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THE IMPACT OF ABRUPT ENVIRONMENTAL TRANSITIONS ON HUMAN DISPERSALS AND ADAPTATION

Abstract

This paper sets out new methodologies for analysing the effects of Abrupt Environmental Transitions (AETs) on cultural change in the late Middle and Upper Palaeolithic. Archaeologists need to conceive the Palaeolithic record as a series of dynamic and often asynchronous social processes, rather than as a succession of essentialist epochs, before they can evaluate the effects (causal, or neutrally contemporaneous?) of evidence of AETs found in archaeological deposits and elsewhere. New scales of analysis, from modifications in tool-forms, to substitution of artefact types by others, to replacement of one culture with another, need to be explored before dispersals of groups across the landscape, and social and economic responses to AETs, can be assessed.

Keywords

Essentialism, Abrupt Environmental Transitions, tephrochronology, hominin dispersal, Neanderthals, modern humans, cultural change, asynchronicity

INTRODUCTION

The demonstration from both ice and marine isotope records that climate change was abrupt has been one of the most significant findings of recent Quaternary science. As a result, the gradual model of changes in ice mass and sea level has been supplemented with one of rapid transitions (e. g., Alley et al., 1993; Siddall et al., 2003). These Abrupt Environmental Transitions (AETs) also impacted on floral and faunal biota, resulting in shifts in temperature of up to 6-7 °C in Late Glacial Europe over the course of a few human generations (e. g., Poland: Goslar et al., 1995; Germany: Brauer et al., 1999). Archaeologists have been keen to exploit AETs as the explanation for changes in aspects of Palaeolithic technology and economy, cultural behaviour and settlement history (e. g., d'Errico et al., 2001; Blockley et al., 2006; Bar-Yosef and Belfer-Cohen, 2002; Baillie, 2000; Weninger et al., 2009). However, the relationship can only be established if a chronological framework exists that combines information on abrupt change from marine, terrestrial and archaeological archives at comparable levels of precision.

The importance of chronological precision is well shown by a recent study dating to the early phases of the Holocene (Blockley et al., 2018), and where temperature shifts on a centennial scale of 4 °C characterise four AETs at 8.2, 9.3, 11.1 and 11.4 ka. The conclusion, however, of this high-resolution study using a suite of environmental indicators from Star Carr, Yorkshire, is that continuity and resilience dominated the human response. Change was not precipitated by external climate drivers as recorded in ice or deep sea cores. Rather, significant changes in behaviour at this site corresponded to local environmental conditions (Blockley et al., 2018: 816).

From the outset we need to distinguish between AETs, and environmental disasters (*sensu* Riede, 2014), with the latter being intense but short-lived. While AETs show a persistent shift from one set of conditions to another, environmental disasters are marked by short-term perturbations (e. g., tsunamis, extreme weather

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conditions and volcanic eruptions), which, according to Riede (2014: 354) exposed "specific systemic weaknesses and vulnerabilities amongst European communities at each time slice." In this contribution, however, we argue that temporal persistence and spatial extent are key in distinguishing AETs from environmental disasters. Rather than identifying catastrophes our approach uses recent advances in tephrochronology to provide a framework for examining human adaptations to environmental change at both a local and continental scale. This work builds on a research strategy exemplified by Martin Street through his investigation, with Elaine Turner, of the key sites of Gönnersdorf and Andernach (Jöris et al., 2011) and his overviews of the European Upper Palaeolithic (Gaudzinski-Windheuser et al., 2011).

Martin has been at the forefront of research refining the chronologies of the Late Glacial and the Early Holocene. In 1997 he was part of the group that used AMS dates from Central and Northwest Europe to model the expansion northwards of humans from the refuges of Southern Europe (Housley et al., 1997). Then with Thomas Terberger he refined this model through the excavation and dating of Wiesbaden-Igstadt in the Rhineland (Street and Terberger, 1999), and later expanded to an analysis of the entire German Upper Palaeolithic (Street and Terberger, 2000). The importance of the Badegoulian outlier, Wiesbaden-Igstadt, is that it contradicted the model of abandonment during the Last Glacial Maximum (LGM) of Central Europe. What Martin uncovered was evidence for a continuing, if small, presence under the harshest conditions; a situation reminiscent of the British Upper Palaeolithic at sites such as Paviland (Jacobi and Higham, 2008) and King Arthur's Cave (ApSimon et al., 1992) in the lead-up to full glacial conditions. Continuity and resilience, albeit at low population numbers, would appear to have been the norm in Late Palaeolithic Europe.

The potential of tephrochronology

In this paper we examine further another of the dating projects with which Martin was associated. RESET (RESponse of humans to abrupt Environmental Transitions) was a five-year (2008-2012) Consortium funded by the UK's Natural Environment Research Council (NERC). Using the potential of cryptic tephras (Davies, 2015) it sought to produce an independent framework to enhance the precision and accuracy of radiocarbon dates (Lowe et al., 2012, 2015). Here we explore the theoretical implications of the RESET tephrochronological lattice for how we analyse the Palaeolithic archaeological record. The lattice enables us to

- evaluate appropriate spatio-temporal scales for analysing change,
- assess similarities and/or differences in cultural records connected by the same tephrochronological marker,
- establish how "universal" or localised and/or contingent changes in human behaviour were across continents and their varied environmental zones.

The success of RESET in identifying new cryptotephra records in archaeological sites (Housley et al., 2012, 2015; Davies et al., 2015; Ramsey et al., 2015) encourages us to reconsider our basic approaches to the Palaeolithic, in particular how we conceive and model drivers of cultural change. Did processes of *selection* (whether social or environmental) operate on the generation of cultural innovations, or did environmental *needs* and stimuli catalyse sudden cultural transitions (with intervening 'epochs' of cultural stability)? The latter model is perhaps easier to falsify, as it is largely dependent on external, large-scale stimuli, such as AETs, to instigate change in the record. The ability to match tephrochronological lattices to increased precision in the dating of diagnostic archaeological artefacts enables us to assess the degree of environmental cause and effect in the instigation of cultural change.

