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# High potential of calcareous tufas for integrative multidisciplinary studies and prospects for archaeology in Europe

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ABSTRACT

Calcareous tufas are continental carbonates from open-air conditions, specific to wet and warm periods. They contain abundant remains of fauna and flora fossilised *in situ* and may accumulate regularly over thousands of years offering high stratigraphic resolution for palaeoenvironmental reconstructions. As they are mainly comprised of calcite, tufas allow direct and precise dating as well as geochemical reconstructions of past climates. Additionally, recent investigations have highlighted their strong potential for archaeology as several studied sequences provided high quality record of *in situ* prehistoric levels. Tufas are thus a unique archive in continental areas for development of synergic multidisciplinary investigations of past human societies and associated environmental and climate evolution. We emphasise that calcareous tufa are key-deposits to investigate human–environment–climate interactions during interglacial periods, from Lower Palaeolithic to Antiquity, in Europe.



## 1. Introduction

Calcareous tufas are continental carbonate rocks deposited in open-air conditions in streams and rivers, widely observed in fluvial areas with calcareous bedrock (Pentecost, 1995). Tufas result from dissolution of the carbonate content of the bedrock in the aquifer, favoured by soil and forest development and the resulting groundwater acidification. When water then flows from the spring, variations of its physicochemical parameters and activity of the instream vegetation (especially cyanobacteria, mosses and algae) lead to rapid calcite precipitation. Detrital and calcite accumulation over years (mm to cm/yr; Pentecost, 2005; Gradziński, 2010; Vázquez-Urbez et al., 2010) generally results to fine, porous, and slightly layered to lenticular deposits (Casanova, 1981; Pedley, 1990; Ford and Pedley, 1996). Those characteristics induce (1) that tufas are specific to wet and warm periods (Pentecost, 2005), which allow significant groundwater flows, deep soil forest development and optimal conditions (warm and sunny environments) for cyanobacteria and algae growing, (2) that they contain abundant remains of fauna and flora fossilised *in situ* (Capezzuoli et al., 2014), and (3) that they may accumulate regularly over thousands of years offering a high stratigraphic resolution for environmental and climatic reconstructions (Pentecost, 2005).

Large fluvial basins running on calcareous geological formations are common in Europe (Thames Basin, Paris and Aquitaine Basins, Iberian range, etc.), which allows a wide geographical distribution of tufa formations (Fig. 1). These fluvial systems are often characterised by terrace sequences. The Seine, Somme, Yonne (France), Thames (UK), Rhine or Meuse (Germany) valleys present at least ten stepped terraces covering the last million years (Antoine, 1994; Lautridou et al., 1999; Chaussé et al., 2004; Bridgland et al., 2004). Multidisciplinary studies, combining stratigraphy, sedimentology, palaeontology and absolute dating, have demonstrated that Quaternary climate cyclical variations that modified fluvial environments were the major factor leading to stepped systems. Fluvial terraces thus result from the glacial/interglacial morphosedimentary variations; their succession correlates to Marine Isotopic Stage (MIS) cyclicity.

In these terrace systems, as for example in the Somme valley (France), temperate periods were initially observed in silts at the top of the fluvial sequences. In these deposits, bioindicators record early or late interglacial environmental conditions whereas climatic optima were not observed (Antoine et al., 2000, 2003). In the early 2000's, a new malacological study of the historical sequence of Saint-Acheul (Somme Valley, France; Fig. 1) demonstrated full

