

Human adaptations to climatic change in Liguria across the Middle–Upper Paleolithic transition

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ABSTRACT: There has been much focus on the disruptive effects of dramatic climatic shifts on Paleolithic population dynamics, but the topic of cultural continuity across such events has been less intensely investigated, despite its importance to the way archeologists think about the ways humans have interacted with their environment in the past. This paper presents data from western Liguria (Italy) and especially the site of Riparo Bombrini, to investigate the nature of the apparent resilience of the Proto-Aurignacian technocomplex in the face of the Phlegrean Fields super-eruption ca. 40 000 cal a BP and the general climatic instability during Marine Isotope Stage 3. While the Proto-Aurignacian shows some internal variability that could reflect an adaptation to changing environmental conditions, overall it remains very stable in terms of its techno-typology and social geography across these events. Additionally, the radiocarbon chronology for the site clearly shows that the Proto-Aurignacian outlasts both the super-eruption and Heinrich Event 4 as a whole, by as much as 2000 years. Comparisons with the regional Mousterian record indicate that the Proto-Aurignacian marks the advent of a new way for humans to respond to climatic change, which opens up new avenues to reflect on the disappearance of the Mousterian.

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KEYWORDS: environmental change; Liguria; lithic technology; Mousterian; Proto-Aurignacian.

Introduction

In the context of recent discussions of what impact drastic environmental change may have had on prehistoric forager technologies, it can be beneficial to use instances characterized by a lack of behavioral disruption following a paleoclimatic event to shed light on the question from a different angle. In this paper, we thus tackle the question of why the Proto-Aurignacian of Liguria (the technocomplex associated with the earliest *Homo sapiens* in the region) displays such apparent resilience in the face of potentially severe ecological disruptions and fluctuating climatic background. We begin with a discussion of recent attempts to characterize human–environment interactions during the Early Upper Paleolithic (EUP) in Europe, before presenting the site of Riparo Bombrini as a case study in which to test some of these ideas. This is followed by a review of working hypotheses raised recently by studies of the impact of the super-eruption of the Phlegrean Fields on EUP foragers. A detailed examination of the available radiometric evidence from the Balzi Rossi (and Riparo Bombrini in particular) will follow, showing significant discrepancies between these expectations and the empirical chronological evidence, with attendant implications for the resilience of human systems during the Proto-Aurignacian. This sets up a discussion of the technological dimensions of this resilience and of how it departs from some of the patterns visible in the preceding Late Mousterian. The paper closes with a discussion of how these different lines of data contribute to a reconceptualization of some dimensions of the process of the Middle–Upper Paleolithic transition as well as of how Paleolithic hunter-gatherers more broadly reacted to drastic environmental change during the latter part of the Late Pleistocene.

Environmental change and the Middle–Upper Paleolithic Transition

The ability to rapidly adapt technological systems in part as a response to changing local ecological conditions has been said to be one of the defining elements of what makes humans ‘modern’ (Mellars 2005: 13; see also Bar-Yosef, 2002). This builds on the realization that, among ethnographically documented forager groups, human adaptations are conditioned to an important degree by their environment, especially as concerns mobility and concomitant technological organization strategies (e.g. Kelly, 1995; Binford, 2001). In the early 2000s, the ‘Stage 3 Project’ set the standard for investigating the nature of human–environment interactions in the Late Pleistocene by showing the breadth of data necessary to productively address that link (van Andel *et al.*, 2003). These studies gave rise to several analyses that sought to demonstrate how various climatic parameters operating on different scales could have played a determining role in the disappearance of Neanderthals and their subsequent replacement by modern humans in the fossil and archeological records (Gamble *et al.*, 2004; Tzedakis *et al.*, 2007; Bradtmöller *et al.*, 2012). Often, however, this has resulted in a tendency to try to correlate specific, dramatic paleoclimatic events with the disappearance of Neanderthals or the diffusion of modern humans rather than to spur a discussion of the full complexity of these processes that probably must have been mosaic in their manifestation (e.g. Müller, 2011; Nigst *et al.*, 2014; Benazzi *et al.*, 2015; *cf.* Lowe *et al.*, 2012).

In fact, studying the idea of resilience in prehistoric socio-ecological systems is much more complex than searching for straightforward catalyst–reaction relationships (for a recent review of resilience theory in archeology, see Bradtmöller *et al.*, 2017). Continental-scale paleoenvironmental modeling has further shown that what made a suitable habitat is best

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understood as the result of the intersection of local topography and hydrology, overall climate and different types of indices of climatic variability (e.g. seasonal temperatures and rainfall) rather than the result of climatic conditions alone (e.g. Burke *et al.*, 2017). Thus, by themselves, climatic events – no matter how drastic – are probably insufficient explanations for both micro- and macro-scale patterns of behavioral change in the archeological record, as shown for instance by recent reevaluations of the impact of the Toba super-eruption (Yost *et al.*, 2018). In addition, it has already been shown that the unfortunate tendency to equate the advent of colder conditions with more challenging times for Paleolithic hunter-gatherers is a side effect of what can best be termed ‘agricultural thinking’, whereby expectations about the potential of a given climatic regime are filtered through implicit preconceptions about what is good for settled food producers rather than through an appreciation that this simply meant a different set of resources being available to foragers (Gamble *et al.*, 2004). An especially clear example of this tendency is provided by the discussions about human reactions to the Phelgrean Fields super-eruption ca. 40kcal a BP, an event which has almost universally been seen as dramatically disruptive to human populations from Italy to Russia (e.g. Mussi, 2001; Fedele *et al.*, 2002, 2008; Giaccio *et al.*, 2006, 2017; Zilhão, 2006; Fitzsimmons *et al.*, 2013).