The demonstrable AETs recorded in ice and marine cores do not describe all the rates of change. Indeed, it is important to emphasize that much of what happened in the Pleistocene cannot be described as abrupt. But in the last 48 ka, in the region influenced by the North Atlantic climate system, the palaeo-environmental record identifies several AETs that ushered in both warmer and colder conditions (Blockley et al., 2012; Lowe et al., 2008). The evidence consists of the relatively short-lived D-O cycles and Heinrich events, as well as the longer Greenland GI-1 Interstadial, GS-1 Younger Dryas and Holocene, within which there are significant environmental 'spikes' (Blockley et al., 2018). Whilst there were periods of prolonged relative warm and cold climates, it is the speed of the switch between these states, their onset and ending, which rightly impresses (Steffensen et al., 2008), and which earns them the status of AET. The rapidity of these environmental changes poses a challenge to the analysis of other forms of archaeological data where temporal precision has been less detailed.

Whilst environmental and climate studies increasingly focus on high resolution records, archaeologists struggle to link human behavioural change to observed abrupt climate change. The improvement of archaeological chronologies is the key, for knowledge of the order of events gives insight into possible consequences, and explanations are reliant on an accurate understanding of cause and effect. At the moment high resolution environmental records tend to 'hook' or 'suck in' less well-dated cultural developments. Too often an epochal change in the archaeology is observed and an AET or environmental disaster is sought to match and correlate to it. Soon correlation becomes causality for the observed cultural change and an 'explanation' is developed. Given the mismatch in the dating resolutions, such a procedure cannot be described as satisfactory. But is there a better approach? Can the chronology of the archaeology be improved so that the correct sequence of steps may be discerned and we become more confident of distinguishing cause from effect?

THE IMPACT OF ABRUPT ENVIRONMENTAL TRANSITIONS

Many researchers see tephrochronology as the key to improving chronological resolution (Davies et al., 2002; Turney et al., 2006; Davies, 2015). Lasting hours, days or weeks, volcanic eruptions provide almost instantaneous (in geological terms) marker horizons to link spatially-separated sedimentary archives (Westgate and Gorton, 1981; Sarna-Wojcicki, 2000; Lowe, 2011). Additionally, when of sufficient magnitude, eruptions are believed to have the potential to trigger rapid environmental change and produce a corresponding human response. The 39.3 ka super-eruption in the Campi Flegrei, Naples, and the production of 105-300 km^3 of ash (Pyle et al., 2006; Fedele et al., 2008; Oppenheimer, 2011: 209) that fell in a northeast direction across South-East Europe and Russia, has been interpreted as the cause of the demise of European Neanderthals, thus allowing anatomically modern humans into the continent (e. g., Golovanova et al., 2010); an interpretation not however shared by all (e. g., Lowe et al., 2012; Fedele et al., 2008). The Laacher See Eruption (LSE) in Germany at 12.92 ka has been used to explain the distribution of certain Late Glacial hunters on the North European Plain, and is seen as the cause of a major re-organisation of technology and subsistence at the end of the Allerød (Riede, 2007, 2008, 2009). But how convincing are such hypotheses? Abrupt 'Pompeii-like' volcanic-induced catastrophic environmental change could have impacted very significantly on individual human groups, leading to local extinction or abandonment of specific areas (Grattan, 2006). Magnifying the impact to larger regions does call for more careful evaluation. Fisher-gatherer-hunter (FGH) groups differ from agriculturalists in having much larger territories and higher rates of mobility; they have more scope to avoid volcanically-impacted areas without suffering population consequences. Binford's (2001) observation that FGH groups do not exploit all productive niches in their territories, but rather keep back favourable resource centres for times of stress, warns against assuming depopulation of one area necessarily had adverse long-term consequences. Thus Eriksen's (1996) suggestion of a regional occupation hiatus in the Thuringian Basin in the late Allerød and early Younger Dryas, and Riede's (2008: 594) documentation of the same phenomenon in a number of stratified Federmesser-Gruppen sites on the margins of the Central European Uplands are interesting, but need not have been particularly detrimental to the groups affected. Low population levels, large territories and high mobility would allow FGHs to buffer against such adverse AETs. One needs to look for more direct evidence of adverse consequences. Attempts to 'test' the causal relationship between volcanic events and environmental response (e. g., Lotter and Birks, 1993; Riede and Wheeler, 2009) are to be welcomed, though Riede (2014: 347, Tab. 5) has so far been unable to obtain a significant correlation between cultural change and any perturbation caused by LSE tephra fallout.

Whether volcanic-induced catastrophic environmental changes were of a magnitude and frequency to elicit an observable cultural response from European FGH groups is uncertain. Given the low population densities and large territories proposed, for example, for Western Europe in this period by Bocquet-Appel (et al., 2005), we contend that the influence of volcanoes as drivers of cultural change on human populations at a continental scale remains to be demonstrated. Using ethnographic estimates from the Arctic and Sub-Arctic, Bocquet-Appel et al. (2005) put forward population estimates for the Aquitaine region in France of 9000 persons at the LGM. If Iberia and the other intermittently occupied areas of the refugium are included, a meta-population estimate of 17,000 persons in GS-2 is obtained, rising to 64,000 in GI-1 (Gamble et al., 2005: 201); the increase being ascribed to an expansion in the settled area and a demographic response to richer resource conditions in the Interstadial. Like Sørensen (2010), we are sceptical however that patterns of summed probability distributions for Federmesser-Gruppen, Bromme and Perstunian ^{14}C dates necessarily reflect the impact of the LSE (Riede, 2007, 2008). Given the sometimes poor resolution of the ^{14}C data sets and the variable analytical quality of the age determinations, we believe changes consequent with the onset of GS-1 (ca. 200 years later) are responsible for the observed patterns. The suggestion that the impact of the LSE can be observed in the British Isles (Riede, 2008: 594), a region where Laacher See Tephra has never been unequivocally confirmed geochemically, is perhaps another symptom of the lure of AETs and environmental disasters.