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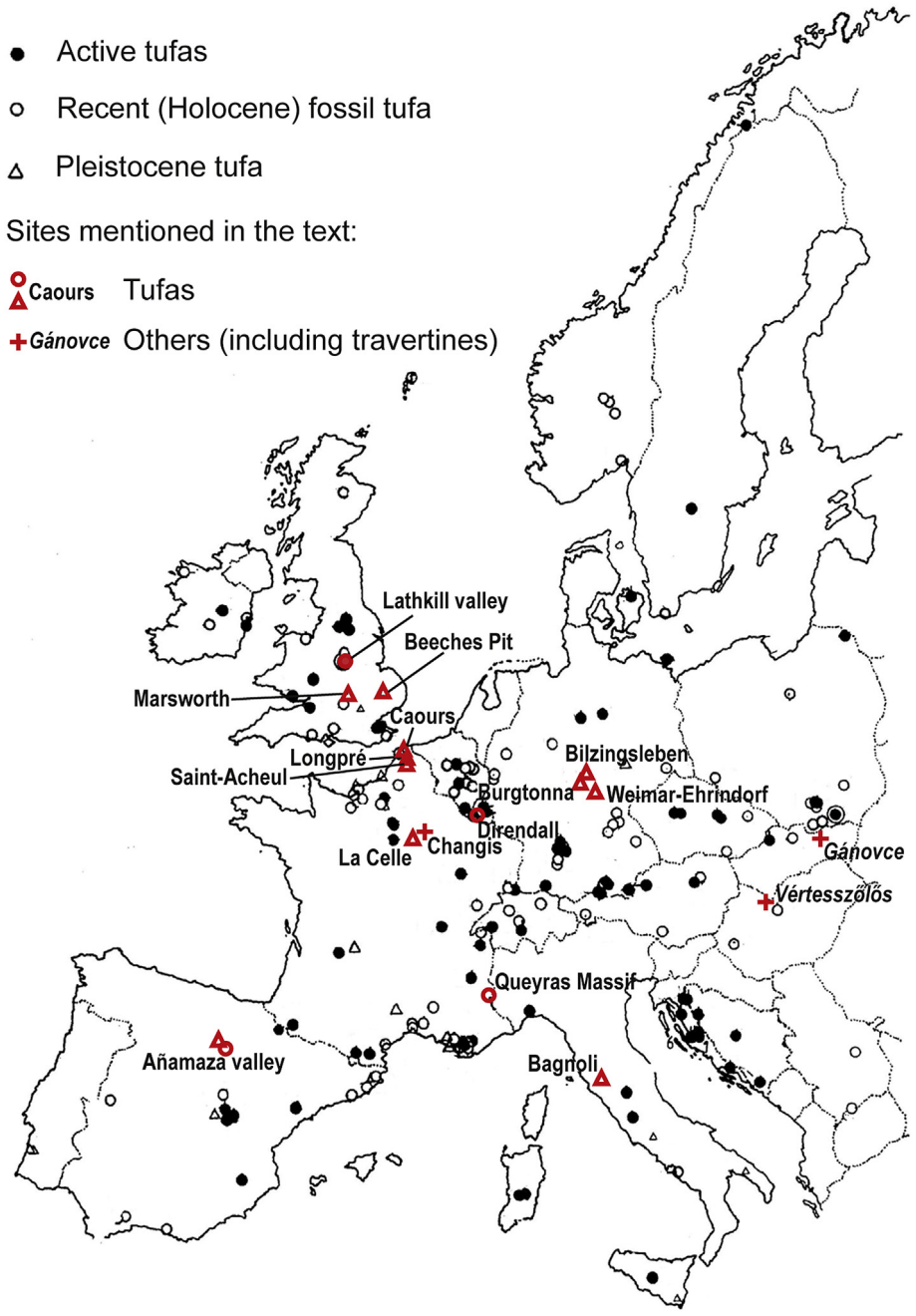


**Fig. 1.** Distribution of calcareous tufas in Europe (modified after Pentecost, 1995) and localisation of tufa sites mentioned in text. For detailed information on each site, refer to the following publications: **Añamaza valley**, Holocene to MIS 5, Arenas et al., 2014; **Bagnoli**, MIS 5, Bertini et al., 2014; **Beeches Pit**, MIS 11, Preece et al., 2006, 2007; **Caours**, MIS 5e, Antoine et al., 2006, Dabkowski, 2011, Dabkowski et al., 2010, 2011, submitted for publication, Locht et al., 2009; **Direndall**, Holocene, Meyrick, 2002; **Gánovce**, MIS 5, Vlček, 1955, 1995; **La Celle**, MIS 11, Dabkowski, 2011, Dabkowski et al., 2011, 2012; Limondin-Lozouet et al., 2006, 2010, **Lathkill valley**, Holocene and modern, Andrews et al., 1994, Pedley et al., 2000; **Marsworth**, MIS 11, Green et al., 1984; **Queyras Massif**, Holocene, Ali et al., 2004; **Saint-Acheul**, MIS 11, Antoine and Limondin-Lozouet, 2004, Limondin-Lozouet and Antoine, 2006; **Thuringia** (Bilzingsleben, Burgtonna, Weimar-Ehringsdorf), MIS 5 and MIS 11, Kahlke, 2002, Kahlke and Wunderlich, 2003, Meyrick and Schreve, 2002, Müller and Pasda, 2011; **Vértesszöllös**, MIS 11, Pentecost, 2005.

temperate conditions in a tufa unit characterised by forest thermophilous fauna and assigned to the MIS 11 climatic optimum (Antoine and Limondin-Lozouet, 2004; Limondin-Lozouet and Antoine, 2006). Calcareous tufas actually appear to be the only deposits recording the interglacial optima in fluvial contexts (Antoine et al., 2003). Regained interest in tufas over the last decade involved different research fields such as sedimentology, palaeontology, hydrology, and geochemistry in order to reconstruct past environmental succession and climate of Pleistocene temperate periods.

Recent investigations have highlighted the strong potential of calcareous tufa for archaeology as several studied sequences also provided high quality record of prehistoric settlements. We present here some tufa specificities that might have an extensive potential for archaeology, illustrated by selected examples from fossil tufa sequences generally associated to human occupations.