News and views

Bottleneck at Jaramillo for human migration to Iberia and the rest of Europe?

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In the contemporary paleoanthropological literature, there is a general consensus that the earliest peopling of Europe occurred before the Brunhes–Matuyama geomagnetic polarity reversal at 0.78 Ma, based on convincing magnetostratigraphic evidence from Spain (e.g., Carbonell et al., 1995; Parés and Perez-Gonzalez, 1999), Italy (Muttoni et al., 2011), and northern Europe (e.g., Parfitt et al., 2005). However, there is intense debate about how much before 0.78 Ma the earliest peopling occurred.

Proponents of a long chronology claim that Europe was inhabited well before 1 Ma. For example, the lithic tool-bearing site of Pirro Nord in southern Italy has a stated biostratigraphic age of 1.6–1.3 Ma (Pavia et al., 2012; López-García et al., 2014), and sections with lithic tools from the Guadix-Baza basin of southern Spain near Orce were claimed to have magnetostratigraphic and Electron Spin Resonance (ESR) ages of 1.4–1.3 Ma (Scott et al., 2007; Toro-Moyano et al., 2013; but see Muttoni et al., 2013), while Sima del Elefante (Atapuerca) in northern Spain has a reported cosmogenic burial age of 1.2 Ma (Carbonell et al., 2008; Garcia et al., 2014). These dates, close to the earliest ages available for western Asia (~1.7 Ma at Dmanisi; Gabunia et al., 2000; Lordkipanidze et al.,

2007), imply peopling of Europe before the Jaramillo normal geomagnetic polarity subchron (1.07–0.99 Ma; time scale of Lourens et al., 2004), even though the Jaramillo is nowhere to be found in these sections.

Proponents of a shorter chronology (Muttoni et al., 2010, 2013, 2014) put emphasis on the presence (or absence) of the Jaramillo in key hominin sections, while calling attention to large uncertainties in some of the other dating methods (biostratigraphic, ESR, cosmogenic), to infer that the earliest peopling of Europe occurred in a narrow time window of reverse polarity prior to the Brunhes–Matuyama boundary (0.78 Ma) but after the Jaramillo normal polarity subchron (0.99–1.07 Ma), coinciding with the most profound global climatic and biological changes of the Pleistocene. The Jaramillo has therefore attained the status of a marker datum useful for separating the long (>1 Ma) from the short (<1 Ma) chronology of the earliest peopling of Europe. However, sites with hominin remains and/or lithic tools containing even partial records of a demonstrable Jaramillo remain exceptionally rare in Europe; these sites are:

1) <u>Cà Belvedere</u>. In northern Italy, the tool-bearing site of Cà Belvedere near Monte Poggiolo was dated using magnetostratigraphy and interfingered marine (nannofossil) biostratigraphy from five distinct sections and a long drill core to ~0.85 Ma in a time interval of reverse polarity between the top of the Jaramillo and the base of the Brunhes (Muttoni et al., 2011).

2) <u>Cúllar.</u> In southern Spain near Orce, after the pioneering magnetostratigraphic work of Garces et al. (1997), the Jaramillo was pinned down in the continuous and expanded (80 m thick) magnetostratigraphic profile at Cúllar extending from the Olduvai across the Jaramillo into the Brunhes, with lithic tools of the Cúllar Baza-1 site traced only 2 m above the Brunhes–Matuyama boundary (Gibert et al., 2007).

3) <u>Gran Dolina</u>. In northern Spain, the Gran Dolina section at Atapuerca yielded lithic tools and hominin remains from an interval of reverse polarity located just below the Brunhes–Matuyama boundary (Parés and Pérez-Gonzalez, 1999; see also Parés et al.,

2013). One sample from the base of the section yielded a normal polarity direction that was tentatively attributed to the Jaramillo (Parés and Pérez-Gonzalez, 1999).

4) Vallparadís. In northeastern Spain, the 14 m thick Vallparadís section near Barcelona contains a clear normal-reverse-normal polarity sequence interpreted as a credible record of the latest Jaramillo—Matuyama—earliest Brunhes, but no pre-Jaramillo levels of reverse polarity have been found (see Vallparadís Profile 1 in Madurell-Malapeira et al., 2010:Supplementary Figure S4). The nearby 7 m thick conglomerate-rich Cal Guardiola section yielded data from thirteen stratigraphically distributed paleomagnetic samples with noisy but predominantly reverse polarity signals (Madurell-Malapeira et al., 2010:Supplementary Figure S4). Lithic tools from unit EVT7 of the Vallparadís section (Martínez et al., 2010), some of which are of debated anthropogenic origin (Madurell-Malapeira et al., 2012 versus Garcia et al., 2012), have been recovered in levels of reverse polarity between the top of the Jaramillo and the base of the Brunhes (Madurell-Malapeira et al., 2010) and associated with an average age of 0.83 Ma based on ESR-U/series dating of two equine molars and OSL dating of four quartz grain samples (Martínez et al., 2010, 2014), virtually the same as the weighted mean ESR age of 0.86 Ma obtained on quartz grains from level EVT7 (Duval et al., in press).