This is not to deny the role of volcanic events as correlation points and chronological age markers (isochrons). The presence of such reference markers in natural sedimentary archives has long been recognised (e. g., Lowe, 2001; Lowe et al., 2001; Mangerud et al., 1984; Turney and Lowe, 2001; Vernet and Raynal, 2001). Methodological developments in the recognition of non-visible ash horizons (cryptotephra) have significantly extended the geographical area where tephra may be detected (Blockley et al., 2005; Turney, 1998; Turney et al., 2004). In recent years the resolution of natural environment proxy records has improved very significantly due to the application of tephrostratigraphy with high precision AMS ^{14}C dating of well-characterised molecular fractions, Bayesian age modelling, and the analysis of laminated (sometimes annually-varved) sediments (Blackwell and Buck, 2003; Blockley et al., 2004, 2007, 2008a, 2008b; Lane et al., 2013; Wulf et al., 2013). Extending such developments to archaeological settings is a priority but as we will now discuss, cultural layers have their own concerns.

QUANTIFYING ASYNCHRONICITY IN THE ARCHAEOLOGICAL RECORD

Scales and drivers of change

Scales of analysis in our analyses of asynchronicity (also known as time-transgression) in hominin behaviour comprise our second theme. Since the nineteenth century, it has been customary among archaeologists to consider cultural change as 'epochal' and essentialist, i.e., that change moves in short bursts ('transitions') between one stable phase (a 'culture' or 'industry') and its successor. Essentialism is here used to describe the concept that particular artefact combinations arise quickly, and then remain stable in form and composition ('epochs') until replacement by another. The short periods of transition are often explained by population replacement, by environmental stimuli, or by a combination of both factors. Such models of change are Lamarckian, relying either on ill-defined 'migrations' of peoples, or on changing environments, causing the rupture of stable adaptations through 'urges' or 'needs' to change (Cullen, 2000). Absolute dates, inasmuch as they are used in such essentialist analytical frameworks, exist only to provide 'range-finder' ages for particular cultures or epochs, and are seldom used in a dynamic sense to measure changing artefact morphologies and combinations across time and space. Despite the advances of archaeological theory since Binford (1962), many archaeologists prefer to retain lightly-sketched 19th and early 20th century conceptions of 'culture', in which artefacts respond to changing environments almost irrespectively of human agency (e.g., Djindjian, 1993; Banks et al., 2009) and realistically-conceived social interactions (e.g., Powell et al., 2009).

This section will explore the potential of tephrochronological frameworks (lattices) for measuring archaeological change across time and space, evaluating not only scales and levels of synchronicity between similarities, differences and changes across regions, but also the spatio-temporal relationships of hominin behavioural changes to environmental shifts. "Catastrophic" AETs and environmental disasters, such as the Campanian Ignimbrite eruption and Heinrich Events, are frequently held to have significantly affected hominin economies and survival patterns (Fedele et al., 2002, 2003, 2008; Giaccio et al., 2006; Golovanova et al., 2010; Banks et al., 2013). Among records of such AETs, tephras have distinct advantages: the principal one being that visible and cryptic tephras can be found in archaeological contexts. This evidence of major environmental events within or between archaeological assemblages allows much easier consideration of hominin responses to them than when we try to infer the effects of Heinrich Events, for example, on patterns of behaviour and regional occupation.

In order to assess the supposed deleterious effects of Heinrich Events (for which direct evidence is not found in terrestrial contexts, such as archaeological sites) on the lives of past hominins, radiometric dates were needed to connect spatio-temporal variation in archaeological site distributions to the environmental proxy records (e.g., Banks et al., 2006). Although tephras (whether visible or cryptic) are not found in every archaeological context, and vary in their frequencies of occurrence (Housley et al., 2015), they do occur in archaeological sites, and sometimes more than one eruption is archived in site deposits (e.g., Karkanas et al., 2015). Using these lattices, hypotheses of cultural phasing and asynchronicity can be tested. Change or stasis in the archaeological record can be tested against climatic and environmental conditions, including those created by abrupt events.

Inter-site cultural comparisons

Archaeological stratigraphic analyses are still founded on insights made in the seventeenth century that vertical sequences of layers can be characterised by particular fossil forms, and that these strata can span large geographic areas. Since the mid-nineteenth century, Palaeolithic archaeologists have identified cultural 'phases' at key sites and extrapolated these sequences to all other sites dug subsequently (e. g., Banks et al., 2013; Dinnis et al., 2019). Thus, the stratigraphic sequence of Aurignacian assemblages from "key" SW French sites has been taken as the diagnostic diachronic framework for that technocomplex (culture), for example, despite the absence of some of those 'phases' anywhere else (e. g., Aurignacian IV) (Peyrony, 1933: 559; Djindjian, 1986: 101; Dinnis et al., 2019).

