer very different questions. Furthermore, bridging open air and cave sequences relies on the comparison of chronological datasets, which are not always comparable between inside and outside of a cave, or the identification of lithological or pedological markers (e.g. Karkanas et al., 2015; Pirson et al., 2012), which do not necessarily extend from the open air into a cave environment.

In this paper, we present a case study conducted in the Ach and Lone valleys of the Swabian Jura, southwestern Germany—a region rich in Paleolithic cave sites, dynamic landscapes and a long research tradition. Here we attempt to link a paleolandscape study with geoarchaeological analysis of cave sediments by applying macro- and microscopic methods to both “outside” and “inside” deposits. This holistic approach to paleolandscape reconstruction and site formation processes allows us to assess the role that past environments played on depositional and post-depositional processes in the caves. Furthermore, by placing these important cave sites within a paleolandscape context, we are able to determine how landscape change in the Swabian Jura influenced the archaeological record of the caves and how humans in the Pleistocene exploited these natural shelters.

1.2. Geographic setting, geology and geomorphology

The Swabian Jura (or *Schwäbische Alb*) is a karstic plateau (between 500 and 1500 m amsl) located in southwestern Germany and delimited by The Neckar Valley to the north, the Black Forest to the west, the Nördlinger Ries to the east and The Danube Valley to the south (Fig. 1). The predominant bedrock present in this area is composed of limestones, mudstones, marls and sandstones which formed in the Jurassic period (Black, Brown and White Jura in Fig. 1. Geyer and Gwinner, 1991; Schall, 2002). Part of the Swabian bedrock is composed of molasse and volcanic rocks formed in the course of the Miocene (Geyer and Gwinner, 1991). Relicts of tertiary sediments are often found reworked within karst features and dry valleys. Among them, the Bohnerz-Formation is composed of pea-sized, iron oxide/hydroxide concretions embedded in kaolinite clay, and well sorted, rounded quartz sand (Ufrecht, 2008).

The presence of silt-sized particles of quartz, micas, hornblende and epidote in Quaternary-aged sediments indicate that during the Pleistocene the Swabian Jura was covered with loess (Gwinner, 1989; Schall, 2002; Goldberg et al., 2003, Miller, 2015; Barbieri and Miller, in press). However *in situ* loess deposits are nearly absent in the Swabian Jura north from the Danube (Sauer et al., 2016). Schall (2002) hypothesized that this absence is likely due to the relatively weak aeolian sedimentation and the intensive hillside denudation which were active in this region during and after the Würm Glaciation. After reworking, the loess of Swabia has been also affected by intensive diagenesis (Riek, 1957; Gwinner, 1989; Schall, 2002). In the study region, reworked but non-decalcified loess is commonly reported admixed with fine, elongated, platy, immature limestone gravel. This sediment type is named *Bergkies* and has been correlated with the breakdown of exposed bedrock during the stadials of the Würm glaciation (Riek, 1957, 1973; Wolff, 1962; Campen, 1990; Freund, 1998). *Bergkies* has been documented as an infilling of dry valleys (Wolff, 1962), caves, rockshelters and *abris* (e.g. Riek, 1957, Riek, 1973; Kind, 1987; Campen, 1990; Freund, 1998). Although it presents a lithology similar to the French *Grèzes Litées* (Bertran et al., 1992, 1994; Ozouf et al., 1995), the term *Bergkies* seems to indicate a slightly different sediment type, being coarser (up to 20 mm, Wolff, 1962) and not always bedded (Wolff, 1962).

The Ach and Lone valleys have been considerably shaped by alluvial processes. Starting from the Miocene, the Lone headwaters have been captured by the progressive southward expansion of the Neckar (Schall, 2002; Strasser et al., 2009). This process led to the present-day configuration of these two river basins probably around the Mindel-Haslach Interglacial (Schall, 2002; Strasser et al., 2009). On the contrary the Ach Valley formed in the Early Pleistocene, when the Paleo-Danube flowed in the Jura plateau between Ulm and Schelklingen (Fig. 1, detail 1 and 2. Gwinner, 1989; Strasser et al., 2009). Probably after the Eemian, the Danube migrated southward, roughly in its present location. Since then, the Ach is drained by three smaller karstic rivers: the Schmiech, Ach and Blau (Gwinner, 1989; German et al., 1995). Alluvial processes shaped these two valleys also in more recently in the Pleistocene; these processes were likely more active during colder periods when the aggradation of permafrost favored the formation of surficial drainages (German et al., 1995). In both valleys phases of river valley incision and floodplain aggradation resulted in the formation of river terraces, which, however, have been poorly studied (Dongus, 1974; German et al., 1995).

1.3. The Swabian Paleolithic

The Swabian Jura has been a key region for the study of the Paleolithic for the past 150 years, beginning with the pioneering work of Oscar Friedrich Fraas, Robert Rudolf Schmidt and Gustav Riek in the 19th and early 20th century and continuing to today, with recent excavations at Hohle Fels, Hohlenstein, and other localities (Schmidt, 1912; Riek, 1934; Kind and Beutelspacher, 2010; Beutelspacher et al., 2011; Bolus and Conard, 2012; Conard et al., 2015).

Although the region is probably best known for its evidence of early music and figurative art dating to the Aurignacian, the

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