Title: New chronology for the Middle Palaeolithic of the Southern Caucasus confirms early demise of Neanderthals in this region

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Abstract (300 words)

Neanderthal populations of the southern and northern Caucasus became locallyextinct during the Late Pleistocene. The timing of their extinction is one key inour understanding of the relationship between Neanderthals and anatomically modern humans (AMH) in Eurasia. Recent re-dating of the end of the Middle Palaeolithic (MP) at Mezmaiskaya Cave, Northern Caucasus and Ortvale Klde, southern Caucasus, suggest that Neanderthals did not survive after 39 ka cal BP. In this paperwe extend the analysis and present a revised regional chronology for MP occupational phases in western Georgia that is based on a series of model-based Bayesian analyses of radiocarbon dates from the caves of Sakajia, Ortvala and Bronze

Cave. This allows the establishment of probability intervals for the onset and ending of each of the dated levels and for the end of the MP occupation at the three sites.

Our results for Sakajia indicate the ending of the late Middle Palaeolithic (LMP) and the start of the Upper Palaeolithic (UP) occurred between 40200 – 37140 cal BP. The end of the MP in the neighbouring site of Ortvala occurred earlier at 43540–41420 cal BP (at 68.2% prob.). The dating of MP layers from Bronze cave confirms that it does not contain LMP phases.

These results imply that Neanderthals did not survive in the southern Caucasus after 37 ka cal BP. It fits best with a model of Neanderthal extinction around the same period as the one reported for the northern Caucasus and for regions of Europe. Taken together with previous reports of the earliest UP phases in the region and the lack of archaeological evidence for an*insitu* transition, these results indicate that AMH arrived in the Caucasus a few millennia after this demise and hence suggest that the two species did not interact in this region. Further dating work is planned to add strength to the developing chronological picture.

Key words: Radiocarbon, Chronology, Middle Palaeolithic, Neanderthals, Caucasus

Introduction

The Caucasus was a major dispersal corridor that periodically enabled hominin expansions between Anatolia, the Near East, Europe and Central Asia. The Greater Caucasus Range stretches over 1200 km along a southeast-northwest transect between the Black and Caspian Seas and divides the Caucasus into two major geographic units: the southern Caucasus, and the northern Caucasus. It has been postulated that transgression of the Caspian and Black seas (Kozlowski, 1998) and a glacial system that covered the Greater and Lesser Caucasus mountain ranges (Hublin, 1998) during the Last Interglacial and Last Glacial periods (oxygen isotope stages 5–3, 125,000–30,000 years before present [125–30 ka]) formed a biogeographic barrier between the southern and northern Caucasus regions. Phylogeographic studies of mitochondrial DNA (mtDNA) sequences of house mouse (*Mus musculus*, (Orth et al., 1996), wild goats (Manceau et al., 1999), and the white-breasted hedgehog (*Erinaceus concolor*, (Seddon et al., 2002) confirms genetic differentiation of southern and northern Caucasian populations of these species and supports this claim. It has been hypothesised that the Greater Caucasus range also divided the southern and northern Caucasus Neanderthals, the former being part of a Near Eastern network, and the latter belonging to an Eastern European network (Adler and Tushabramishvili, 2004; Meignen and Tushabramishvili, 2010). This hypothesis is supported by lithic analyses that document techno-typological similarities between northern Caucasian Neanderthals and those from Eastern Europe and the Crimea on the one hand (Cohen and Stepanchuk, 1999; Golovanova and Doronichev, 2003), and southern Caucasian Neanderthals with those from the Levant and the Zagros regions in relation with an *in situ* development from the Acheulian (Beliaeva and Liubin, 1998; Tushabramishvili et al., 2002; Tushabramishvili et al., 2007). However, techno-typological differences between Neanderthal populations from the two regions do not by itself indicate demographic isolation of the two populations.

Palaeoanthropological and Palaeolithic research has addressed the question of the Neanderthal-AMH interface, and the timing and nature of the MP–UP transition both in Europe, the Near East and the Caucasus (Hublin, 1998; d'Errico et al., 1998; Adler et al., 2006a, b;Delson and Harvati, 2006; Hublin and Bailey, 2006; Finlayson and Carrión, 2007; Banks et al., 2008). However, in order to test various models regarding these aspects it is essential to first develop reliable and accurate chronostratigraphic sequences for key sites that span the Middle to Upper Palaeolithic transition (Jöris et al., 2011) in conjunction with the direct dating of human fossils from relevant contexts. The latter is of particular importance since it is known that there need not be congruence between cultural and biological similarities, as different human species can manufacture similar lithic industries. This has been well documented in the case of the Levant for example (Shea, 2003). In Europe a range of lithic industries has been excavated from various Palaeolithic sites and these include the Proto-Aurignacian and other so-called Initial Upper Palaeolithic industries that may have been made by AMHs and also may have originated from the Near East (Hoffecker, 2009, 2011) . However, confidence in diagnosing the manufacturer is low due to the limited number of hominin fossils (mostly isolated teeth) in association. Clearly, the paucity of fossils is a major issue that cannot be overcome in the near future, but it is important that it is taken into consideration in cases where key assemblages cannot be attributed with a sufficient level of confidence to a particular hominin species.

In the case of both the northern and southern Caucasus there is a clear association between LMP assemblages and Neanderthal fossils when human remains are available. There is no evidence of what may be called 'transitional lithic industries' in any of the sites from these regions (Adler et al., 2006b). The archaeological and behavioral records of UP occupational phases in both the northern and southern Caucasus are attributed to AMH (Adler et al. 2006b; Golovanova et al. 2010).

