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Examination of Late Palaeolithic archaeological sites in northern Europe for the preservation of cryptotephra layers

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A B S T R A C T

We report the first major study of cryptotephra (non-visible volcanic ash layers) on Late Palaeolithic archaeological sites in northern Europe. Examination of 34 sites dating from the Last Termination reveals seven with identifiable cryptotephra layers. Preservation is observed in minerogenic and organic deposits, although tephra is more common in organic sediments. Cryptotephra layers normally occur stratigraphically above or below the archaeology. Nearby off-site palaeoclimate archives (peat bogs and lakes <0.3 km distant) were better locations for detecting tephra. However in most cases the archaeology can only be correlated indirectly with such cryptotephras. Patterns affecting the presence/absence of cryptotephra include geographic position of sites relative to the emitting volcanic centre; the influence of past atmospherics on the quantity, direction and patterns of cryptotephra transport; the nature and timing of local site sedimentation; sampling considerations and subsequent taphonomic processes. Overall, while tephrostratigraphy has the potential to improve significantly the chronology of such sites many limiting factors currently impacts the successful application.

1. Introduction

It has been observed that tephrostratigraphy and tephrochronology have the potential to be of major significance to the study of the environmental history of the Last Termination, c18–8 ka BP (Davies et al., 2002; Turney et al., 2004, 2006). Tephra layers, once securely identified, provide the means to accurately link and synchronize diverse sedimentary records including terrestrial and marine palaeoenvironmental and archaeological sites, with their archives of palaeoclimate and past human behaviour (Lowe, 2011). Developments in the detection, isolation and characterisation of cryptotephra (Turney, 1998; Blockley et al., 2005) have allowed tephrostratigraphy to be applied to more situations than hitherto was the case (Davies et al., 2002) including the application to archaeological settings (Balascio et al., 2011). The new contexts open up interesting developments, but as this paper demonstrates, do not come without attendant complexities for the taphonomy of the depositional layers have an all-important influence. Recovery of trustworthy data is not always straightforward and is dependent on multiple, sometimes interrelated, factors.

The focus of this paper is the application of tephrostratigraphy to distal Late Palaeolithic sites in northern Europe which date from the Last Termination (i.e. the Oldest Dryas, Bølling, Older Dryas, Allerød, Younger Dryas and Preboreal Chronozones). The research took place in the context of the RESET research initiative, a 5-year Consortium funded by the UK's Natural Environment Research Council (NERC). The aim of RESET was to bring together archaeologists, volcanologists, tephrochronologists and stratigraphers to investigate the chronology of major phases of human dispersal and development in Europe in the past 100,000 years, and to examine the degree to which these were influenced by abrupt environmental transitions (http://c14.arch.ox.ac.uk/reset/). A survey of Late Palaeolithic sites from north of the Alps, Sudeten, Tatra and Carpathian mountains reveals only one-fifth have identifiable cryptotephra. Tephra is detected in both organic and minerogenic sediments, however depositional context, temporal duration of sediment accumulation and site taphonomy appear to be important influencing factors.

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2. Tephrostratigraphy in the context of the north European Late Palaeolithic

2.1. The principles and application of tephrostratigraphy

Tephrostratigraphy is a method for correlating diverse sedimentary sequences, whether they are palaeoenvironmental, geological or archaeological in nature. It has the advantage over many other chronological tools in that the precision is commonly significantly better (Lowe, 2011). The use of tephra is grounded in the principle that layers are deposited in a stratigraphic sequence and the position is governed by the Law of Superposition (Feibel, 1999). If a tephra layer can be identified and characterised, it can be correlated to another tephra layer in another locality and this links the two loci in time (Westgate and Gorton, 1981). Matching of tephra layers can be done by physical properties in the field or using single grain geochemical analyses in the laboratory (e.g. electron microprobe WDS-EPMA and LA-ICP-MS). In some instances the palaeoenvironmental or palaeoclimatic context of a tephra in conjunction with its geochemical-signature may be significant thus allowing correlation (the Borrobol and Penifiler, Vedde Ash and AF555 tephras are prime examples of this, see Matthews et al., 2011). Where an existing age for the tephra is known, be it from historical records, radiometric dating (e.g. ^{14}C or Ar–Ar; Sarna-Wojcicki, 2000), or an incremental archive (e.g. varves or ice core layers; Grönvold et al., 1995), the age may be transferred from one locality to another provided compositional properties, e.g. chemical characteristics, are the same. In such situations tephrostratigraphy becomes tephrochronology, a powerful tool for dating.

Many factors potentially limit the application of tephrostratigraphy (Lowe, 2011). Those of most relevance in the context of this investigation are as follows.