In the context of such discussions, individual sites with a diachronic record spanning the period of interest provide important case studies to critically evaluate the exact nature of the population and behavioral dynamics that characterized the human response to such dramatic events. In this paper, we will therefore investigate one such case study – the site of Riparo Bombrini, in Liguria, NW Italy – to empirically test the validity of the idea that events such as volcanic super-eruptions had particularly negative impacts on groups of prehistoric hunter-gatherers. The choice of this case study is driven by two elements. First, the site has been recently excavated using modern recovery methods, with an abundance of accelerator mass spectrometry (AMS) radiocarbon dates that allow it to be precisely placed against the climatic background of its occupations. Second, recent analyses suggest that the Proto-Aurignacian levels at the site straddle the super-eruption while showing little evidence of cultural disruption or major population change (Negrino and Riel-Salvatore, 2018; Riel-Salvatore and Negrino, 2018). In

particular, this analysis will allow us to move beyond this observation of fact to tackle the larger question of what made the Proto-Aurignacian such an apparently resilient socio-ecological system in the specific context of Liguria.

Overview of the Middle–Upper Paleolithic Transition at Riparo Bombrini

Riparo Bombrini is a collapsed rockshelter found in the Balzi Rossi site complex on the Italian side of the Franco-Italian border. The site contains rich Late Mousterian and Proto-Aurignacian deposits (Fig. 1; Vicino, 1984; Riel-Salvatore, 2007; Bertola *et al.*, 2013; Riel-Salvatore *et al.*, 2013; Holt *et al.*, 2018). Before the Balzi Rossi were bisected by the Genoa–Marseille railway in the late 1800s (see Villeneuve, 1906), Riparo Bombrini probably represented the eastern edge of a large talus that sloped from the entrance of Grotta del Caviglione towards the sea (Riel-Salvatore and Negrino, 2018). The western edge of the talus would have comprised the area currently known as the site of Riparo Mochi, which was originally excavated in the 1950s and then again in the late 1990s and 2000s by teams lead by A. Bietti and S. Grimaldi (Kuhn and Stiner, 1998; Alhaique *et al.*, 2000; Douka *et al.*, 2012; Grimaldi *et al.*, 2017). Due to the steepness of the coastal shelf of Liguria, the site was always within a short distance of the sea even during phases of low sea stand during glacial periods, as shown by the presence of conspicuous amounts of mollusk shells in all layers at the site, including the Mousterian. The site was first tested in 1938 but was first excavated using controlled recovery and documentation in 1976, when a walkway was built to facilitate access to the Balzi Rossi sites as part of the visits of the 1976 UISPP meetings (Vicino, 1984). In 2002–2005, our team conducted controlled excavations at the site to clarify the nature and tempo of the Middle–Upper Paleolithic transition at the Balzi Rossi and Italy more generally (Negrino, 2002; Bertola *et al.*, 2013; Riel-Salvatore *et al.*, 2013; Holt *et al.*, 2018). Renewed fieldwork at the site began in 2015 under the direction of the two authors, and are planned to continue until at least 2021 (Riel-Salvatore *et al.*, 2016).

Because this new work is ongoing, we will focus most of the present discussion on the data gathered in 2002–2005. Over the course of this project, we identified three sedimentary macro-units one of which comprises two distinct Proto-

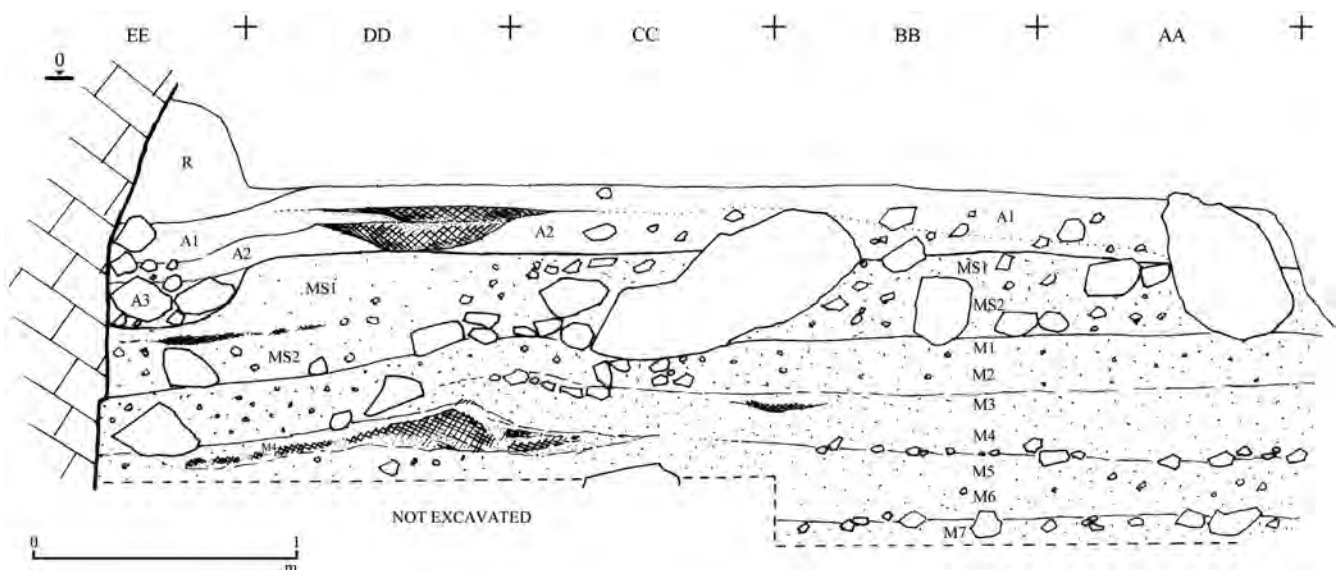


Figure 1. Stratigraphy of the Proto-Aurignacian and Late Mousterian deposits at Riparo Bombrini (Ventimiglia, Imperia).