Several Neanderthal fossils have been recovered from the sites of Mezmaiskaya, Barakaiskaya, Monasheskaya in the northern Caucasus. Of these the only directly dated fossils are Mezmaiskaya 1 from Layer 2B which has been dated to 29,195 ± 965 BP[1] (Ua-14512) (Ovchinnikov et al., 2000). However, for a variety of archaeological and taphonomic reasons this date is likely a serious underestimate of the sample's true age. In a more recent study the Mezmaiskaya 2 Neanderthal infant from the overlying Layer 2 has been directly dated to 39,700 ± 1,100 BP (Pinhasi et al., 2011), confirming that the date of Mezmaiskaya 1 must bean underestimate of its true age. The age of other human fossils, such as those from Monasheskaya and

[1]Radiocarbon ages in this paper are expressed as conventional ages BP, whilst calibrated or calendar ages are expressed as 'cal BP'.

Barakaiskaya, is currently unknown. Attempts made by our team to date these bones failed due to low bone nitrogen yields, between 0.1 and 0.31% for several bone samples of Monasheskaya, while the Barakiskaya mandible sample had a nitrogen yield of 0.88 but produced an insufficient collagen yield and was therefore not dateable.

In the southern Caucasus all known Neanderthal fossils are from MP contexts and are fromsites in western Georgia (Imereti Region). These fossils are fragmentary and lack a clear burial context. With the exception of a partial maxilla from the site of Sakajia (see below), all other remains consist of a few isolated teeth. These come from the sites of Bronze Cave (level 8), Djruchula (level 2), Ortvala (level 3a), and Ortvale Klde (level 5) (Liubin, 1977, 1989; Gabunia et al., 1978; Vekua, 1991; Schwartz and Tattersall, 2002). Recently, a lower right deciduous second molar was recovered from and Upper Paleolithic sub-layer Vb at Bondi Cave. The anthropological analysis of this tooth (based on external morphology) could not ascertain whether it belonged to a Neanderthal or AMH (Tushabramishvili et al. 2012).

Sites in the Caucasus with MP occupational sequences have yielded a range of diverse Mousterian lithic assemblages. Historically, five major groups of 'traditions'have beenidentified mainly based on typological criteria, and were correlated to different Mousterian groups (Liubin, 1977, 1989; Tushabramishvili, 1978, 1984; Golovanova and Doronichev, 2003): the 'Tsopi complex' (Tsopi site), the 'Tsuthksvati complex' (Bronze Cave), the 'Djruchula-Kudaro complex' (Kudaro 1 and 3 , Tsona and Djruchula caves), the 'Tskinvali complex' (sites of Kusreti I-III, Pekvinary), and the 'Tskaltsitela complex' (Ortvale and Sakajia caves) (Golovanova and Doronichev, 2003). During the past 20 years, new studies of assemblages from these sites confirmed this typological diversity and tried to assess whether it reflects regional variation in local resources, local adaptation to different ecotones, climatic variations, or a combination of these elements. In any case, the ability to attempt to test hypotheses and develop new ones in regards to such aspects first requires the refinement of existing chronologies and the new dates from stratigraphic sequences in key sites (Meignen and Tushabramishvili, 2006; Pleurdeau et al., 2007; Tushabramishvili et al., 2007).

Our current archaeological knowledge about the timing of the LMP and EUP in the northern Caucasus is based on >50 radiometric dates from the site of Mezmaiskaya (Golovanova et al., 1998, 1999, 2006, 2010a, b). The timing of the MP-UP transition in Mezmaiskaya was until recently based on 6 AMS dates for the earliest UP layer (Layer 1C). The age of the latest MP layer (Layer 2) was based on 3 radiocarbon dates which fell in the range of 32–35 ka ^{14}C BP, and ESR dates which fell in the range of 36.4 and 41.8 ka BP (early uptake) or between 36.9 and 42.3 ka BP (linear uptake) (Golovanova et al., 2010b). While these EUP and LMP ranges overlap, the stratigraphic record of the cave indicates an erosional gap consisting of a sterile layer, 1D, which had been deposited after the formation of Layer 2 and before the formation of Layer 1C. In a recent paper Pinhasi et al. (2011) systematically dated a series of 16 ultrafiltered bone collagen samples from LMP layers and obtained a direct date for the Mez 2 Neanderthal infant from Layer 2. Bayesian modeling was used to produce a boundary probability distribution function (PDF) corresponding to the end of the LMP. The direct date of the fossil (39,700 ± 1,100 14C BP) is in good agreement with the PDF, indicating that Neanderthals were not present at Mezmaiskaya Cave after 39 ka cal BP.

Until recently, the chronology of the Middle and Upper Palaeolithic of the southern Caucasus was predominantly based on the chronometric record of 76 radiocarbon, thermoluminescence (TL), and electron spin resonance (ESR) determinations from the site of Ortvale Klde (Adler et al., 2008) and 30 radiocarbon dates from the site of Dzudzuana; both located in western Georgia (Bar-Yosef et al., 2006, 2011). However, there are no direct dates for any Neanderthal fossils from this region. Prior to the present study, our knowledge about the timing of the MP in other cave sites in western Georgia was based on a single non-AMS radiocarbon determination on a piece of animal bone (GIN-6250, 27,000 ±800 BP) for MP Layer 3c in Sakajia (Nioradze, 1991). This determination appears to be too young and of questionable quality (Pleurdeau et al., 2007).

