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Evaluating the transitional mosaic: frameworks of change from Neanderthals to *Homo sapiens* in eastern Europe

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A B S T R A C T

Defining varying spatial and temporal analytical scales is essential before evaluating the responses of late Neanderthals and early *Homo sapiens* to Abrupt Environmental Transitions (AETs) and environmental disasters for the period 130–25 ka. Recent advances in addressing the population histories and interactions (using both genetic and archaeological evidence) of Neanderthals and *H. sapiens* have encouraged consideration of more subtle dynamics of archaeological change. Descriptions of change based on methodologies pioneered some 160 years ago are no longer adequate to explain the patterning we now see in the record. New chronological results, using multiple dating methods, allow us to begin to unpick the spatial and temporal scales of change. Isochronic markers (such as specific volcanic eruptions) can be used to create temporal frameworks (lattices), and results from other dating techniques compared against them. A combination of chronological lattices and direct dating of diagnostic artefacts and human fossils permits us, for the first time, to have greater confidence in connecting human (recent hominin) species and their behavioural responses to environmental conditions, and in quantifying scales of change over time and space (time-transgression). The timing of innovations, particularly those in bone, antler and ivory, can be directly quantified and tested, and used to re-evaluate longstanding models of cultural change. This paper also uses these new chronologies to explore the ecologies of late Neanderthals and early *H. sapiens*: their population densities, mobilities, resources exploited and possible interactions. Environmental productivity estimates are used to generate new questions of potential population densities and mobilities, and thus the sensitivity of these groups to environmental perturbations. Scales and intensities of effect on environments from natural disasters and AETs (notably Heinrich Events and the Campanian Ignimbrite eruption) are defined as a scale from "proximal" to "distal," with local conditions (topographic shelter or exposure) serving to intensify or mitigate those effects.

1. Introduction

This paper sets the results obtained by Work Package 1 (henceforth "WP-1") of the RESponse of humans to abrupt Environmental Transitions ("RESET") into a broader Eurasian context (Lowe, in this issue). It will augment the new chronological lattice (Lowe, in this issue; Bronk Ramsey et al., in this issue) from the RESET project with direct radiocarbon determinations on diagnostic organic artefacts, and evaluate the results in the light of time-transgressive change in hominin (late Neanderthal and early *Homo sapiens*) behaviours and landscape occupation between ~130 and 25 ka (in particular the period 50–30 ka) (Table 1). The following themes will be addressed:

- The implications of the tephrochronological lattice for tracking Neanderthal and early *H. sapiens* occupation patterns (including population retreat and expansion).
- Differential effects in proximal versus distal eruption signatures on hominin occupation patterns and economies.
- The chronology and social contexts of innovations in organic technology.
- Time-transgressive patterning in changes seen in the archaeological record.

The limitations in the record need to be considered, in order for the major advances made by the RESET project to be developed

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further. It should be noted that, despite the best efforts of the project, no tephra records (whether visible or cryptic) have yet been identified in western Europe for the period ~130–25 ka; instead numerous tephra records were recovered from archaeological sites in eastern Europe (Italy and further east), allowing a multi-tephra lattice to be constructed for this region. This lattice has potential for increased detail when currently-unknown tephras are identified to source and new cryptotephra occurrences found. If current models of population replacement of Neanderthals by *H. sapiens* are correct (e.g. Hublin, 2010; Stringer, 2012), then the tephrochronological lattice is of crucial importance, for it ties together sites in the part of Europe where we should expect to see the earliest *H. sapiens* occupation, and the start of Neanderthal territorial contraction. Nevertheless, the lack of tephra records in western Europe currently hampers the construction of a lattice in the areas that may contain final Neanderthal occupations.

As set out below, the ideal combination is the presence of tephra records and dateable artefacts at each site. While this co-occurrence does seem to occur at some sites, tephrochronology has yet to be augmented by direct dating of organic artefacts at a single location. Sites such as Szeleta cave, in Hungary, have yielded insufficient cryptotephra for identification, and the single Aurignacian split-based point from the site did not contain enough collagen for dating (Table S4). So far, the two dating methods seem to be mutually-exclusive at archaeological sites, though the potential for both methods to be employed (e.g. at one of the Kostenki sites) exists, and should continue as a research ambition for this key period of human prehistory.