Aurignacian layers (Levels A1 and A2; A3 is an older level almost completely devoid of artifacts and that is present only as a localized relict deposit against parts of the site's back wall), and the other two (MS 1-2 and M1-7) are attributed to the Late Mousterian (Fig. 1). Preliminary analyses have demonstrated the presence of distinct activity areas in the Mousterian levels (Riel-Salvatore *et al.*, 2013), and that despite technological differences between the Proto-Aurignacian and the Mousterian, the ability to shift mobility strategies along something akin to a forager–collector continuum characterizes both industries (Riel-Salvatore, 2007, 2010; Riel-Salvatore and Negrino, 2018). In contrast, raw material provisioning strategies differ markedly, with the Mousterian showing a predominantly local and circum-local procurement pattern with very rare exotic elements (e.g. pieces on rhyolite from Esterel, in southern France), while the Proto-Aurignacian comprises up to 20% of exotic lithotypes and little use of even high-quality circum-local stone, such as fine-grained micro-quartzite from San Remo (Negrino, 2002; Riel-Salvatore, 2007; Riel-Salvatore and Negrino, 2009, 2017; Bertola *et al.*, 2013). In addition, the Late Mousterian levels show evidence of shellfish exploitation for dietary purposes, with *Phorcus turbinatus* the most frequent species in levels M1-7 and sandy environment species found in levels MS1-2, indicating that Neanderthals were collecting these small gastropods in rocky intertidal zones whenever they occupied the site (Negrino *et al.*, 2017). In contrast, while this behaviour continues in the Proto-Aurignacian, these levels have also yielded abundant evidence of ochre, as well as of incised steatite, notched bird bones, shell ornaments and a diversified osseous industry (Bertola *et al.*, 2013; *cf.* Vicino 1984); of these, only ochre has been reported in the Mousterian levels (Riel-Salvatore *et al.*, 2013).

Technologically, it is possible to characterize the lithic assemblages from Riparo Bombrini based on a study material from the entire excavated area during the 2002–2005 excavations (about 12 m² in the Proto-Aurignacian and about 5 m² in the Mousterian, see Riel-Salvatore *et al.*, 2013). The latest Mousterian corresponds to levels MS1-2 which immediately underlie the Proto-Aurignacian of A1-3, from which it is separated by an erosional horizon, and levels M1-7 beneath levels MS1-2. The MS levels are a 30- to 40-cm-thick layer of clayey loam sedimentary matrix encasing coarse clasts, including several large blocks of roof fall. A few discrete concentrations of charcoal in these levels indicate that fires were lit in hearths located towards the back of the shelter. Techno-typologically, the scarce lithic artifacts recovered from this level can be attributed to the Mousterian; notably, a few Discoid cores are documented. Almost all lithics are made on local raw materials, namely flint from the I Ciotti conglomerates located a few kilometers away (del Lucchese *et al.* 2001–2002). The scant traces of human activity and the presence of carnivore coprolites combine to suggest that the shelter was, at that time, occupied only sporadically.

The underlying levels M1-7 have so far been explored to a depth of about 70 cm, comprising an abundance of roof spall, with the sedimentary matrix becoming increasingly redder and more clayey down the stratigraphy. Large numbers of lithic implements have been recovered which, in some levels, are concentrated spatially towards the back wall of the shelter, close to conspicuous hearths. Both flakes and cores attributable to the Discoid method are found throughout the sequence, although the Levallois technique is also documented to a lesser degree. The faunal assemblages recovered from those levels are heavily fragmented and often burned; they document a varied faunal spectrum comprising cervids,

caprids, equids, bovids, as well as examples of boar, rhinoceros and bear. Analyses of pollen samples indicate a gradual shift from humid and temperate conditions in the lower levels to a colder, more rigorous climatic regime in the upper levels of the Mousterian (Arobba and Caramiello, 2009). The presence of large blocks of vault collapse in the terminal Mousterian levels provides further support for this reconstruction, as do preliminary analyses of the micro- and macro-faunal assemblages (Negrino and Riel-Salvatore, 2018; Holt *et al.*, 2018).

In contrast, the Proto-Aurignacian is characterized by the use of two distinct *chaîne opératoires* that clearly distinguish it from the underlying Mousterian. The main one aimed to produce bladelets from predominantly unidirectional prismatic cores. The resulting bladelets could then be steeply retouched (often in an alternating, bilateral manner) to produce typical Dufour bladelets. Since larger blade cores (and indeed, large blades themselves) are absent at Bombrini, it is safe to say that bladelet production was the intentional goal of this reduction sequence rather than simply the result of dwindling core dimensions as laminar production progressed. The second *chaîne opératoire* was a flake production strategy and is more opportunistic, suggesting that flake production may have been a secondary product of blade production as core reduction advanced. The morphology of the resulting flake blanks is more heterogeneous, and they served as supports for notches, *pièces esquillées*, denticulates and sidescrapers.

The typological inventory of both assemblages is largely dominated by retouched bladelets, especially Dufour bladelets with the typical curved (but not twisted) profile and semi-/steep alternating marginal retouch (Dufour sub-type; Fig. 2). Notches and denticulates are the most frequent tools although some more typically 'Upper Paleolithic' tool types are also present (endscrapers, burins and splintered pieces). Cores are very rare, with a single amorphous specimen for Level A1, while Level A2 yielded nine, including prismatic, bladelet and bidirectional forms (Fig. 2). This is similar to what has been documented at Riparo Mochi, the main difference being that laminar technology proper is almost unknown at Bombrini; lamellar production was unquestionably the main end goal at Bombrini (Kuhn and Stiner, 1998; Negrino, 2002).

