The first Human settlements out Africa into Europe: a chronological perspective

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Abstract

A reliable chronology for the oldest settlements of Europe from the Early to the beginning of the Middle Pleistocene is an important requirement for understanding human evolution and especially the routes used to reach Western Europe from Africa. The paucity of sites, plus the limited number of available samples for dating, and the many contexts which do not favor the use of particular dating methods, further complicate the picture. This contribution addresses several questions: Which dating methods are relevant for establishing the chronology of the main sites? Are the first settlements older than the Jaramillo event? Which routes were used to enter Europe? Were the earliest human occupations intermittent or continuous?

Key-words: Early and Middle Pleistocene, dating methods, human evolution, Europe

Highlights: Contribution of dating methods and their reliability to the knowledge of the oldest human settlements in Europe, first before Jaramillo event, and then during the early period of Middle Pleistocene.

1/ Introduction

Few prehistoric sites in Europe and around the Mediterranean Basin document the Early Pleistocene period (i.e. 2 to 0.8Ma). The lack of a reliable chronological framework is a major issue in considering the possibility that the first European human occupations took place before the Jaramillo subchron. Some authors suggest that the earliest settlements in Europe occurred between the Jaramillo subchron and the Brunhes–Matuyama boundary, about 1.0 and 0.8 Ma including MIS22, the first important cold stage of the Pleistocene (Muttoni et al., 2010). This 200 ka period coincides with the late Early Pleistocene global climate transition. The survey relies on sites including magnetostratigraphy and radiometric dates based essentially on K-Ar and Ar-Ar dates performed mainly on Italian sites. Other researchers are in favor of older human dispersals peopling Europe before 1.1 Ma particularly in Spain, France and Italy where some radiometric dates are associated with magnetostratigraphic data and biochronologic studies (Arzarello et al., 2007; Carbonell et al., 2008; Garcia et al., 2014; Michel et al., 2017;).

With the exception of Dmanisi in Georgia, for which $^{40}Ar/^{39}Ar$ dates plus palaeomagnetic data suggest that hominins reached the Caucasus 1.8 Ma ago from Africa (Gabunia et al., 2000; Garcia et al., 2010), most other relevant sites are not reliably dated mainly because of the absence of volcanic layers “associated” with archaeological horizons. Few dating methods are available to this time period, and chronometric ages need to be compared with results obtained by other methods such as biochronology and magnetostratigraphy. Archaeological and palaeoenvironmental evidence, though scarce, suggest that while Western Europe was initially inhabited by hominins from 1.4 to 0.8 Ma, the archaeological record suggests that a continuous human occupation did not occur until later (Dennell et al., 2011; MacDonald et al., 2012). From the end of Lower Pleistocene, the strong climatic amplitudes that prevail with major longer periods of glaciations and the absence of human control of fire, (Roebroeks and Villa, 2011) could be a reason for the episodic human presence particularly in northern Europe until at least 600-700 ka with the arrival of technological Acheulean assemblages (Lefèvre et al., 2010; Moncel et al., 2013; Mosquera et al., 2013). Furthermore, the scarcity of sites found between 1 Ma and 600 ka emphasizes the difficulty of postulating for an eventual continuity in the peopling of Europe.

The issue of the routes to enter Europe is not solved though the main and oldest way to leave Africa was likely the Levantine corridor, the only one terrestrial gateway. The site of Dmanisi, located 2000 km straight to the north in the Caucasus region, at the crossroads of Europe and Asia, was probably reached by using this route (Figure 1). The other possibilities to reach Europe from Africa are Turkey with an access to Europe by the Bosphorus, and also Spain by the Gibraltar strait and this will be discussed in the paper. The last possibility could be an access by Sicily considering that the Italian peninsula has very old sites such as Pirro Nord and Montepoggiolo, although only upper Palaeolithic sites presently attest a human presence in the largest Mediterranean island (Di Maida et al., 2019) which was never connected with the continent.

In this work we rely on chronology using dating methods other than argon-argon particularly in karstic environments and on open-air sites without a volcanic context to demonstrate the presence of hominins before the Jaramillo event in Europe. This is notably the case with paleodosimetric methods such as electron spin resonance (ESR) applied to detrital quartz which has provided the opportunity to date old open-air sites in northern Europe (Voinchet et al., 2010) but also important sites in karstic environment such as the lowest layers of Gran Dolina (Moreno et al., 2015). The ESR method when combined with uranium-series is also applied to fossil dental enamel of large herbivores and yields modelled ages (Grün et al., 1988; Shao et al., 2012) which are compared with palaeomagnetic and mammalian biozonation data to cross-check and constrain the results particularly for the Early Pleistocene period. The multi-methods approach allows the building of a chronological framework by providing guide-marks for these old sites. A review of the oldest European and North-African sites is presented including those whose ages are already published. The main sites post Brunhes-Matuyama are also presented with the dating methods that can be applied according the environmental contexts are discussed.