Figure 1a adopts a schematic rendering of a hypothetical cultural sequence within a region, whose sites have been geographically-ordered by longitude. Three out of the five sites have the same four archaeological industries in the same stratigraphic order, while the remaining two show the absence of one or two industries in their sequences. The provision of absolute dates for many archaeological assemblages has encouraged archaeologists to search for proof of penecontemporaneous phasing of industries over large areas, with each phase being treated as a diagnostic fossil assemblage (*sensu* Hooke [1705] and Steno [1916 (1669)]): each archaeological assemblage is seen as identical in its *essentials* to those attributed to the same phase found elsewhere (e. g., Dinnis et al., 2019). There is assumed to be no change in artefactual morphologies and combinations between the initiation and extinction of a phase, and little consideration of parallel/independent evolution. **Figure 1b** is the result of such assumptions: each industrial 'phase' can be fitted into a discrete period (A, B, C or D), even if some sites have apparently 'incomplete' occupation sequences. The latter 'gaps' at these sites are explained as occupational hiatuses, with a 'missing' industry failing to utilise these locations during its epoch. Each archaeological industrial phase is assumed to have spread consistently across space from its source (**Fig. 1: c**) in a spatio-temporal gradient, and it is thought to be homogeneous in its composition, with no discernible change in its essential aspects (tool types, morphologies and combinations). Transitional change only occurs when one industrial phase is replaced by another. These essentialist views of change assume landscapes of uniform affordances and resistances ('table-top models') for industries to spread rapidly across; little attention is given to environmental variation (topography, biomass and ecotones), and the role it might have played in facilitating or impeding hominin mobility.

Isochronic markers within a chronological lattice allow us to evaluate these universalist and essentialist models of change with more confidence. We cannot assume that cultural successions happened as universal phases across large areas, and lattices enable us to identify the spatio-temporal scales of hominin behavioural mosaics with more confidence. Unravelling the variation in hominin behavioural patterns across time and space enables us to ask the more interesting questions about what might explain such patterning (environmental affordances?, social choices?, movements of individuals and groups?). The culture-historical approach of Dinnis et al. (2019) makes some effort to link typological epochs to a single tephra, but their approach cannot be said to use a tephrochronological lattice. In addition, their epochal treatment of the Aurignacian, with modelled penecontemporaneous diachronic phases, has no evident framework to explain such changes. It is not clear where each phase of the Aurignacian originated (all in SW France?), or what drove their claimed rapid and universal spread over several thousand kilometres: climatic/environmental forcing (assuming no significant time-transgression in AETs across Europe), population turnover (demic replacement), and/or rapid acculturation (social selection at different scales, from artefact forms or types to assemblage replacement)?

Figure 1d shows how isochronic markers can connect together archaeological sites at different spatial and temporal scales. Sites containing just one such isochron can be connected to others with more than one tephrochronological marker, and crytotephras vastly increase the spatial coverage and detail of our comparisons by augmenting the number of locations with such records. In addition, artefacts diagnostic of particular archaeological industries can be fitted into this lattice, ideally using direct (radiocarbon) dates, and their morphological variation over space and time measured to test dynamic (rather than essentialist) hypotheses

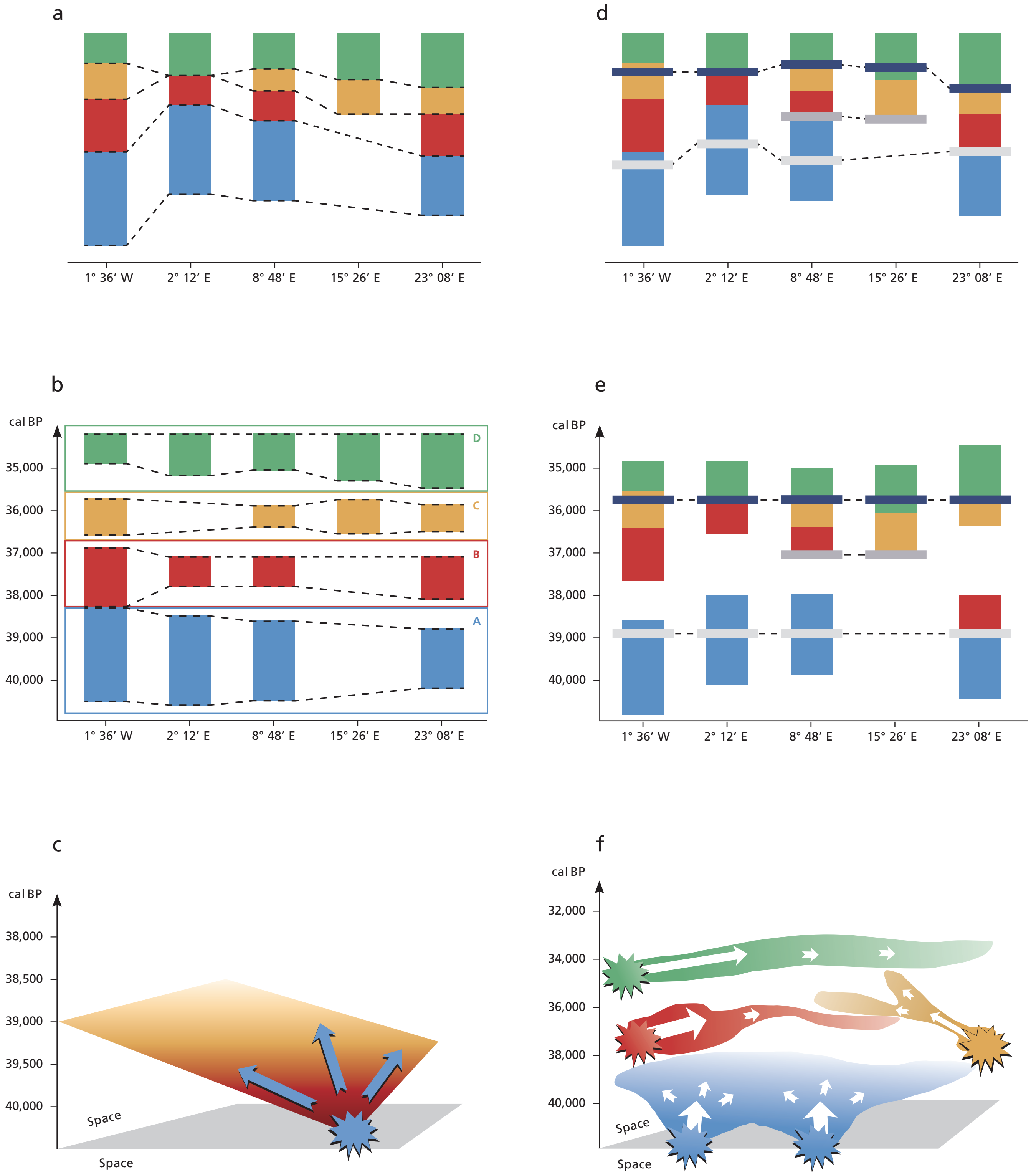

Fig. 1 Schematic depiction of archaeological approaches to behavioural change over time and space. **a-c** 'epochal' views of archaeological cultural successions; **d-f** dynamic and time-transgressive views of cultural change and diversity in the archaeological record.