At Ortvale Klde an occupational hiatus of undetermined length overlies stratigraphically the latest MP layer (Layer 5) and is overlain by the earliest UP layer (Layer 4) (Adler and Tushabramishvili, 2004). Moreover, the analysis of the archaeological and chronometric data suggests a rapid techno-typological change in lithic assemblages which best agrees with a scenario of a biological replacement of MP Neanderthals by UP AMHs. The age of the boundary between the Middle and Upper Palaeolithic is currently assessed to fall ~42.8 ka cal BP_{Hulu} (calibration curve based at the time on the Chinese Hulu Cave speleothem records), with a conservative estimate between 42.8—41.6 ka cal BP_{Hulu}. However, the actual dating of the LMP occupation is determined on the basis of two independent dates on a single bone from this layer which yielded a calibrated weighted mean range of 42860 ± 588 cal BP_{Hulu}(Adler et al., 2008).

Recent results from the nearby site of Bondi Cave have provided some new information about the MP-UP transition in the region. So far, excavations have yielded two cultural complexes, with layer VII (uppermost layer of MP affinities) dated to between 38.7—35 ka BP (43—40 ka cal BP_{Hulu}) and layers V to III (UP levels) from 24.6—14 ka BP (29—17 ka cal BP_{Hulu}) (Tushabramishvili et al., 2012). These two complexes are separated by Layer VI, which is predominantly sterile (with a few UP lithics that may bederived from the overlying UP Layer V) and contains large collapsed blocks. Its age is currently based on a single determination: 31.3 ka BP (35.4 ka cal BP_{Hulu}). The timing of the end of the MP and of the UP replacement at this cave is not currently clear. The transition may have been rapid or may have involved a hiatus. Nonetheless, the timing of the LMP occupation at Bondi seems to be within the confidence range of that reported for Ortvale Klde.

These chronometric sequences suggest that Neanderthals may have not existed in the southern or northern Caucasus after 39 ka cal BP. However, this claim is currently based on results from only a few sites and as such it cannot account for possible intra regional variations in the nature and timing of Neanderthal occupation in the Caucasus. In this paper we provide a new chronology for the MP occupational phases in the caves of Sakajia, Ortvala and Bronze Cave based on fieldwork in western Georgia during 2009-2010. The radiometric dates obtained for these sites have been assessed through a series of model-based Bayesian analyses of the calibrated determinations. This has allowed the establishment of probability intervals for the beginningand end of each of the dated levels and for the end of the MP occupation at the three sites. We then assess the implications of the revised chronology in the context of the timing of the final Neanderthal occupation of Neanderthals in western

Georgia, and address the broader implications of these results in the context of Neanderthal extinction and the end of the MP in the Caucasus and neighboring regions.

Methods

All radiocarbon samples were obtained during the 2009 fieldwork season. This involved the following steps:

(1) The establishment of the original grid foreach cave based on datum and marked points in the cave using a Leica Total Station and NewPlot software.
(2) Cleaning and documentation of key sections in each cave (see below) and recording of topographic lines for all key archaeological stratigraphic units (or layers).
(3) Sampling of ungulate bones and teeth from the cleaned sections thatwere recorded with the Total Station/New Plot. The sampling strategy was aimed at obtaining several samples for each layer with a particular focus on adequate sampling of layers that yielded Neanderthal fossils.

A total of 81 bone samples were selected and a quality assessment of the potential collagen yield of each bone was based on the analysis of percent nitrogen (%N) yield and the C:N atomic ratio of the whole bone. The cut off point for samples which had the potential to yield sufficient collagen was %N> ~0.7 (Brock et al., 2010). Experience shows that samples with lower nitrogen yield tend to have very low to no collagen yields. These bones are often more likely to be affected deleteriously by modern carbon contamination and therefore to produce unreliable radiocarbon determinations (van Klinken, 1999; Brock et al., 2010; Higham et al., 2010, 2011). Bone samples were also taken from a Neanderthal maxilla from Sakajia cave, and a Neanderthal tooth from Ortvala.

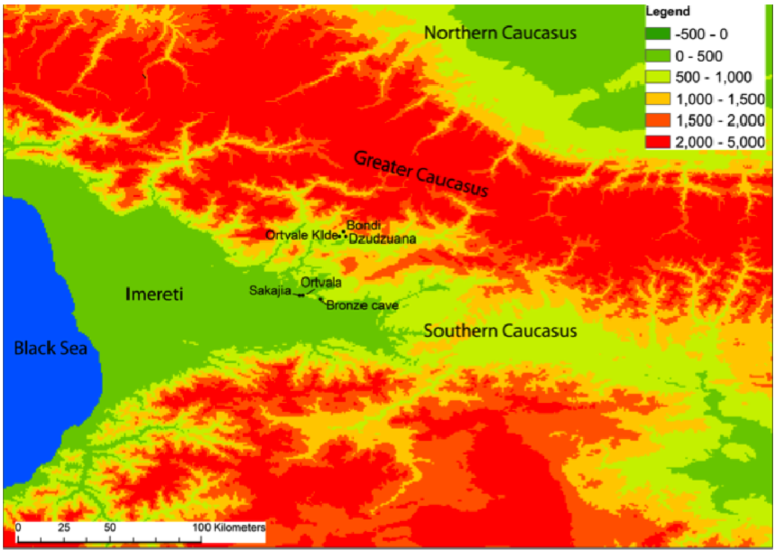
Of the total number of samples only 14 had percent nitrogen yields higher than 0.7 and these were taken to full pretreatmentand then AMS dating at the Oxford Radiocarbon Accelerator Unit (ORAU), University of Oxford. In the case of the Neanderthal fossils, %N yields for the two samples were below the established cut-off point for dating (%N=0.02 for Ortvala and 0.05 for Sakajia) and these were therefore not dated.