The Riparo Bombrini chronology and the Campanian ignimbrite

Recently published AMS radiocarbon ages from various laboratories also provide us with a robust chronology for the site, including the only directly dated Mousterian deposits from Liguria to date (Riel-Salvatore, 2007; Higham *et al.*, 2014; Benazzi *et al.*, 2015; Holt *et al.*, 2018). These dates indicate that Levels A2 and A1 are in sedimentary continuity and are not separated by a significant gap. The dates indicate a potential occupation span of about 5000 years (i.e. 40 710–35 640 cal a BP), with the cold phase associated with the beginning of Heinrich Event 4 (HE4) taking place in Level A2. The deposits documenting the earliest Proto-Aurignacian, while present at nearby Riparo Mochi, have apparently been eroded at Riparo Bombrini, where it is documented only by the very limited and localized remains of Level A3. Regardless, these chronological data allow us to establish that Level A2 was associated with the cold conditions of HE4, while Level A1 was associated with overall slightly more temperate and mesic conditions. This is supported by palynological data that show that Level A1 is associated with a greater frequency of oak and a lower frequency of pine than Level A2 (Arobba and Caramiello, 2009). That, as well as the presence of the

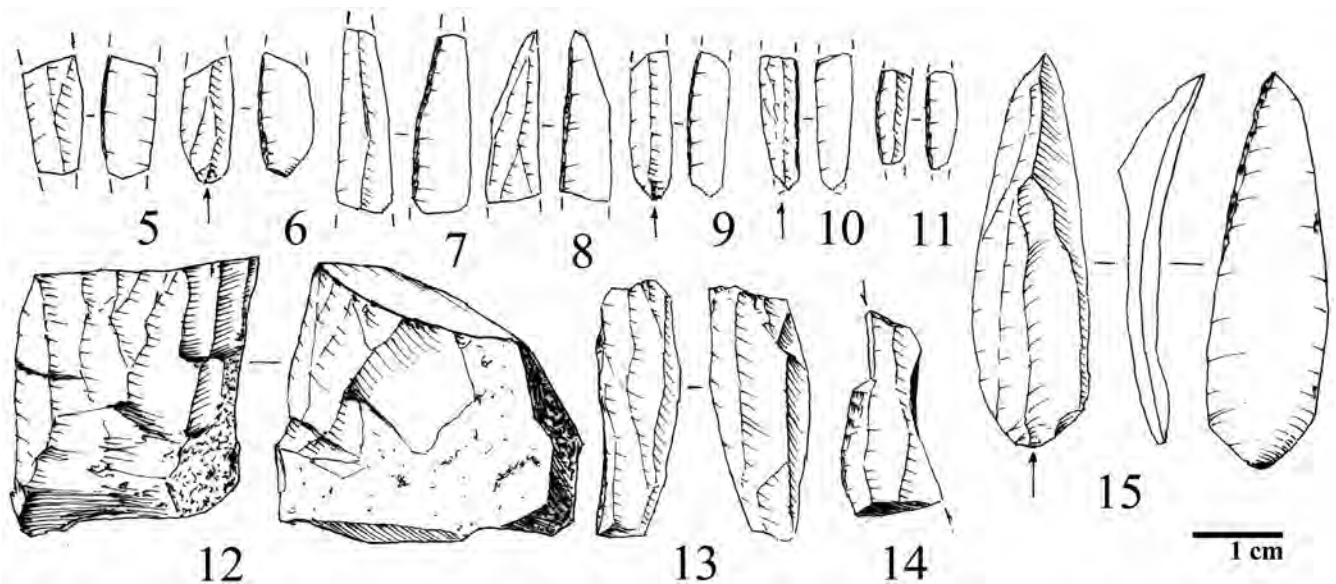


Figure 2. Proto-Aurignacian lithics from Riparo Bombrini. 5–11: Dufour bladelets; 12–13: cores; 14: burin; 15: point (drawings by F. Negrino).

temperate/subtropical buckthorn (*Rhamnus*) in Level A1, lends empirical support to the idea that this phase of the proto-Aurignacian was associated with warmer conditions (see discussion in Riel-Salvatore and Negrino, 2018). While the arboreal pollen frequencies appear to suggest more open conditions in Level A1, this apparent discrepancy is probably due to the low overall absolute pollen frequency at the site. Finally, while the faunal data are scarce so far, the animal species documented in both levels also indicate that equids and rhinoceros, species generally associated with colder, more open conditions, are only documented in Level A2. In contrast, boar and caprines are much more frequent in Level A1 (A. Arellano, personal communication). These complementary lines of evidence thus converge to indicate rather different conditions in the two well-documented Proto-Aurignacian levels from Riparo Bombrini. Importantly, it also established that Level A2 was associated with HE4, whose beginning is associated with the Phlegrean Fields super-eruption around 40 000 cal a BP. This event deposited the well-known CI tephra over a large part of Eurasia, probably resulting in significant ecological alterations, at least in the near term, and it has been linked by several researchers to the disappearance of the proto-Aurignacian in several parts of the continent (Fedele *et al.*, 2002, 2008; Giaccio *et al.*, 2006, 2017), while others have argued it better explains the disappearance of Neanderthals in some regions (Golovanova *et al.*, 2010). The exact ecological impacts of the eruption of the Phlegrean Fields are difficult to determine and have been interpreted in more or less credible manners (Zilhão, 2006; Golovanova, 2010). Here we emphasize only that despite a large-scale effect, such as potentially triggering HE4, the impacts of these shifts was not uniform on regional ecological and human communities (Lowe *et al.*, 2012; Fitzsimmons *et al.*, 2013). Our goal here is not to review this literature in detail but rather to investigate what the impact of this single volcanic event might have been in an area – Liguria – where the CI tephra did not accumulate but which is nonetheless linked culturally to areas in central and southern Italy that were directly impacted by this event.