about hominin responses to environmental conditions. Isochronic markers encourage the re-evaluation of hypotheses of dynamic change in the archaeological record, rather than the presupposition of essentialist phases/epochs of hominin behaviour. Such ideas can be further tested by incorporating morphometric studies of (directly-dated) diagnostic artefact types, to identify any spatio-temporal patterning in behavioural changes and hominin responses to environmental conditions. Not only can independent invention of similar artefact types in different places at different times be addressed, but the *nature* of technological variation across assemblages from the 'same' industries can be evaluated, allowing us the opportunity of dating morphological variation in diagnostic tool types. Ideas of localism and contingency in hominin behaviour, rather than generalising and universalist ones, can be made the main focus of our analyses.

Figure 1e clarifies the different durations and timings of hominin industries at different sites, showing how the spatio-temporal scales of behavioural mosaics might be identified. Reasons other than AETs must be sought to explain 'universal' changes and transitions in Palaeolithic societies and hominin species. Thus, we are evaluating different spatio-temporal behavioural mosaics, with different lead and lag times in their patterns of change (Fig. 1: f). More subtle and inflected conceptualisations of mobility in Palaeolithic populations are thus needed, ranging from daily migrations to trans-generational dispersals (Baker, 1978: 23; Davies, 2012). The reconstruction of different scales of mobility (from tethered movements/return migrations to long-distance displacements) allows us to model the likely effects of varying scales of environmental change (e.g., the proximal and distal effects of volcanic eruptions) on hominin movements. Mobility scales for each region need to be identified, which can then be scaled chronologically within our lattices, and related to assemblage characteristics and resources exploited. This increased spatio-temporal confidence in identifying localised characteristics will allow us to restore perspectives of contingency to our analyses of the archaeological record, rather than in assuming large-scale, universalist 'phases.'

Achieving scales of contingency in archaeology

A combination of direct dating of diagnostic artefacts and the use of tephrochronological lattices allows, for the first time, the potential to measure artefactual changes over time and space. At what spatio-temporal scales do similar behaviours occur? Are they contemporary, spatio-temporally restricted, or apparently unconnected? These questions need to be addressed before we can ask questions about causality of such behaviours and their changes. If we believe that abrupt environmental transitions, such as volcanic eruptions, caused cultural change, then the ecological effects of such transitions need to be clearly modelled (Fedele et al., 2008). Archaeological sites close to an eruption might be expected to display different responses (e.g., extinction/displacement, adaptive change) from those further away (in the distal zone). However, even if tephras are found at the base of an archaeological cultural level, they cannot be assumed *a priori* to have caused that change. Instead, careful evaluation must be made of all sites containing the same tephra marker, and the different stratigraphic positions of the event (at the base of, within or overlying one or more types of archaeological industry: see Fig. 1e) at all available spatial distribution scales (ranging from adjoining sites, to ones hundreds of kilometres apart). If, for example, a tephra marker event is found in various stratigraphic positions, within different archaeological industries, then Lamarckian assumptions of abrupt environmental transitions creating the need/urge for universalist cultural change can be falsified. Universalist assertions of cultural change, such as the transition from Proto-Aurignacian to Early Aurignacian industries as a result of environmental deteriorations attributable to Heinrich Event 4 (Banks et al., 2013), can thus be tested using tephrochronological lattices and direct dating of diagnostic Aurignacian osseous points.

ARCHAEOLOGICAL SIGNATURES FOR DISPERSAL

Culture-people-language signatures and archaeogenetics

Our final theme deals with the spatial and temporal scales of human and hominin dispersal. Among archaeologists it is a long-established tenet that population movements can be distinguished by changes in archaeological cultures. Childe's (1929) famous formulation that a 'people' could be identified by their cultural materials that recurred in space and persisted through time was driven by an interest in the movement of population. As this culture-people model was inspired by an *ethnos*, its full formulation should include a linguistic component. The culture-people-language signature for the analysis of past population movements remains popular among archaeologists, for example Bellwood's (2005) early farming hypothesis and Renfrew's (1987) study of archaeology and language.

Thanks to archaeogenetics, Childe's 'peoples' have now become haplogroup populations, or 'clans', traced predominantly through mitochondrial DNA (mtDNA) (Forster, 2004) and the male specific segment of the Y chromosome (MSY) (Underhill et al., 2001). Increasingly full genome data as well as information from the HLA immune system are extending the power of archaeogenetic techniques (Green et al., 2010; Krause et al., 2010; Thorsby, 2012). Archaeogeneticists have favoured the linkage to culture-population-language signatures (Cavalli-Sforza, 1991; Oppenheimer, 2006), and have developed a phylogeography of genetic dispersal calibrated from language trees. However, the time depth for these population movement signatures extends only as far back as the Neolithic; a limit imposed by the assumed non-survival of Palaeolithic languages.