Collagen was extracted using the methods outlined by Bronk Ramsey et al. (2004), Higham et al. (2006a, b) and Brock et al. (2010). A final ultrafiltration step was applied after Brown et al. (1988) and Bronk Ramsey et al. (2004). This method has been shown to improve the reliability of the ages obtained by more effectively removing low-molecular weight contaminants (Higham et al., 2006b). Radiocarbon ages are given as conventional ages BP (Stuiver and Polach, 1977). The ^{14}C ages have been corrected for laboratory pretreatment background using a bone specific background correction (Wood et al., 2010). All analytical parameters measured were within accepted ranges (see Tables 1-3)

Below we provide the results for each of the sites, including the new uncalibrated radiocarbon determinations as well as the all the other published radiocarbon determinations for these sites. Bayesian modeling was applied to the sequences from Ortvala and Sakajia, but not to Bronze Cave, as all of the obtained AMS determinations were 'greater than' ages BP, and hence could not be modeled accurately with respect to the calibration curve. Bayesian models were built using OxCal4.1 (Bronk Ramsey, 2009a) and the INTCAL09 calibration curve (Reimer et al., 2009). Bayesian modeling allows the relative stratigraphic information gleaned from the site during the excavation to be modeled within a formal chronometric framework along with the calibrated radiocarbon likelihoods. Posterior probability distributions incorporatingan outlier detection analysis method (after Bronk Ramsey, 2009b) were used to assess outliers in the models we ran. In each model a general *t*-type outlier model was included, with a prior probability set at 0.05.

New chronometric data for western Georgia

The three cave sites are located in the forested region of western Georgia, close to the foothills of the Greater Caucasus range at an altitude of between 240–350 m above sea level (asl) (Figure 1).



Sakajia

Sakajia Cave is situated in the Imereti, Region, about 10 km northeast of the village of Kutaisi at an altitude of 222 m asl 80 m above the left bank of the Tskhaltsitela river. The cave was discovered in 1914 by Rudolph Schmidt and Leon Koslowski and was first excavated by G. Nioradze during 1936-1937 (Nioradze, 1937, 1953). These excavations showed the presence of an UP layer but work was stopped during WWII and no results have been published. In 1971, M. Nioradze continued research on the site and between 1974 and 1980; she directed excavations that demonstrated the existence of MP layers (Gabunia et al., 1978; Nioradze, 1994).

The cave has an oval entrance of 5-6 m width and 7 m height. Ten m into the cave, from the drip line, it separates into two galleries, one is 20 m long and the other is 70 m long (Pleurdeau et al., 2007). Sakajia's stratigraphy consists of a total of 7 archaeological layers that were studied and sampled at the inferior section of the longer gallery with a total thickness of sandy sediments of 4.5 m (Figure 2). The topmost Layer 1 yielded Bronze Age and Chalcolithic artifacts and overlies Layer 2 ,which yielded Upper Paleolithic artifacts. The stratigraphic sequence contains six Middle Paleolithic Mousterian layers (3a–3f) which yielded 1500 lithics in total, mainly made on local flint/chert (Sakajia means 'flint place'), the majority of these (75%) are from layer 3a and 3b and there were only isolated artifacts from the lower layers 3e and 3f (Pleurdeau et al., 2007). Neanderthal remains were recovered from Layer 3a (skull fragments), Layer 3b (a lower molar), and Layer 3d (maxillary fragment with four teeth: upper first canine, upper first premolar, upper second premolar and upper first molar) (Gabunia and Vekua, 1990).

At Sakajia, as at Ortvala Cave (G. Nioradze,1953; M. Nioradze, 1992; Pleurdeau et al., 2007), Levallois core technology is clearly identified (the use of both preferential and recurrent methods) and reduction is for the most part oriented towards elongated-blady products. Tools are abundant. They are mainly made on blades and include retouched points, simple, convergent, and *déjeté* side-scrapers, and denticulated and notched tools (Golovanova and Doronichev, 2003).

The uncalibrated AMS determinations and information about the chemistry are provided in Table 1. We performed a sequential model Bayesian analysis on this series and the results are provided in Figure 3. The boundary distribution for the end of 3a is equivalent to 40200 –37140 cal BP (68.2 % prob.), but the range is wide because there appears to be a temporal gap between layers 3a and 3b at the site. Despite this imprecision, the boundary marks the start of the UP at the site. The estimated age for the Neanderthal remains in the uppermost level within which they occur is 46800–42200 cal BP (at 68.2% prob. calculated using a 'Date' command nested within the 3a level using OxCal).