Within the framework of this well-established pre-Brunhes and post-Jaramillo chronology of the first hominin presence in Europe, we maintain (see Muttoni et al., 2010, 2014) that there is no compelling chronological evidence of hominin presence before or during the Jaramillo, supported by our critical review of evidence from Pirro Nord, Sima del Elefante, Barranco León and Cal Guardiola:

1) Pirro Nord. The Pirro Nord karst fissure fills from Apulia in southern Italy yielded (scarce) lithic artifacts (Pavia et al., 2012 and references therein). The biostratigraphic age of 1.6—1.3 Ma claimed for Pirro Nord (Pavia et al., 2012) is strongly dependent on the assumption that the Pirro faunal unit is older than the Colle Curti faunal unit attributed to the Jaramillo in the Colle Curti type section (Coltorti et al., 1998) where there is indication of magnetic overprinting of diagenetic origin (Coltorti et al., 1998; Muttoni et al., 2010, 2014). Pending the results of a reanalysis of the Colle Curti paleomagnetic profile, we maintain that in the absence of a clear Jaramillo, both the Colle Curti and the Pirro faunal units of the Italian mammal biochronological scale (Gliozzi et al., 1997) are, so to speak, 'lost in the Matuyama' without any meaningful numerical age constraint other than 0.78 Ma, should the magnetizations indeed record reverse geomagnetic polarity.

The identification of the extinct arvicolid rodent Allophaiomys ruffoi at Pirro Nord-13 led López-García et al. (2014) to conclude that Pirro Nord-13 was older than the Lower Red Unit from Trinchera Elefante (TELRU) at Atapuerca, and thus older than 1.2 Ma. A. ruffoi displays undifferentiated enamel of the molars, whereas Allophaiomys lavocati, a relative from TELRU, exhibits positively differentiated enamel, considered by most arvicolid sepcialists as a more advanced (derived) condition relative to undifferentiated enamel. Thus, if the cosmogenic date of 1.2 Ma published for TELRU is correct, López-García et al. (2014) reasoned that Pirrod Nord-13 must be older than 1.2 Ma.

There are two problems with this logic. First, as shown by Muttoni et al. (2010) and discussed below, absence of the Jaramillo in the excavations and the error margin published with the dates allow for a post-Jaramillo age for TELRU. Second, to the extent that

mosaic evolution is common in the history of organismal lineages, allowing for both underived and derived character states to exist simultaneously, a linear temporal relationship between undifferentiated and positively differentiated enamel cannot be assumed (Martin, 2014).

Indeed, the type population of Allophaiomys pliocaenicus from Betfia, Romania (Hir, 1998) is characterized by a range of differentiation including negative, undifferentiated, and positive enamel, with a mean SDQ1 (a measure of differentiation) of about 100 (undifferentiated). Negative enamel differentiation, as is commonly seen in Mimomys, the extinct ancestor of Allophaiomys, is certainly the most primitive condition relative to Allophaiomys, but it is very likely that as Allophaiomys was dispersing and branching into numerous species in the early Pleistocene, populations both within and between species displayed various combinations of enamel differentiation. Finally, there are extant Microtus species in North America that display all the categories of differentiation (Martin, 1998).

2) Sima del Elefante. The Sima del Elefante karst fissure fills from Atapuerca in northern Spain yielded lithic artifacts and a human mandible (Carbonell et al., 2008 and references therein). Archeological levels of the TELRU are associated with two out-of-sequence cosmogenic nuclide burial ages of 1.22 ± 0.16 Ma (level TE9) and 1.13 ± 0.18 Ma (level TE7), both quoted at only 1σ level of confidence (Carbonell et al., 2008), which, as noted previously (Muttoni et al., 2010, 2013), when expressed at 2σ level (95% confidence) would indicate an age range for hominin level TE9 of about 0.9—1.54 Ma (and 0.77 to 1.49 Ma in level TE7 below).

These revised ages would not preclude hominin occupation between the Brunhes—Matuyama boundary, which was found a few meters above level TE9, and the Jaramillo, which was not found in the section despite repeated and detailed sampling (Parés et al., 2006; Carbonell et al., 2008).

3) Barranco León. The Barranco León section from the Guadix-Baza basin of southern Spain yielded lithic artifacts and a human tooth (Toro-Moyano et al., 2013 and references therein). The ESR age attribution to ~1.4 Ma of the human tooth level (Toro-Moyano et al., 2013) was recently criticized because there seems to have been insufficient transport distance of quartz grains to adequately reset the noisy ESR signal prior to sediment deposition (Muttoni et al., 2013). All that can be said with any acceptable degree of confidence about the age of the archeological layer at Barranco León is that the reverse polarity interval in which it was found (Oms et al., 2000; Toro-Moyano et al., 2013) shows it is older than 0.78 Ma, the age of the Brunhes—Matuyama boundary (Muttoni et al., 2013).

The presence of A. lavocati at Barranco León-D and the correlated Fuentenueva-3 does not necessarily indicate a pre-Jaramillo age (contra Cuenca-Bescós et al., 2013), as this age attribution comes from the Sima del Elefante TELRU where A. lavocati is supposedly associated with cosmogenic nuclide dates of debated error resolution (see above), and a dubious 1.19 Ma date from Fuentenueva-3 (Martin, 2014). In addition, as noted below, A. lavocati has been recovered from a site considered to be post-Jaramillo in age in El Chaparral, Spain.