This important time limit has not stopped the basic culture-people-language model being widely applied to the investigation of prehistoric hunters and gatherers. In particular, the material culture signatures for the Middle and Upper Palaeolithic of Europe have been used as markers not only for peoples but for differentiating hominin species, *H. neanderthalensis* and *H. sapiens*. The use of traits found in the European Upper Palaeolithic (Klein, 1995) has been criticised when applied to a universal human revolution (McBrearty, 2007). Yet despite this vigorous and well-made critique, the same traits (ornaments, Mode 4 lithic blades*, burials, art, settlement, etc.) are widely used as a match of archaeological to archaeogenetic data when studying human dispersal out of Africa and into the rest of the world (Powell et al., 2009; Mellars et al., 2013).

Our concern is that the correlation of culture-people-language (clans) is misplaced. It lacks the chronostratigraphic control, for example the tephra-lattice established through RESET, that would allow an independent test of the culture-people assumption. Without robust chronostratigraphic frameworks, the environmental context for dispersal and the impact, or not, that abrupt environmental transitions may have had on the process, remain conjectural. The process of data-fitting, for example in the correlations drawn between pots, languages and phylogeography in the Neolithic dispersals, or matching small pieces of scratched ochre and projectile point typologies to the various haplogroup 'clans' of the preceding Palaeolithic, is no substitute for a rigorous critique of independently-dated lines of evidence.

While archaeogenetics has revolutionised the field of population history, we are in danger of minimising those advances by applying outmoded archaeological taxonomies to their results. For all the sophistication that archaeogenetics has brought to population history, the expectation still exists for the correspondence

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* Clark (1961, 1969) defined five Modes of stone tool production, of which Modes 2, 3 and 4 are used here. Mode 2 encompasses bifacial (handaxe) technologies of the Acheulean and later periods, where a nodule is flaked on both surfaces to produce a cutting tool. Mode 3 is defined by careful preparation of the stone core, allowing flakes of predictable dimensions and shape to be removed; a key example of Mode 3 is Levallois technology. Mode 4 is also dependent on careful core preparation, in this case to produce elongated, consistently-shaped products – called *blades* – significantly longer than they are wide, with straight, parallel margins.

Archaeological evidence	Weak	Strong
Human remains	None or very few	Many
Geographically and temporally distinctive stone and organic artefacts (projectile points, bifacial hand-held tools, boats, houses, ways-of-making)	None or few. Poorly-defined hronological spans. Reductive technologies with an instrument focus. Some additive ways of making.	Present, sometimes in quantity. Composite, additive and container-based technologies, as shown by tools, dwellings and transport. Well-defined chronological spans.
Geographically and temporally distinctive display objects (body, dress ornament, materials which change surface colour and texture, e.g., ochre)	None or few. Poorly-defined chronological spans.	Present, sometimes in quantity. Well-defined chronological spans.
Accumulation of distinctive artefacts	Rare, and only as sets of similar objects and materials	Common as sets of similar and diverse objects and materials
Enchainment through materials and artefacts	Short distances and rare occurrences	Longer distances and common occurrence
Domestic resources (plants, animals, food and power)	None or rare	Present, and usually essential for population dispersal

Tab. 1 Two archaeological signatures for population dispersal.

with culture-people-language signatures. This is clearly seen with the claims for a rapid Clovis expansion (Martin, 1973), which is of interest from the perspective of spatial and chronological scales. It operates at a continental scale and over comparatively short Late Glacial timescales. A robust audit of the available radiocarbon dates has undermined the likelihood of a Clovis population movement, pointing instead to the existence of a pre-Clovis population through which the distinctive projectile points spread like a virus (Waters and Stafford, 2007). The interest in Clovis is no longer one of culture-people as a signature of dispersal but instead an analysis of how demographic frameworks govern the transmission of novel information (Richerson and Boyd, 2005). A contrasting example is the case of Late Glacial Europe, where a similar robust analysis of the available radiocarbon dates confirms Dolukhanov's (1979) original model that human populations dispersed northwards from a south western refuge (Housley et al., 1997; Gamble et al., 2005); a pattern subsequently supported by archaeogenetics (Pala et al., 2012; Torroni et al., 1998).

Strong and weak signatures: importance of archaeological visibility

From these examples we generalise that the evidence for population movement comes in two forms: weak and strong archaeological signatures. The expectations are set out in **Table 1** and are confined to archaeological evidence alone. In **Table 2** some examples are provided. One obvious, but important, distinction between the Clovis and the Magdalenian / Epigravettian studies is the demonstration for the latter that they moved into unoccupied territory (the Badegoulian outlier excepted). Both are strong, highly visible signatures based on similarity among artefact types that are well constrained by the chronological evidence. But they represent two different processes: cultural diffusion vs. the physical movement of people.

These examples sharpen the focus on another strong signature, the appearance of the Upper Palaeolithic in Europe. As we have discussed this presents an extreme case of the culture-people-species assumption. The power of the assumption overrides the scanty evidence prior to 40 ka for any stratigraphic association between anatomically modern human skeletal evidence and the traits of the Upper Palaeolithic (Zilhão, 2007; Hublin et al., 2020). Yet when found, blades and beads are instantly regarded as evidence for the arrival of a new species and the start of the demise of the existing Neanderthals. The impossible coincidence that Neanderthals could have decided to become modern at the moment *H. sapiens* arrived in Europe (Mellars, 2005) needs to be rephrased to consider the lack of evidence linking the Upper Palaeolithic to *H. sapiens* in the first place. Debates concerning the contemporaneity of Neanderthals and anatomically modern humans in north-western Croatia (Karavanic, 1995; Karavanic and Smith, 1998), south-western France (Hublin et al., 1996), and Hungary and Moravia (Allsworth-Jones, 1986, 2000) question the assumption that acculturation may not be an agent.