Fig 2

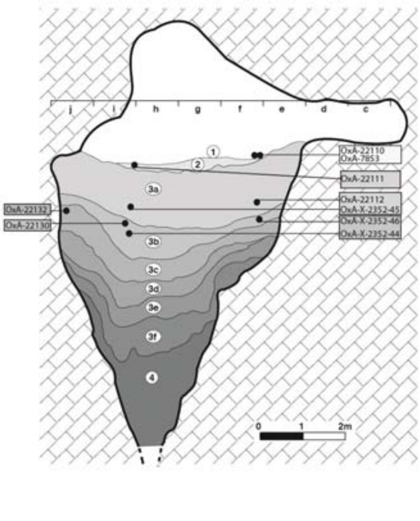
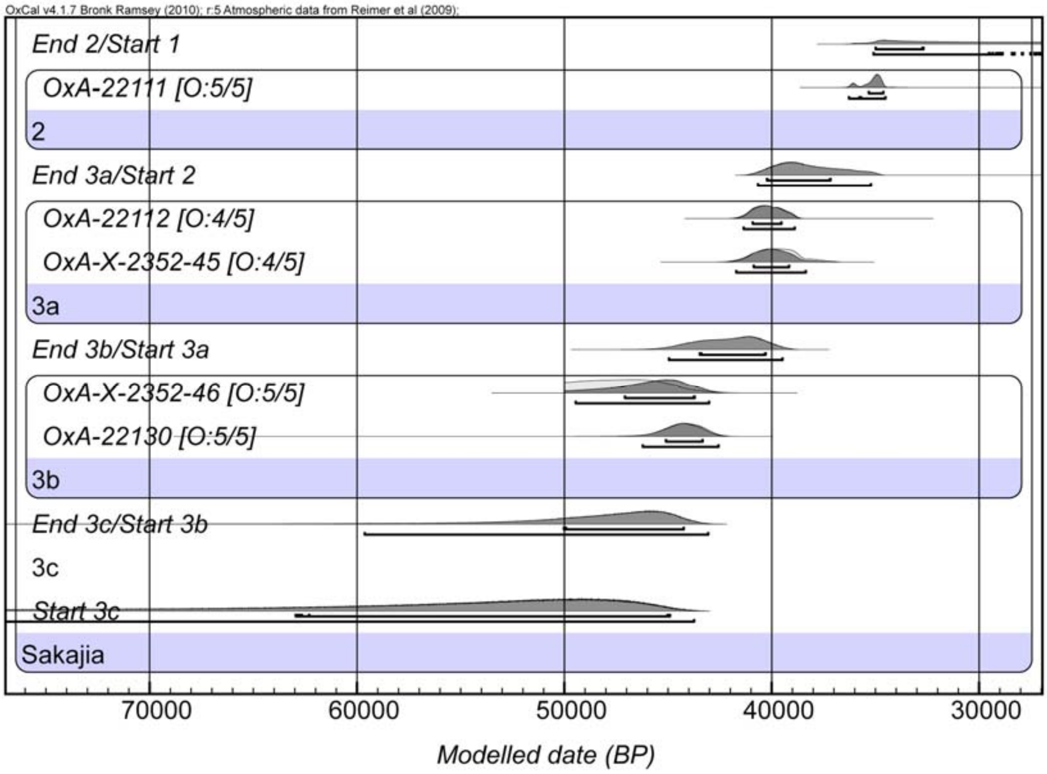


Figure 3



<<Table 1>>

Ortvala

Ortvala Cave is situated in the Imereti region near the village of Didi Rgani at an altitude of 240 m asl. The cave was excavated by M. Nioradze during the 1974-75 and 1980-1989. The cave at its current entrance is four m wide and two m high. At eleven m depth from the entrance the cave divides into two galleries: the right corridor is 3.5 m high, 1.5 m wide and 40 m long; and the left corridor is 3 m high, 1.3 m wide and 20 m long. Our chronometric study focused on the longitudinal section of the right corridor (Figure 4). Seven archaeological layers have been excavated. Layer 1 of the cave yielded Chalcolithic and Early Bronze Age artefacts and pottery. The underlying Layer 2 yielded UP artefacts and bones. The underlying layers, 3, 3a–3d yielded MP artefacts. Two Neanderthal teeth have been found in Layer 3a. Underlying the MP strata there is a sterile layer (layer 4), which overlies the bedrock. The total thickness of the sediments is between 2-2.5 m.Five strata (3–3d) yielded MP lithics. In total 450 artifacts were reported, but most of them (303 pieces) were found in the lower layers

3c and 3d (Nioradze, 1992). In all the MP layers, production is almost exclusively oriented towards flakes and there are very few blades and points. The few cores are mostly of a Levallois-type flaking surface. Retouched flakes are abundant, and contain retouched points, side-scrapers, and denticulates. These have been attributed by M. Nioradze (1992) as Levallois, faceted Mousterian, with a Middle to Upper Paleolithic transitional character in the uppermost layers (Golovanova and Doronichev, 2003).

The AMS determinations and information about the chemistry are provided in Table 2.

There are few results that one can include in a Bayesian model, so the model we have produced is very simple and only consists of a single phase. We used the two duplicate results from Layer 3, and excluded the 'greater than' age from the model. The results are provided in Figure 5. A Neanderthal molar was recovered below layer 3 in level 3a. Modeling results indicate that this molar probably dates prior to 44580–42420 cal BP (at 68.2%), this being the boundary for the end of Level 3a and the start of Level 3.

Fig 4

Ortvala Longitudinal Section H8-H17

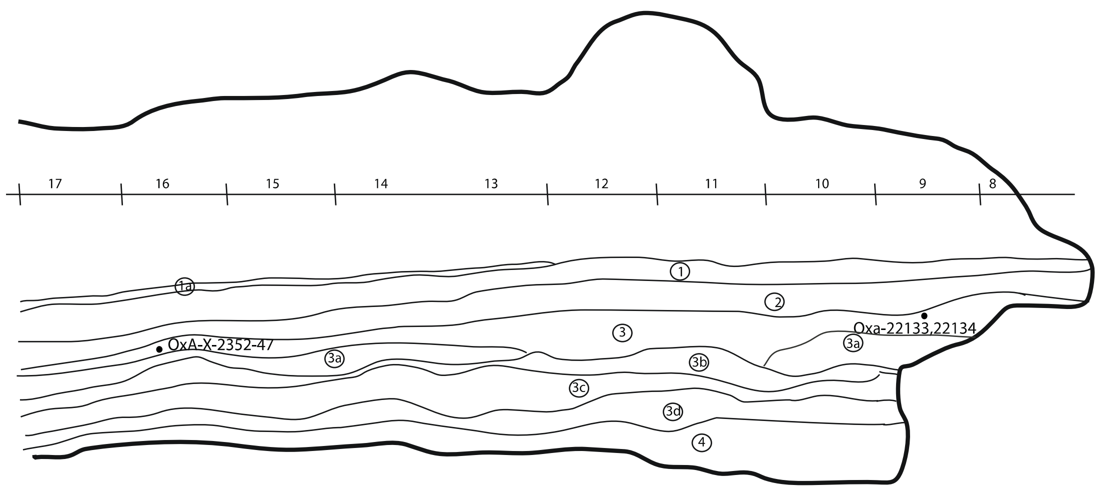
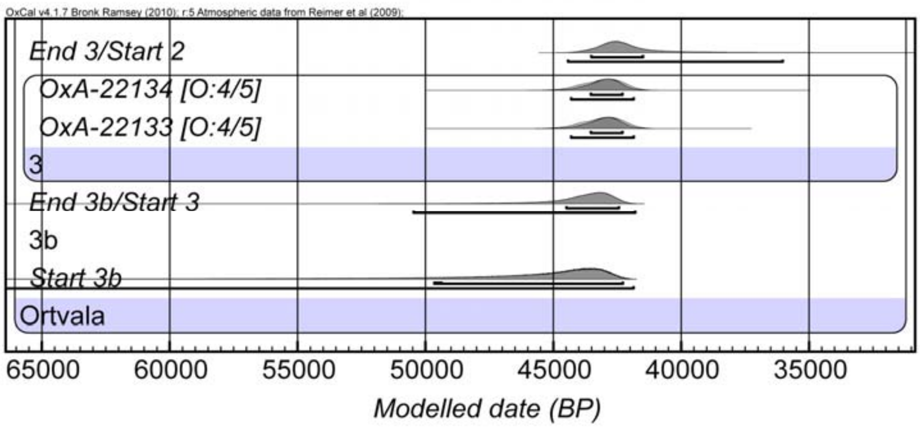