2. Evaluating hominin demography, 130–25 ka

Before assessing the effects of environmental disasters and Abrupt Environmental Transitions (AETs) (Table 1) on Neanderthal and *H. sapiens* populations, it is necessary to establish what we know about their demographic structures and spatial extents. Neanderthal societies have often been characterised as localised and small-scale, based on raw material transport distances, limb proportions, ancient DNA variability and energetic requirements (e.g. Féblot-Augustins, 1999; Finlayson, 2004; Verpoorte, 2006; Dalén et al., 2012). This is frequently contrasted with patterns identified for Upper Palaeolithic *H. sapiens* (see section 8), who, as a non-native European hominin species, are often presumed to be more mobile and wider-ranging, perhaps even targeting particular biome types across a region (Davies, 2001). We should remember, though, that the localised spatial patterning of Neanderthals is most apparent near the end of their existence, given additional emphasis by depleted and isolated populations (e.g. Castellano et al., 2014; Sankararaman et al., 2014). Although there is genetic evidence of long-term demographic attrition on their populations (see below), at times the Neanderthals were able to disperse and expand their ranges (Serangeli and Bolus, 2008). As discussed below (Section 3), the tephrochronological lattice for WP-1 extends back to ~130 ka, covering periods of Neanderthal range expansion and relative stability, as well as their later (post-60 ka) range contractions prior to, or penecontemporaneous with, *H. sapiens* range expansions.

Establishing the demographies (population levels, histories, structures) of *H. sapiens* and Neanderthals has proved problematic, whether one uses archaeological, climatic or genetic proxies. The issue, however, requires consideration if we are to assess the effects of volcanic eruptions and climatic shifts (environmental disasters and AETs, respectively) on hominin populations. How many hominins might have been affected, to what extent, and were patterns of landscape occupation altered? Palaeodemographic estimates are mostly restricted to the post-100 ka period; they agree that hominin populations in western Eurasia were low at about 40 ka, with archaeogenetic models of Neanderthal census metapopulation ranging between 25,000 and 200,000 individuals (Fabre et al., 2009). This metapopulation was calculated using an estimate from mitochondrial DNA (mtDNA) that effective Neanderthal populations (i.e. numbers of breeding females) represented ~25% (3125–25,000 individuals) of the total female metapopulation, and ~12.5% of the census metapopulation. Based on sizes and numbers of known archaeological sites, Bocquet-Appel et al. (2005)

Table 1
Definitions of key terms of reference.

Abrupt Environmental Transition ("AET")	Pronounced shift from one set of prevailing environmental conditions to another, e.g. Heinrich Events (see below).
Aurignacian	Technocomplex spanning Europe and western Asia, dated ~44–32 ka, and characterised particularly by distinctive osseous (bone, antler and ivory) projectile point forms.
Bond cycle	A series of short-lived warming (interstadial) events that show progressive coooling, culminating in a severe HE (Bond et al., 1993; Lowe and Walker, 2015).
Contingency	Spatio-temporally localised hominin behavioural patterning; shifts from one state to another may have multiple social and environmental explanations.
Environmental/natural disaster	Short-term environmental perturbations, e.g. tsunamis, volcanic eruptions.
Heinrich Event ("HE")	Rapid and massive intermittent discharges of icebergs that tracked the southern margin of the polar gyre, depositing layers of ice-rafted debris (Heinrich layers) on the floor of the North Atlantic. These reflected episodes of marked reduction of sea surface temperature during climatic episodes referred to as Heinrich Events (Bond et al., 1992; Lowe and Walker, 2015). The Campanian Ignimbrite ("CI") appears to have occurred in the early part of one of these events, HE4 (Lowe et al., 2012).
Hominin	All hominid taxa ancestral or closely-related to *Homo sapiens*, i.e. australopithecines and members of the genus *Homo* (Wood and Richmond, 2000).
Isochron	Contemporaneous event horizons, which allow temporal correlations at a range of spatial scales (Lowe and Walker, 2015; pp. 348 & 364).
ka	Thousand years (calendric, not ^{14}C) BP.
Marine Oxygen Isotope Stage ("MOIS")	Marine oxygen isotope records show characteristic fluctuations throughout the Quaternary that reflect (in the main) glacial–interglacial climatic cycles. Glacial and interglacial stages can be defined as isotopically light (interglacial) stages, which are given odd numbers, and isotopically heavy (glacial) stages (even numbers), the sequence of stages being numbered with depth from the present (Holocene) interglacial stage (MOIS-1). In total, the Quaternary comprises 103 stages (see Lisiecki and Raymo, 2005).
Technocomplex	A huge system, with an estimated range of ~1200–4800 km, encompassing connected archaeological culture groups, material cultures, assemblages and (finally) artefact-types (Clarke, 1968, p. 323, 331).
(Tephrochronological) lattice	Chronological framework of identified tephra horizons, allowing single and/or multiple markers to be connected temporally at discrete sites.
Tephra	Volcanic fragmental clasts contained in either visible and/or microscopic (cryptic) deposits.
Time-transgression	Sedimentary and archaeological event boundaries that do not start or end at the same temporal points across their spatial ranges (Lowe and Walker, 2015, p. 349–354).