Such data-fitting is also evident in the debate surrounding the dispersal of modern humans from Africa. Currently two models are on offer. An older dispersal, that occurs on stratigraphic grounds before the Toba ash and the onset of MIS 4 at 71 ka (Petraglia et al., 2007), is contrasted with a more recent dispersal ~60-50 ka (Mellars et al., 2013). Both interpretations have their problems. The long chronology relies on a weak signature based on the lithic data. Because moderns, as they passed eastwards through South Asia, did not have a European-style Upper Palaeolithic they are archaeologically invisible. This is not due to lack of evidence but to the character of the lithic assemblages they made (Mode 3 *). Rather than seeing a European-style signature with new items made in a distinctive way, we are instead left searching for hints from a Mode 3 technology that passed through an existing Mode 3 technology (Foley and Lahr, 1997; Armitage et al., 2011).

Supporters of the later chronology have similar procedural difficulties. They subscribe to the view that modern humans will be distinguished archaeologically by a strong signature; a view derived from the European record. This leads them to draw comparisons between artefact types in South Africa and Sri Lanka and present the similarities in backed segment forms as evidence for people on the move (Mellars et al., 2013: Fig. 3). This analysis does not consider the demographic framework for the transmission of culture (see the Clovis example above) or the possibility of convergence in cultural innovation. Instead it belies a

	Weak	Strong
Population dispersal into unoccupied land		Humans first arrival in Australia, the western hemisphere, Late Glacial northern Europe and remote Oceania
Population dispersal and displacement within a previously inhabited continent	Repeated *Homo* dispersals in the Old World that involve Modes 1 and 2 technology; Movement of Mode 3 using humans from Arabia to Sunda pre-Toba ash	Modern humans into Neanderthal occupied Europe and southern Siberia; Neolithic farmers into Mesolithic Europe; Bantu migrations within Africa
Transmission of cultural material and information within an inhabited continent that involves no population movement or displacement	Mode 2 Acheulean bifaces; Mode 3 Levallois technology	*Nassarius* shell ornaments in south and north Africa; Clovis bifaces throughout the western hemisphere

Tab. 2 Examples of weak and strong signatures for population movement. Modes refer to Clark's (1961, 1969) technological divisions *.

rather outmoded view of how population movement is to be traced archaeologically; one, moreover, that is subservient to the non-radiometric dating used by archaeogeneticists.

Potential impact of a chronological lattice

This debate is set to run for a long time. It could of course be truncated if a chronological lattice existed through which competing claims could be evaluated. But even at this stage of lattice development we can see that archaeologists urgently need to revise their traditional notions of what constitutes a signature of dispersal (Gamble, 2013). It is not enough to be told by archaeogeneticists (whose molecular chronologies are, in the absence of a tie-in with archaeological data, unverified by independent means) that a dispersal took place and then search for its signature. The challenge for supporters of the pre-Toba chronology is to devise further ways to boost the weak signature while adherents to the post-Toba timing need to abandon the idea inherited from Childe's European data that a strong signature *must* exist to mark the passing-through a region of a people and a species.

The experience from RESET, which built a continental-wide lattice, is that an issue such as the timing of the transition between two strong signatures – the Middle and Upper Palaeolithic of Europe – can be resolved. Moreover, the role that AETs might, or might not have played can then be established (Lowe et al., 2012). In this example (**Fig. 2**), the presence of a distinctive major tephra horizon (CI or Campanian Ignimbrite) demonstrated cold/arid conditions associated with Heinrich Event 4 (HE4) were not the primary driver of cultural changes, population dispersals or regional Neanderthal extinction in Northern and Eastern Europe over this period. Moreover, the eruption was not in itself responsible for the demise of hunter-gatherer groups except for those in proximity to the eruptive centre. However, the RESET example is still some way from providing understanding of such a major transition in terms of the most popular explanation – the incoming *movement* of a new species with a Mode 4 technology into the continent occupied by a hominin with a Mode 3 technology. Whilst a searchlight can be shone on the weaknesses in current archaeological approaches to culture change, chronology is only part of the equation.

CONCLUSIONS

This paper has largely been critical of established archaeological methods of correlating behavioural change in the Palaeolithic with specific environmental events (AETs and environmental disasters). Many of our analytical techniques and units were defined in the nineteenth century, and have not been seriously re-evaluated for the twenty-first century; they are incompatible with population models created by archaeogeneticists (phylogeographers). We now have more refined and detailed models of environmental change over time and space, created by tephrochronological lattices and direct dates on diagnostic artefacts, which allow us to address time-transgression and localised responses to environmental change. We argue that our chronological frameworks need to serve the evaluation of archaeological models emphasising social interactions and mobility strategies in response to fluctuations in environmental resources, rather than to calibrate the transitions of epochs.

We need more subtle methodologies to differentiate the archaeological signatures of diffusion of ideas and concepts within established groups from those left by dispersing populations. Key to this methodological advance is the recognition of different scales of change within archaeological contexts, from (1) morpho-