Figure 5



<<Table 2>>

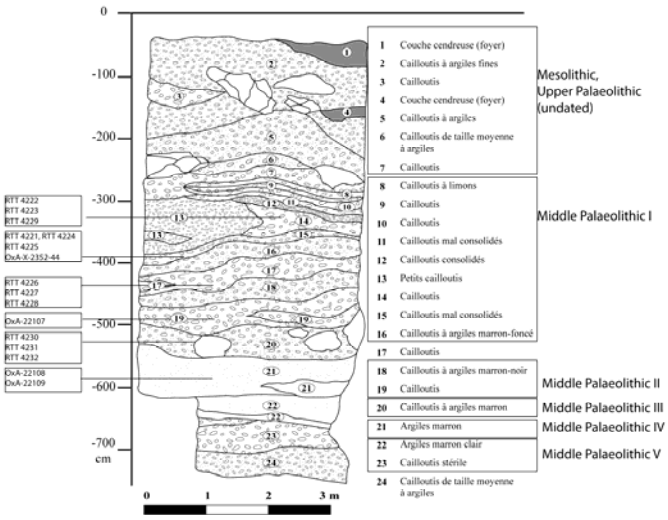
Bronze Cave

Bronze Cave is part of the Tsutskhvati cave complex which includes five cave sites and is located 12 km north of Kutaisi in western Georgia at an altitude of 300-350 m asl. All sites were excavated in 1970-1971 and 1974-1978 under the direction of D. Tushabramishvili of the Georgian National Museum. Four of these sites yielded a very limited number of diagnostic lithic artefacts. Subsequent fieldwork in 1993-1994, 2003-2004 (directed by N. Tushabramishvili) focused on Bronze Cave, which is the most promising site in the complex in terms of the density of lithics, bone preservation and anthropogenic indicators(combustion areas, bone processing evidence, etc.). The cave has 24 lithological layers that are ~18 m thick in total. Five MP layers were identified that are 6m thick, spanning twelve lithological layers (Tushabramishvili, 1978). The first MP layer (Layer MP 1) has a thickness of 3 m which is approximately half of the total MP thickness. Only layers MP2-MP5 are regarded as *in situ* occupation layers and their thickness varies between 0.5 to 0.8 m (Figure 6). A total of 12,500 lithics were excavated from layers MP2-MP5. The industry is characterized by a unipolar recurrent reduction sequence (non-laminar), partly by a Levallois core technology (25% of the cores), discoid-type flaking (Pleurdeau et al., 2007), and a predominance of side-scrapers and denticulated/notched tools (26–29%). Retouched points are poorly represented (Golovanova and Doronichev, 2003). The industry has been defined as part of the 'Tsutskhvati Group'(Golovanova and Doronichev, 2003). The high percentage of denticulates in the Tsutskhvati complex lithic assemblages (Tushabramishvili, 1978) areeither an indicator of a local tradition (Golovanova and Doronichev, 2003), the products of specific activities or are due to taphonomic processes (Pleurdeau et al., 2007). Influences coming from the Zagros area have also been suggested to explain these series, mainly based on the small size of the products. However, more data are necessary before one can favour one of these alternatives.

Radiocarbon results indicate that Layer MP1 is >44100 BP (OxA-X-2352-44). This date is in agreement with the one for the underlying layer MP2 which is >48500 BP (OxA-22107), and >50,000 BP AMS determinations for layers MP 3 and MP4 (OxA-22108, OxA-22109, respectively). This suggests that all previous determinations are very likely to be underestimates. The MP archaeology of the site is older than ~46000 cal BP and therefore more ancient than the other sites we have analyzed. A Neanderthal deciduous molar was recovered from level 8 (MP1) but due to its fragmentary condition it has not been sampled for direct dating.

<<Table 3.>>

Fig 6



Discussion

Our aim in this work was to develop reliable chronostratigraphic sequences for MP occupation at the sites of Bronze Cave, Sakajia and Ortvala based on Bayesian modeling of new ultrafiltered radiocarbon determinations. A particular focus has been the direct dating of Neanderthal fossils from these sites (the molar from Ortvala and a maxilla fragment from Sakajia). However, as indicated above, the nitrogen preservation in these fossils indicates that they are unlikely to have enoughcollagen for reliable radiocarbon dating. Nonetheless, we were able to date ungulate teeth and bone obtained from sections at these sites with a particular focus on layers that yielded Neanderthal fossils. We also concentrated on the dating of the latest MP occupation at each site in order to derive reliable estimates for the age of the ending of the MP and possible Neanderthal extinction at each site.