(i) The possibility of tephra being reworked leading to the dissemination or remobilisation of glass shards. This can significantly influence whether correlation is feasible as reworked (remobilised) tephra form diachronous, rather than isochronous, surfaces. The non-reworked part of a tephra deposit does provide an isochron of maximum age (the date of the tephra eruption and primary deposition) but any reworked components are always younger.

(ii) The vertical spread (dissemination) of shards in a vertical profile may conceal the exact point in the sediments where a primary tephra layer was deposited.

(iii) Patchy tephra distribution patterns in peat deposits have sometimes been attributed to post-depositional processes associated with fallout on snow cover, including redeposition by wind and meltwater. Snow entrapment, wherein cold conditions with little or no summer melt cause a significant lag between the initial deposition of ash and its subsequent deposition into a lake, was identified by Davies et al. (2007) as another factor that could lead to an incorrect interpretation of the true position of the tephrostratigraphic isochron in cold environment lacustrine deposits.

(iv) Multiple profiles will sometimes document periods of erosion and reworking, revealing differential effects even when distances are small. Within-site variability is a factor, suggesting that local geographic and stratigraphic taphonomic processes may be complex, requiring careful study and interpretation. Boygle (1999) and Pyne-O'Donnell (2011) highlight the drawbacks of single profile cryptotephrostratigraphic surveys.

(v) Repeated eruptions may sometimes result in chemically similar geochemical datasets. Indeed many Icelandic tephra produced by different eruptions tend to have very similar major element geochemical compositions (Larsen and Eiríksson, 2007). External dating control may be required to differentiate temporally-separate, but compositionally similar, tephra.

Tephra detection, albeit the crucial starting point in a tephrostratigraphical study, is not sufficient on its own; there are many ancillary requirements if good chronological data are to come from the presence of tephra on an archaeological site.

2.2. Linking volcanic ash layers and Late Palaeolithic archaeology

Association between Late Palaeolithic archaeology and tephra is most commonly observed in areas proximal to active Late Pleistocene volcanoes. In such settings volcanic and archaeological layers may be readily observed and characterised in the field. Association between archaeology and volcanic eruption need not be direct, for volcanic sediments can overlie abandoned sites. Lateglacial northern European examples of this include the open-air Magdalenian sites of Andernach-Martinsburg and Gonnersdorf in the middle Rhine, which were discovered beneath thick Laacher See tephra (LST) deposits (Baales et al., 2002); and the Grotte du Coléoptère in the Ardennes, a Magdalenian cave site in which the occupation horizon was covered by tephra of the same east Eifel-sourced eruption (Dewez, 1975; Juvigné, 1977).

More direct 'Pompeii-like' association between ash-fall and cessation of human occupation would be expected but are not easily demonstrated in the Lateglacial of north Europe. The situation at l'Abri Durif à Enval, a rockshelter in the commune de Vic-Le-Comte, Puy-de-Dôme excavated between 1969 and 1979 by Yves Bourdelle, illustrates some of the complexities. On this site volcanic ash was identified in layers I, II and IV in direct contact with a Magdalénien supérieur occupation horizon (Bourdelle, 1979). The tephra originates from the French Massif Central and is dated to 12,010 ± 150 ^{14}C yr BP (GifTan-91102). On the basis of geochemistry Vernet and Raynal (1995) correlate it with the eruption of La Tephra des Roches. However direct contact is not enough to demonstrate a causal connection between ash-fall and human abandonment since subsequent reworking may bring remobilised tephra into contact with archaeological material. Layer Ia in l'Abri Durif à Enval "… contained a large amount of volcanic ash. These ashes are in contact with the flints and bones found in this level (0.02 m)". This would suggest direct association, whilst the ash in the underlying layers (Niveau Ib, II and IVa) could represent remobilised tephra. Residuality of archaeological material needs to be considered. For these reasons, in the absence of compelling associations, direct linkage of ash-fall to human abandonment is hard to prove.

Visible ash horizons may sometimes be observed in contact with archaeological material in distal and mid distal settings. The early Upper Palaeolithic sites in Kostenki-Borshchevo (Sinitsyn, 2001; Anikovich, 2005; Anikovich et al., 2007) are examples which have been known for many years (Melekestsev et al., 1984). At Kostenki-Borshchevo aeolian reworking of the tephra together with cryoturbation is believed responsible for making a 1–2 cm ash-fall into 10–30 cm in thickness horizons (Pyle et al., 2006). Distance from source in this instance is 2250 km. Bettenroder Berg IX in the valley of the River Leine in central Germany is a Lateglacial example of a visible volcanic layer on a mid distal site located 280 km from source. Here layer 17a – an occupation horizon of the Federmesser-Gruppen technocomplex is overlain by layer 16, a substantial 20–40 cm thick primary deposit of LST, demonstrating thickness and distance from source are influenced by the dynamics of ash transport, fall and sedimentation (Riede, 2008; Riede et al., 2011). This example would appear to represent the rapid fallout of very