That said, a recent study has given new life to the idea that the eruption of the Phlegrean Fields was a catalyst of major bio-cultural change in the Upper Paleolithic. Taking the CI tephra as a stratigraphic marker of that super-eruption when it is found in archeological sites, Giaccio *et al.* (2017) present a

series of radiometric ages, honing on the age of 39.85 ± 0.14 k cal a BP (95% confidence level) for that tephra. In their reconstruction, the deposition of the CI marks the beginning of HE4, which then lasts until about 38.2 k cal a BP, a moment which they argue coincides with the upper boundary of EUP technocomplexes, which include the Uluzzian and Proto-Aurignacian in the Italian Peninsula. This leads them to conclude that HE4, triggered by the CI eruption, led to the demise of the earliest Upper Paleolithic in the region. With an admittedly finer-grained technology, that study reaches a conclusion broadly similar to those of other papers published by this research group over the past 15 years (Fedele *et al.*, 2002, 2008; Giaccio *et al.*, 2006, 2008).

However, as demonstrated by Lowe *et al.* (2012), both Neanderthal and modern human groups appear to have survived the CI eruption, establishing that both populations were considerably more resilient to the dramatic environmental change precipitated by the eruption than often thought and that '[w]ith respect to the impacts on humans of the CI eruption, there must have been different outcomes in areas proximal or distal to the volcanic source' (Lowe *et al.*, 2012, p. 13536). Given that none of the Balzi Rossi sites have yielded the CI tephra, all published distribution maps of it indicate that Riparo Mochi and Riparo Bombrini would have been quite far removed from the direct impact of the Phlegrean Fields eruption (see Giaccio *et al.*, 2017: fig. 1). Given this, it is puzzling that these authors cite Riparo Mochi as showing evidence of the disappearance of the Proto-Aurignacian by 38 k cal a BP, especially since Douka *et al.* (2012) have recently published dates for Proto-Aurignacian level G that are more recent than that limit by up to 3000 years. This unease is compounded by the fact that Giaccio *et al.* (2017) make no mention of the recently published dates for the Proto-Aurignacian levels of Riparo Bombrini (Riel-Salvatore, 2007; Higham *et al.*, 2014; Benazzi *et al.*, 2015) that also clearly show it lasting beyond the end of HE4. The situation for Mochi is explained when one realizes that Giaccio *et al.* (2017) use d'Errico and Banks' (2015) debatable criteria as a justification to exclude the site's most recent Proto-Aurignacian levels. The problems with the *ad hoc* manner in which d'Errico and Banks (2015; see also Banks *et al.*, 2013) ignore the record from the Balzi Rossi and reject the Proto-Aurignacian attribution of some Italian EUP

assemblages simply because they are more recent than 39.9k cal a BP have been described elsewhere (Higham *et al.*, 2013; Ronchitelli *et al.*, 2014; Riel-Salvatore and Negrino, 2018), especially in light of more recent discoveries that undermine the widespread validity of that chronological cut-off, but suffice it to say here that for much of the Italian Peninsula, the Proto-Aurignacian appears to last much longer than it does in other parts of Europe (cf. Anderson *et al.*, 2015).

This discussion, and the fact that Giaccio *et al.* (2017) completely omit Riparo Bombrini from their analysis, make the present paper a good setting in which to synthesize the available radiocarbon dates for the site, to see whether the Proto-Aurignacian last beyond 38k cal a BP at Bombrini. Figure 3 presents the distribution of dates calibrated using OxCal 4.3 (Bronk Ramsey, 2009) for levels A1, A2, M2, M3, M4 and M5 at the site obtained over the past decade (Riel-Salvatore, 2007; Higham *et al.*, 2014; Benazzi *et al.*, 2015). It bears emphasizing that the dates were obtained from three different laboratories (Beta Analytic, Max Planck Institute Department of Human Evolution, Oxford Radiocarbon Accelerator Unit) and agree generally on the chronology of the site, although the Oxford dates for some of the Mousterian levels appear slightly young relative to the other ones (see discussion

in Negrino and Riel-Salvatore, 2018); this issue is not relevant in the context of an evaluation of the Proto-Aurignacian dates, however. The first thing shown clearly by Fig. 3 is that, in marked contrast to what Giaccio *et al.* (2017) argue for Riparo Mochi, Level A1 at Bombrini lasts until about 36k cal a BP, while the CI event itself would have taken place during the accumulation of Level A2. Furthermore, there seems to be little to no apparent discontinuity between the two levels, which suggests a continuity in human occupation at the site during the Proto-Aurignacian (Riel-Salvatore and Negrino, 2018). Thus, in a nutshell, the Proto-Aurignacian appears in fact to have not only survived the super-eruption but also, and perhaps most importantly, to have considerably outlasted HE4 with little alteration of its fundamental defining characteristics. The question now becomes that of explaining this apparent resilience, as Fig. 3 clearly indicates that the interval 45–35k cal a BP was marked by extensive climatic variability.

Proto-Aurignacian adaptations to HE4 and beyond

The lithic technology of the Proto-Aurignacian was heavily geared towards the production of standardized bladelets, many of which were retouched into characteristic Dufour