The analyses of radiocarbon dates for LMP occupational phases in Sakajia and Ortvala support a model of a coincident/simultaneous/synchronous Neanderthal disappearance at both sites, although more precision is required to increase confidence. The modeled calibrated chronology for Sakajia indicates the ending of the Late MP (Layer 3a) occurred between 41—36.6 ka cal BP (95.4% prob.). Further radiometric analysis, utilizing Bayesian sequential modeling and additional radiocarbon determinations from the LMP and EUP levels would be required to provide a narrower time interval for the ending of the MP. In the case of Ortvala the latest Middle Paleolithic occupation level is older than 41.7 ka cal BP.

The MP sequence obtained for Layers MP1-MP5 at Bronze Cave indicates that the upper level, MP1, is older than >44100 ka BP. Adler et al (Adler et al., 2008) obtained eight bone and twelve charcoal samples from Levels MP1–MP3 of the same section in Bronze Cave (Figure 6). Only the 12 charcoal samples have been processed (Adler et al., 2008, Table 10) and these did not provide a coherent set of dates (as some determinations for MP1 vary between uncalibrated estimates of ~23 ka BP to ones that suggest an age >45 ka BP). It is possible that the inconsistency in the obtained range was due to sample contamination as these charcoal fragments were not pretreated with the ABOx-SC step (acid-base-oxidation-stepped combustion) (cf. (Brock and Higham, 2009; Higham et al., 2009a) although it is also likely that these inconsistencies reflect the dynamic taphonomic history of the site in which younger, small charcoal fragments are more likely to get into lower layers via bioturbation and other means (Adler et al., 2008). Our new determinations on selected bone samples provide a chronologically consistent age range. They are also in agreement with Golovanova and Dornoichev's (2003) assessment which is based on lithic typology and suggests that layer MP1–MP5 is older than MP levels 5-7 in Ortvale Klde and Levels 3b and 3c at Sakajia (Golovanova and Doronichev, 2003). This would have formed during Marine Isotope Stage (MIS) 4/early MIS 3 (~76-50 ka BP).

The Bayesian model for Sakajia indicates that the onset of the UP (Layer 2) started between 39.3 and 34.7 ka cal BP (95.4% confidence interval), however, this is currently based on a single radiocarbon date. At Ortvale Klde the demise of the last Neanderthals and the establishment of modem human populations took place 38–34 ka BP (42–39 ka cal BP) but the onset of the UP is currently based on a single radiocarbon determination from Unit 4d.

The first appearance of modern humans in the region and the earliest stages of the UP are evident from the lowermost UP Layer D at the nearby site of Dzudzuana which has been radiocarbon dated to c. 34.5–32.2 ka cal BP. The industry of Unit D also resembles the early UP assemblages from Unit 4 at Ortvale Klde and Level 1C at Mezmaiskaya. The latter is radiocarbon dated to c. 38.2–36.8 ka cal BP (Golovanova et al., 2006). These dates taken together with the lack of evidence for techno-typological continuity imply that the current data best supports a model of AMH arrival in both the northern and southern Caucasus after the last occupation of these regions by local Neanderthal populations. The lack of evidence for a local MP–UP transition and the evidence makes this the most plausible scenario.

Recently revised chronologies for the timing of the MP–UP transition in various parts of Europe indicate that previous determinations are often underestimates of the true age (Golovanova et al., 1999; Higham et al., 2009b, 2010, 2011). At present, there are no reliably dated Neanderthal fossils younger than 38 ka BP (~40 ka cal BP, [cf. (Jöris et al., 2011; Pinhasi et al., 2011). In Europe, directly AMS dated late Neanderthals from MP layer 7a at the Kůlna cave in the Czech Republic, the Neanderthal site in Germany, the cave of El Sidron in Cantabrian Spain, and of Vindija Vi-80 from Layer G3 at Vindija in Croatia produced ages which are greater than or equal to 38 ka BP.The key site of Spy, in Belgium, has produced two direct AMS dates on Neanderthal bone and teeth that can be refitted to the adultNeanderthals Spy I and II, and date to ~36,000 BP (41 ka BP) (Semal et al., 2009; Pirson et al., 2011).The teeth and bones were found among unsorted fauna and were not affected by the varnish contamination that had been a problem for the majority of the human remains (Pirson et al., 2011). These direct ages are the most recent for any Neanderthals in Europe. Taken together, these results imply that Neanderthals may well not have survived in Europe after ~40 ka Cal BP.

Until recently, there were no unambiguous AMH fossils in Europe between 38–35 ka BP (43-40 ka cal BP). The earliest reliably dated AMH fossils in Europe had been from Peştera cu Oase in Romania, dated to ~38.9—41.0 ka cal BP (Trinkaus, 2007; Trinkaus and Shang, 2008). However, recently published data have shown that AMH were present in Europe prior to this, from ~45-42 ka cal BP. At Kent's Cavern in Britain a human maxilla (KC4) dates to 44.2–41.5 ka cal BP (Higham et al., 2011) based on the analysis output from a Bayesian model rather than a direct AMS date. In addition, a recent study by Benazzi et al. (Benazzi et al., 2011) showed that the Uluzzian is likely to be an AMH industry based on the reanalysis of the teeth from the site of Cavallo, southern Italy and dates to ~45-43 ka cal BP (Benazzi et al., 2011; Higham et al., 2009b). Like Kent's Cavern, the date range is also determined using a sequential Bayesian model.