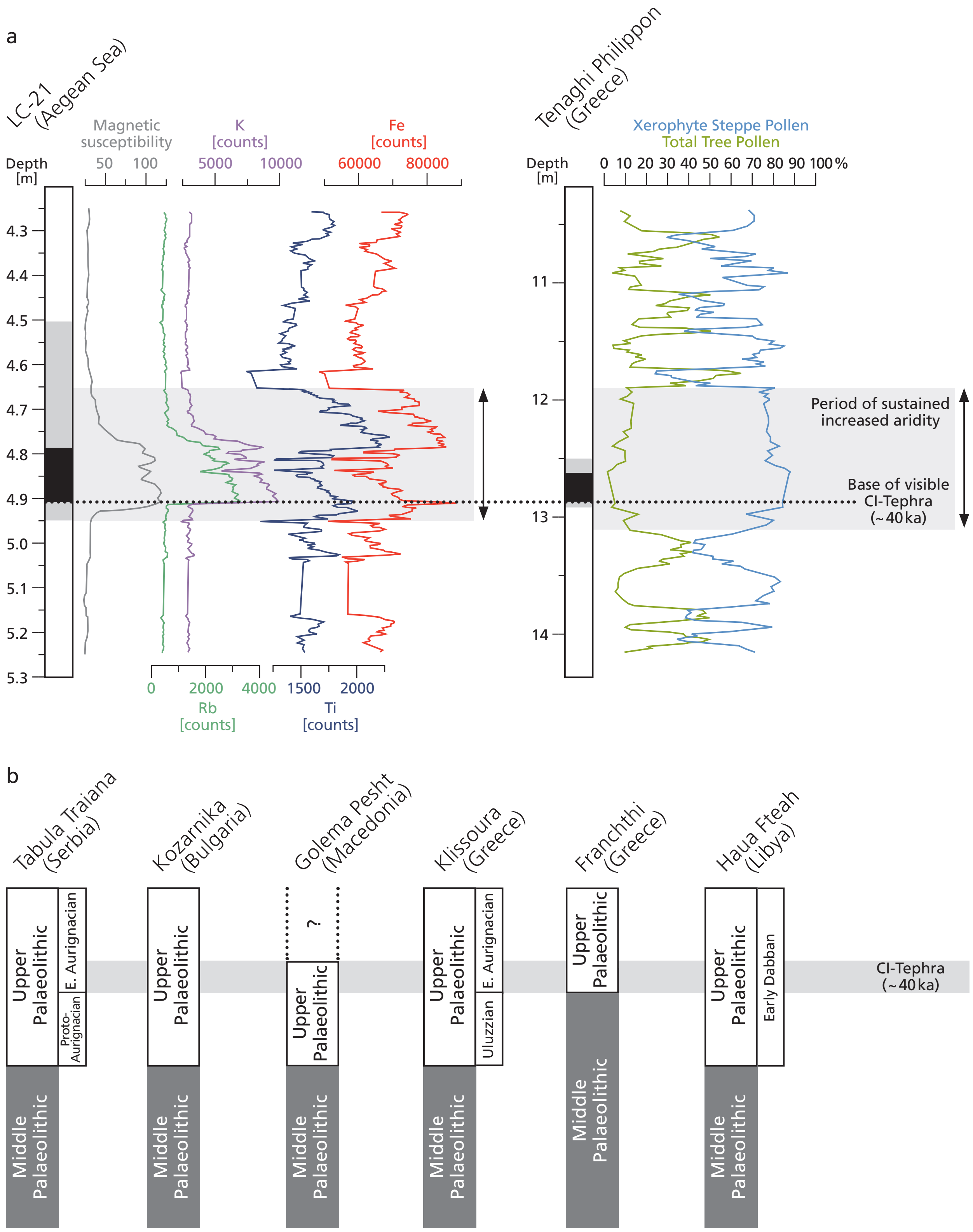

Fig. 2 **a** Position of the Campagnian Ignimbrite (CI): (black, visible glass shards; grey, cryptotephra) with respect to proxy evidence for a period of dry conditions in the eastern Mediterranean considered to approximate Heinrich Event 4 (HE 4). In core LC21, peaks in concentrations of magnetic susceptibility, Rb, and K correspond to peak CI tephra influx, whereas the longer-lasting high values for Ti and Fe reflect higher atmospheric dust influx. The marked reduction in tree pollen percentages in the Tenaghi Philippon sequence is also considered to reflect adversely dry conditions. The CI occurs early in this dry phase, which dates it to the lower part of HE 4. – **b** Schematic representation of the position of the CI with respect to the Middle Palaeolithic (MP) to the Upper Palaeolithic (UP) transition in six of the archaeological sequences investigated within the RESET Project. – (from Lowe et al., 2012: Fig. 4).

logical modifications of particular artefact forms, to (2) replacement of one artefact type with another, to (3) complete replacement of one industry with another (Davies, 2012). Scale (1) is one of the hardest to analyse in Palaeolithic archaeology, unless clear choices in form can be identified in different regions and/or at different times, because its speed is too fast for the precision and accuracy of most radiometric dating techniques. If, however, morphological variation in artefact forms can be dated across a region using an isochron, then at least we have a chance of identifying some (moderately time-averaged) variation in assemblages where there is a tephra marker. Scale (2) also benefits from being fixed within a tephrochronological lattice, ideally in conjunction with direct dating on the artefact if it is organic. Scale (3), in theory, could have occurred as fast as scale (2), marking the arrival of new cultural practices or ideas as an abrupt cultural event. This complete turnover in cultural practice might be attributable to the sudden wholesale replacement of socially-desirable technologies and techniques by an established population, or – perhaps more likely if it appears to have been sudden – the arrival of groups with new behaviours in a region. Careful evaluation of economies (resources used, and in what fashion, as exemplified by the work of Elaine Turner and Martin Street), as well as of the surviving artefacts, throughout site sequences is needed to provide a social context of assemblage and artefactual turnover for the assessment of scales of change. In addition, scales of environmental alteration by disasters can be modelled for volcanic eruptions: archaeological sites located in the proximal zone (defined largely by visible tephra deposits within stratigraphic sequences) contrasted against those found in the distal zone (largely cryptic tephra markers). We argue that regions in the distal zones would have been less affected (if at all) by eruptions; in these cases, the tephra primarily allows us to construct spatio-temporal lattices, rather than forcing us to model scales of environmental deterioration.

The task for future analyses is to integrate and test/cross-reference different chronometric records. Sites with both directly-dateable diagnostic artefacts *and* tephra isochrons need to be identified, so that the two chronological frameworks can be more tightly meshed. Direct evidence of AETs and environmental disasters in archaeological sites, such as tephra isochrons, can then be matched with direct evidence of hominin responses to their environments (as represented by dateable organic artefacts, including different forms of projectile tip). Only by taking such a multi-aspectual approach can archaeologists grasp something of the dynamism of past FGH responses to environmental variation, and thus overhaul their causal explanations for cultural change. A firmer understanding of *speeds* of change, both environmental and archaeological, will be essential for new explanations of Palaeolithic variation in time and space.

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