4) Cal Guardiola. The Cal Guardiola section, located near the Vallparadís section described above, contains no direct evidence of hominin presence but an important rodent association. The 7 m thick reverse polarity-dominated Cal Guardiola section was split

in two parts, a lower reverse polarity interval R1 in layers D1–D3 and an upper reverse polarity interval R2 in layers D4–D5, separated by a surface regarded as an unconformity between layers D3 and D4 (see Madurell-Malapeira et al., 2010:Fig. 2). Interval R1 was attributed to the pre-Jaramillo Matuyama (>1 Ma), and interval R2 to the post-Jaramillo Matuyama (<1 Ma), with the (undetected) Jaramillo falling in a presumed gap between R1 and R2 (Madurell-Malapeira et al., 2010; Garcia et al., 2014).

The main reason for this polarity attribution is that R1 contains *A. lavocati*, which is absent in Jaramillo or post-Jaramillo levels containing *Iberomys huescarensis* (Garcia et al., 2014). At Sima del Elefante, *A. lavocati* is present in, and *I. huescarensis* absent from, the TELRU levels with associated out-of-sequence cosmogenic burial ages of debated error resolution considered to indicate pre-Jaramillo (Table 1 in Garcia et al., 2014:90; see discussion above).

At Gran Dolina, *I. huescarensis* is present in, and *A. lavocati* absent from, levels above the (absent but assumed) Jaramillo and below the Brunhes–Matuyama boundary (Table 1 in Garcia et al., 2014:90). On these grounds, Garcia et al. (2014) concluded that level D3 at Cal Guardiola with *A. lavocati* is pre-Jaramillo while level D5 immediately above with *I. huescarensis* is post-Jaramillo, and in general they consider *A. lavocati* a reliable proxy for pre-Jaramillo time.

In contrast to this, we suggest that the absence of the Jaramillo from the Cal Guardiola section disallows an assumption of a pre-Jaramillo age for these sediments. To date, there has been no association of *A. lavocati* in a section that also has a complete record of the Jaramillo, making any mutual chronological association questionable. The best that can be said is that *A. lavocati* has been found associated with reverse polarity, which can be explained as indicating a post-Jaramillo Matuyama deposition, including its type locality at Atapuerca.

In addition to criticisms on the use of *A. lavocati* as a chronological marker (Martin, 2014), we emphasize that the apparent chronological distinction between the presumptive pre-Jaramillo *A. lavocati* and the post-Jaramillo *I. huescarensis* at Vallparadís and Atapuerca is flawed by findings in the El Chaparral site of southern Spain, where the two species were recovered together: "*A. lavocati* (…) existed longer than previously known" (López-García et al., 2012:page 1155). Therefore, it seems plausible that level D3 at Cal Guardiola with *A. lavocati* and level D5 with *I. huescarensis* both lie in the post-Jaramillo Matuyama, and that *A. lavocati* cannot be considered at present a reliable proxy to indicate pre-Jaramillo deposition.

What helps motivate our persistence in arguing for a post-Jaramillo hominin dispersal to Europe is the hypothesis that this dispersal was prompted by profound environmental change around 0.9 Ma at the onset of enhanced glacial/interglacial activity marking the late Early Pleistocene revolution (EPR; formerly known as Mid-Pleistocene Revolution; Berger et al., 1993). Muttoni et al. (2010, 2011) hypothesized that hominins entered Europe together with herds of large African and Asian herbivores because they were 'pushed out' of their homelands by enhanced aridity in the Sahara and across Asia during the EPR, finding ultimate refuge in the more temperate Mediterranean realm. In a modified version of the 'follow-the-herd' hypothesis, Muttoni et al. (2014) now speculate that hominins initially entered Europe during the EPR because at that time vast and exploitable lowlands with open vegetation developed along the Danube-Po Gateway in the Balkan peninsula and northern Italy. This new environment provided, possibly for the first time in the Pleistocene, a migratory corridor for grassland-savanna-adapted large mammals and hominins, as part of a common and interlinked food web. In this revised view, the lack of exploitable grassland-savanna ecosystems before the EPR forestalled African and Asian large herbivores from expanding into Europe.

We acknowledge that lack of evidence may not be a compelling argument, but the absence of the Jaramillo and out-of-sequence cosmogenic nuclide dates with wide error margins in the TELRU unit preclude the use of this sequence to substantiate either the presence of humans or *A. lavocati* in Europe prior to the Jaramillo, and thus logically deny applying such conclusions to other systems, such as Vallparadís. Confirmed chronologies document humans in Europe only after the Jaramillo. It may be frustrating that the answer to a basic question, about when humans first inhabited Europe, should have such a simple and yet presently unattainable resolution—namely the presence of the Jaramillo in a stratigraphic sequence with evidence of human activity and appropriate small mammals—but until that sequence is published and confirmed, we urge caution in assuming a pre-Jaramillo peopling of the region.

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