Various theories have been put forward to explain Neanderthal extinction. As pointed out by Banks et al. (Banks et al., 2008), debates regarding Neanderthal extinction in Europe have involved a number of issues: (a) relationships between archaeologically-defined cultures and particular human populations (i.e., Neanderthals or AMH); (b) possible interactions between Neanderthals and AMH; (c) mechanisms behind Neanderthal extinction; and (d) the timing of this population event. As has been discussed above, the relationship between particular archaeologically-defined cultures and human populations requires the association of these technocomplexes diagnostic fossils. As has been pointed out by Jöris et al. (2011), (see alsoHoffecker, 2009) there are still a range of 'transitional' Middle-Upper Palaeolithic technocomplexes (especially in Central Europe) that either have yielded no associated human fossil, a few isolated bones or teeth that cannot be attributed with certainty to Neanderthals or AMH. A number of mechanisms have been suggested to explain Neanderthal extinction. These include a range of models that emphasize one or more of the following aspects: cultural and technological superiority of AMH, demographic advantages of AMH (longer life span, higher reproductive rate, shorter birth spacing (cf.Harvati, 2007), AMH social networks and advantageous hunting capacities, and other factors which explain Neanderthal extinction as an ecological process (cf.Flores, 1998; Harvati, 2007; Banks et al., 2008; Sørensen, 2011). Othersview Neanderthal extinction to be predominantly attributed to changes in climate (Stringer et al., 2003; van Andel and Davies, 2003; Finlayson et al., 2006; Finlayson and Carrión, 2007; Jiménez-Espejo et al., 2007; Tzedakis et al., 2007) or a combination of factors (Stringer, 2012).

At this stage, the extent to which modern humans and Neanderthals in Europe interacted culturally and biologically remains unclear (Hoffecker, 2009). The archaeological record does not provide convincing evidence for interstratifications of Neanderthal and modern human occupation and revised chronological determinations of pendants from Grotte du Renne questions the validity of the claim that all of the 'Châtelperronian' symbolic objects were associated with Neanderthals (cf. Higham et al., 2010; Zilhao et al., 2006). It is therefore clear that the question of the Neanderthal-AMH interface in Europe is far from being resolved. Refined chronologies now indicate that (1) the first appearance of AMH in Europe appears to have substantially predated the demise of the last Neanderthals and (2) Neanderthal-AMH coexistence in some regions of Europe may have occurred during ~45-40 ka cal BP but not during subsequent millennia as was previously assumed.

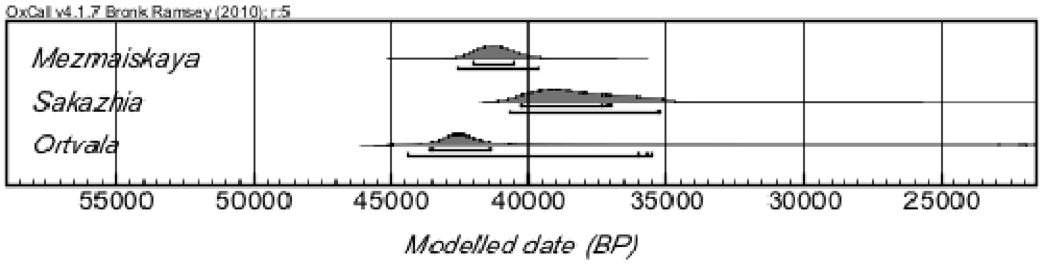
Conclusions

Our modelled calibrated chronology for Sakajia indicates the ending of the Late MP (Layer 3a) and the start of the UP (layer 2) occurred between 40200 – 37140 cal BP. The modelling of MP layers at Ortvala indicates that the ending of the LMP in this site occurred between 43540–41420 cal BP (at 68.2% prob.) and 44460–35340 cal BP (at 95.4% prob.). Both these ranges fit well with those for Ortvale Klde (Adler et al. 2008).

The dating of layers MP1, MP2, MP4 and MP5 Bronze Cave (Figure 7) indicates that these are all older than 44.1 ka BP (date for the uppermost MP layer), and hence this cave does not contain LMP occupational levels, as in the case of Sakajia and Ortvala.

We summarise the results in Figure 7 and compare them with those obtained for Mezmaiskaya (Pinhasi et al., 2011).

Fig 7.



These results refute the previous assumption of late local Neanderthal survival in the Caucasus and the suggestion that this late survival was the reason behind the relatively late AMH colonization of this region (e.g. (Hoffecker, 2009). More research is required in order to refine or challenge these chronologies and Sakajia is, at present, still imprecisely dated. However, at this stage, evidence from both the northern and southern Caucasus best fits with a model of Neanderthal extinction in the region prior to the first arrival of AMH. It also implies that there is no evidence to support the concept of late Neanderthal survival in the Caucasus, suggestingthat this region was not a refugium for final Neanderthals.

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Figure Captions

Figure 1. Location of the three Palaeolithic cave sites, Imereti Region, Republic of Georgia.

Figure 2. Section of Sakajia cave and location of radiometric samples analysed in this study.

Figure 3: Bayesian model for Middle to Upper Palaeolithic levels at the site of Sakajia. OxA-22132 has been left out of the model because it is beyond the range of the calibration curve. There are no significant outliers in the model.

Figure 4. Longitudinal section of Ortvala cave and location of the radiometric samples analysed in this study.

Figure 5. Bayesian model for Ortvala cave.

Figure 6. Stratigraphic section of Bronze Cave with indication of the locations from which (1) ungulate bone samples (OxA determinations, present study) and (2) charcoal samples (RTT determinations, Adler et al. 2008) were selected.

Figure 7. Calibrated modeled intervals for the end of the Middle Paleolithic at the sites of Mezmaiskaya, Ortvala and Sakajia caves.