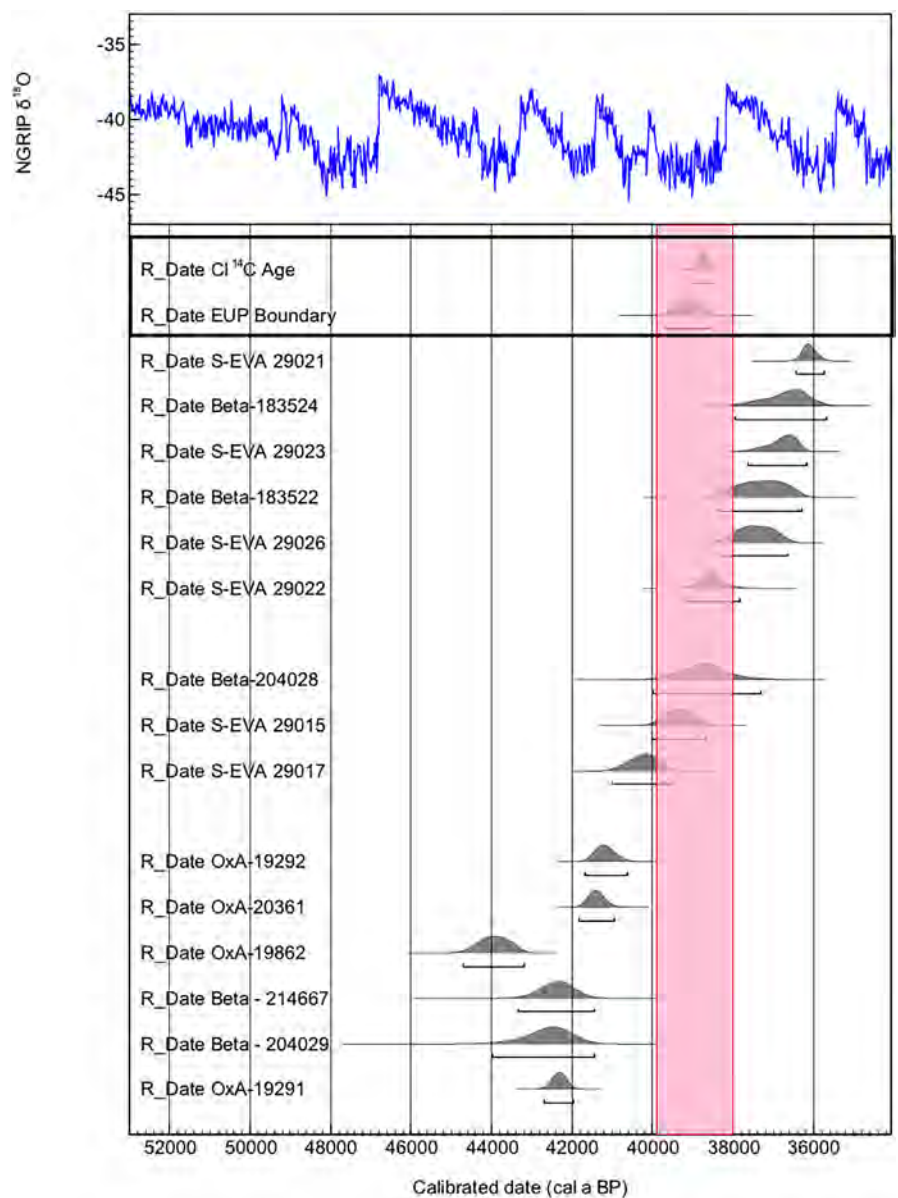


Figure 3. Calibrated radiocarbon dates for Riparo Bombrini: Level A1 (top), Level A2 (middle), Late Mousterian (bottom). The shaded area represents the length of HE4 as per Giaccio *et al.* (2017) and the box at the top includes their weighted mean calibrated radiocarbon ages for the CI tephra and the upper boundary of EUP assemblages in Italy.

types (Bertola *et al.*, 2013). Without dwelling on this now, it bears emphasizing that the Proto-Aurignacian is the main manifestation of the Aurignacian in the Italian Peninsula. This means that it does not have a clear chronological signal, in contrast to the situation in, say, France where it tends to be very early (Anderson *et al.*, 2015). In addition to its distinctive lithic technology, which marks a clear break with the preceding Mousterian, the Proto-Aurignacian is also associated with: a well-developed bone industry that comprises awls and needles; a wide range of perforated mollusk shells which were used as beads in personal ornaments of various types; worked fragments of soft stones such as steatite acquired from the Apennines which were incised, scraped and drilled; the conspicuous use of ochres of different hues and color; and 'cuvette'-type hearths found towards the back of the shelter, which anchor well-defined activity areas inside and outside the shelter. All these elements are found in both Levels A1 and A2. Another interesting element is that Level A2 yielded a deciduous *H. sapiens* incisor, making the site one of the only ones of that period associated with diagnostic human remains (Formicola, 1989; Churchill and Smith, 2000; Benazzi *et al.*, 2015).

Negrino and Starnini (2003) have demonstrated that the social geography implied by the breadth of procured raw material documented in the Proto-Aurignacian was extensive, ranging over 500+ km as the crow flies. What is striking is that there is no difference in the relative importance of these different raw material sources between the two periods (Riel-Salvatore, 2007). In both, French and Central Italian material reaches the site in broadly stable frequencies (Riel-Salvatore, 2007), indicating that the social geography of the earliest Proto-Aurignacian was not more extensive and that HE4 (and perhaps the CI eruption) was not associated with a fundamental shift in the overall range exploited by these foragers, at least in Liguria.

Likewise, it is striking that while there are differences in lithic technological organization between the two Proto-Aurignacian levels at Bombrini, these changes appear to correlate only slightly with the shifts in conditions before, during and after HE4. Like at other Proto-Aurignacian sites in northern Italy, such as Fumane (Broglio *et al.*, 2005; Falcucci *et al.*, 2016), the overall technological system of the industry demonstrates a startling resilience and remains extremely stable, continuing to focus on lamellar production to produce bladelets that were probably hafted into polyvalent and easily maintainable composite tools (O'Farrell, 2005). In fact, a recent analysis of bladelet production in both Proto-Aurignacian levels at Bombrini shows that while both assemblages document the same *chaînes opératoires* used to produce bladelets, the lithic assemblages nonetheless indicate that different land-use strategies were employed in each, leading to the expression of slight but significant distinctions between the two assemblages (Riel-Salvatore and Negrino, 2018). First, building on the results of other empirical and modeling studies (Riel-Salvatore and Barton, 2004; Barton *et al.*, 2011; Barton and Riel-Salvatore, 2014, 2016), the retouch frequency of A1 (~15%) is higher than that for A2 (~5%), consistent with the adoption of more residential and more logistical land-use strategies, respectively. These interpretations are bolstered by the observation that Level A1 displays a lithic organizational strategy emphasizing curation, with a greater exploitation of local resources and the production of stouter but shorter bladelets in this level. Likewise, more retooling took place in A1 than in A2, indicating that retooling activities were undertaken when foragers reached the site and sought to replenish their lithic inventory with local lithotypes (especially flint from the I Ciotti

conglomerate; del Lucchese *et al.*, 2001–2002; Negrino *et al.*, 2006; Riel-Salvatore and Negrino, 2009), discarding broken armatures and replacing them with new ones on-site; this is consistent with Riparo Bombrini being a residential base camp in A1. The patterns in the lithic assemblage from Level A2, in contrast, indicate that during HE4, Proto-Aurignacian hunter-gatherers occupied the site as a logistical base camp which they provisioned with the resources necessary for a prolonged occupation from a range of satellite sites further abroad. This is shown by the more far-ranging raw material procurement patterns and the fact that bladelets were longer and narrower than in Level A1. The presence of greater numbers of cores and fewer broken bladelets also suggest that more primary bladelet production took place in Level A2; in Level A1, bladelet cores appear to have been more curated, leaving the site with their makers as they left for the next leg of their yearly rounds.

Whole assemblage analyses confirm that different mobility strategies characterized Levels A1 and A2, the former being more residential, and the latter being more logistical (Riel-Salvatore, 2007, 2010; Riel-Salvatore and Negrino, 2018). That said, the impact of this shift on the overall organization of technology appears to be fairly minimal, and even the typological disparity between the two assemblages can be explained as an effect of uneven sample size. And while there are some differences in the dimensions of bladelets between the two, none of these are statistically significant. The only difference is that exotic raw material is slightly more frequent in the bladelet assemblage of Level A1 (24 vs. 17.45% for unretouched bladelets; 29.41 vs. 23.94% for retouched bladelets), although the proportional representation of exotic sources remains broadly comparable. All of this combines to suggest that the most significant difference associated with the conditions of HE4 is increased mobility, although this appears to have had little impact on the technological system which permitted this shift to take place.

In sum, there is some variability documented within the Proto-Aurignacian at Riparo Bombrini, but it is most apparent in its technological organization and mobility strategies. While this shift is correlated with a shift from colder to warmer conditions from Level A2 to Level A1, as we have argued in other contexts, we must be careful not to read too much into this correlation, since we are dealing with only two observations (Riel-Salvatore and Negrino, 2018). In the context of this paper, what is perhaps most important to underscore, however, is that the overall techno-typological signature of the industry does not change with climatic variability, indicating that this capacity to adapt to shifting conditions appears to have been an inbuilt capacity of the Proto-Aurignacian, one that gave it a great deal of resilience in the face of periods of even major climatic disruptions.

Discussion: The Late Mousterian of MIS3 in Liguria

Overall, then, it appears that the Proto-Aurignacian at Riparo Bombrini was able to withstand the ecological impact of the drastic climate change represented by the super-eruption of the Phlegrean Fields around 40 000 cal a BP. The eruption also seems to have had little impact on the overall structure of the industries used by foragers during that interval. This is a significant observation that bolsters the view that the impact of this event was in all likelihood multifaceted and extremely variable depending on the region (cf. Lowe *et al.*, 2012), indicating that in some cases at least, instances of major prehistoric paleoenvironmental change were decidedly *not* correlated with marked behavioral change. While the 'Classic Aurignacian' does appear

in Liguria after the Proto-Aurignacian (dated with some inconsistencies to ca. 36–30,000 000 cal aBP at Riparo Mochi; Douka *et al.*, 2012), this shift in lithic and bone technology does not appear to be triggered by a particular climatic event (Negrino and Riel-Salvatore, 2018).

The Late Mousterian of western Liguria provides an interesting counterpoint to evaluate the Proto-Aurignacian pattern (Fig. 4). This is because that phase of the technocomplex is associated with considerable technological variability, all of which was manifested against a largely local lithic procurement backdrop, in notable contrast to the Upper Paleolithic. At Riparo Bombrini, the Late Mousterian is made on local, poor-quality flint with very rare elements on exotic raw materials, but displays an overall Discoid technological signature that includes occasional Levallois elements, which are much more common in Levels M2–M5. As summarized by Riel-Salvatore *et al.* (2013), like the Proto-Aurignacian, the Late Mousterian at Bombrini shows an ability to shift its mobility strategies, although as can be seen in Fig. 3, there does not in this case appear to be a link to shifts in climatic conditions, arguing against the kind of climatically mediated modification in mobility strategies potentially seen in Levels A1 and A2 (Riel-Salvatore and Negrino, 2018).

This situation matches what is known from the Mousterian elsewhere at the Balzi Rossi. At Riparo Mochi, Kuhn and Stiner (1992) observed that the bottom of the Mousterian sequence is dominated by the Levallois technique, while the top (i.e. Late) Mousterian is characterized by a shift towards the dominance of Discoid products (Kuhn, 2004, 2006; Bietti and Negrino, 2007), although whether this shift is accompanied by a functional change in the resulting blanks remains an open question (Grimaldi and Santaniello, 2014). This pattern is also found in the Upper Mousterian levels of the Ex-Casino site also in the Balzi Rossi complex (Vicino, 1972).

The only potential departure from this general technological trend may be found in the sequence from Grotta del Caviglione, where the latest Mousterian has been correlated to MIS 3 and appears to be characterized by the production of Levallois products (Rossoni-Notter *et al.*, 2017), although because the analyzed sample is small ($n=22$) and drawn from Rivière's excavations in the 1870s, this discordant observation remains to be ascertained.

Ongoing excavations in the coeval Late Mousterian deposits of the upland site of Arma Veirana, near modern-day Erli, about 10 km inland and 60 km north-east of Riparo Bombrini, reveal a repeat of the dominant Discoid production scheme with a few Levallois elements, although the exact proportions remain to be clarified by further study (Negrino *et al.*, 2017). While the exploited raw materials are almost all locally available quartz and quartzite, jasper is also present in non-negligible quantities. Given recent observations that jasper sources may be located just a few kilometers away based on its frequency in an Epigravettian assemblage found in the nearby town of Ortovero (Negrino *et al.*, 2016), however, it is perhaps best to reserve judgement for the moment about whether this and other instances of jasper in western Ligurian Mousterian assemblages truly document the procurement of an exotic raw material so far thought to be found only in eastern Liguria and in Emilia (Negrino and Starnini, 2003).

Further east still, the site of Arma delle Manie has yielded what are arguably Late Mousterian deposits, although the exact age of those deposits is still disputed (Arobba *et al.*, 1976; Mehidi, 2005). However, this attribution is reasonable since palynological analyses have shown that Levels I–III were accumulated under relatively temperate conditions, indicating a probable Marine Isotope Stage (MIS) 3 age. The faunal assemblages are dominated by deer, the most common prey in the Late Mousterian of Liguria (Valensi and Psathi,



Figure 4. Location of Riparo Bombrini (i.e. Balzi Rossi site complex, including Riparo Mochi, Grotta del Caviglione and Ex-Casinò) and other Late Mousterian sites mentioned in the text.

2004). Again, the lithic industry is made almost exclusively on coarse-grained local lithotypes that Neanderthals may have been best able to knap using mainly the Discoid method to generate usable flakes, although some Levallois and laminar elements are also documented (Peresani, 2003; Cauche, 2007). The dominance of the Discoid method in the lower levels (IV–VII) provides additional evidence that this reduction strategy was probably a response to constraints imposed by local environmental factors and their determining influence on raw material access rather than being a proper cultural diagnostic, at least in certain cases (Negrino and Riel-Salvatore, 2018). This is interesting because Cauche (2007) suggests that the Levallois method (and a selection for better varieties of raw materials) was used preferentially in MIS 4 and 5, under distinct and more stable climatic regimes than the Late Mousterian assemblages that date to MIS 3.

From this perspective, the heavily laminar assemblage from the site of Via San Francesco (Sanremo, Imperia) made on local high-quality micro-quartzite provides another interesting example of this potential climatically driven technological variability during the Mousterian (Tavoso, 1988; Negrino, 2002). Because of its high laminarity and the presence of some Upper Paleolithic tool types, this assemblage has often been considered a 'transitional' phase of the Mousterian towards the Upper Paleolithic (de Lumley, 1969; Tavoso, 1988); however, recent Electron Spin Resonance age determinations indicating it may date back to as far back as MIS 6 have recently undermined this attribution (Pirouelle, 2006). While more work is needed to confirm the age of Via San Francesco, should this antiquity be confirmed by additional dates, it will require an important revision of the technological, chronological and cultural meaning of this distinctive industry (Bietti and Negrino, 2007). What will not change, however, is its contribution to establishing that the Mousterian in Liguria was a highly variable and locally grounded technocomplex whose variability was probably driven more directly by climatic factors to a greater extent than the Proto-Aurignacian and later Upper Paleolithic technocomplexes.

Conclusions

With these data in mind, to go back to the main theme of this volume, what can we say about forager adaptations to drastic environmental change based on this case study from Liguria? The first and most salient observation is that the Proto-Aurignacian in the region (and probably others) clearly survived the eruption of the Phlegrean Fields ca. 40 000 cal a BP. Not only that, it seems to have done quite well for itself in the five successive millennia despite not showing significant shifts in its techno-typological make-up nor in the social geography it depended on to provision itself with exotic high-quality stone to manufacture lithic implements. If there was something like a volcanic winter or an ash desert to deal with following the super-eruption (cf. Zilhão, 2006), this seems to have created opportunities that Proto-Aurignacian foragers were well positioned to make the most of in the short term. This is likely because the Proto-Aurignacian as an adaptation seems to have been conceived of as a way of dealing with the unexpected, in part but not exclusively through the development of the most extensive social networks possible and the development of a multidimensional human niche at the time (Riel-Salvatore, 2010; Riel-Salvatore and Negrino, 2018). This implies that there is no need to invoke population replacement in the aftermath of disaster to explain long-term human dynamics in the region, since what appears to have changed is not so much people's social geography once the industry was implanted, but rather the way they exploited

their socioecological niche. This stands in notable contrast to the Mousterian where adaptation appears to have been to rather immediate conditions, with significant perturbations being met with what can best be conceptualized as a kind of 'reboot' of the techno-economic system to deal with changing conditions. This also agrees with the view that sees the Proto-Aurignacian at the Balzi Rossi not as a pioneering, short-term phase of modern human occupation but rather one where it is already well implanted on the landscape and connected to other nodes in the broader Proto-Aurignacian world (Negrino and Riel-Salvatore, 2018).

It appears that the Proto-Aurignacian represents a new way of doing new things on the Ligurian landscape, starting about 42 000 cal a BP. It is this aspect that probably best explains its apparent resilience to both short- and long-term drastic climatic swings. In part this was done by conceiving of the natural environment in original ways: not only as a series of areas where given resources could be reliably encountered, but also as comprising different sets of enchainment regions that served to furnish resources and provided conduits to facilitate the movement of goods and ideas (Negrino and Riel-Salvatore, 2017). Raw material exploitation networks give us a first, but partial, glimpse into this landscape, but they are not sufficient: it is clearly essential to consider other elements such as mobility and technological organization to fully understand its defining human component. Likewise, from this perspective, climatic events become but a single, albeit critically important, dimension that conditioned how Paleolithic, and specifically Upper Paleolithic, adaptations could be manifested.

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Abbreviations. AMS, accelerator mass spectrometry; EUP, early upper Paleolithic; HE, Heinrich Event; MIS, Marine Isotope Stage.

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