2/ The appropriate dating methods

The most efficient way to provide a reliable chronological framework to a prehistoric site is to combine and compare results obtained from different independent dating methods and also with those yielded by magnetostratigraphic and biochronologic data as far as it is possible. Several analyses should be performed on the same layer in order to test the reliability and the ages should increase with the stratigraphic order. Figure 2 shows the main dating methods and their potentially applicable range in the Quaternary period. The $^{40}Ar/^{39}Ar$ method is considered as a reference when it can be applied to volcanic layers found in secure stratigraphic association with archaeological sequences. Among the 17-20 mentioned sites in the Figure 1, only two are located in volcanic environment, Dmanisi, where a basalt formation and ash layer underlie the archaeological sequence, and Bois-de-Riquet in France in which the basalt formation is much older than the archaeological sequence as explained in the next part. At Dmanisi, argon dates performed on the Masavera basalt formation gave a maximum age of 1.85 ± 0.01 Ma and palaeomagnetic data yielded a normal polarity, both combined supporting a correlation with the Olduvai subchron (Gabunia et al., 2000). Other $^{40}Ar/^{39}Ar$ analyses were performed on glass grains coming from an ash layer that fits closely with the “fresh” upper surface of the basalt. The samples were extracted from two locations: site A corresponds to the main sector (sector II) in which the major part of human remains were found; site B is a pit dug through sediments down to the Basalt lava flow close to the site A. A weighted mean age from the two distinct locations of

1.81 ± 0.03 Ma, in agreement with previous dating, was obtained for the hominins making them the oldest Eurasians (Garcia et al., 2010).

The period ranging between 2 and 1 Ma is particularly difficult to date when no volcanic layers underlie or seal prehistoric sequences. Uranium-series dating, based on the ingrowth of ^{230}Th cannot cover this period even though mass spectrometry has improved the accuracy and pushed back the applicable age limits to ca. 600 ka with a small error range thanks to Faraday collectors used to measure thorium isotopes in optimal conditions (Potter et al., 2005). U-Pb geochronology of speleothems has for more than 20 years been capable of extending this age range (Woodhead et al., 2006). When samples contain enough Pb, usually in low contents in these kinds of samples, to obtain isotopic ratio for isochron construction, and where very low "common Pb" is observed, it becomes possible to get reliable ages. U-Pb dating in this way showed that a calcitic formation in Corchia Cave, Italy, grew between 970-810 ka with a precision of less than 0.5% (Bajo et al., 2012). This method applied to speleothem formations is however difficult to implement effectively because the oldest European sites are generally not in caves, with the exception of the Vallonnet and Atapuerca sites. For the French cave, U-Pb ages coupled to a reversed polarity of calcite samples, provide age range constraining the archaeological infilling between 1.2 to 1.1 Ma (Michel et al., 2017). New attempts were performed in the lowest levels of Gran Dolina (flowstones at the top of TD1) without success due to large variations and very low Pb concentrations (Pares et al., 2018).

As Ar/Ar and Fission track methods are not available in detritic environments or karstic systems furthermore without speleothem formations, only cosmogenic and palaeodosimetric methods can be applied for dating the period ranging between 2.0 and 1.0 Ma.

Dating burial of quaternary sediment using *in-situ* production of cosmogenic radionuclides (CRN) is a relatively recent method (Granger and Musikar, 2001). As the ratio of the production rates of aluminium (^{26}Al) and beryllium (^{10}Be) is well known, and because their half-lives are long enough, these nuclides can be used to date sediment burial of the order of a million years. The procurement of reliable dates depends on the depth and the rapidity of the buried sediment to prevent cosmogenic nuclide production after burial. This technique offers opportunities to yield ages between 1 and 5 Ma, potentially covering the oldest human sites in Europe and elsewhere. Examples of applications of this approach include Atapuerca Elefante where level TE9 containing a human mandible fragment associated with lithic assemblage and faunal remains was dated to 1.3 -1.1 Ma (Carbonell et al., 2008), and the long sequence having provided travertines, including the Kocabas hominin skull, and conglomerates was dated to 1.6-1.2 Ma (Lebatard et al., 2014).

In spite of difficulties such as sensitivity and large absolute error ranges, palaeodosimetric methods have a good potential to date old sites because they can be applied either on sediments or directly on faunal remains or on burnt flints that are coeval with human bearing occupations.

The ESR method can be implemented on several types of samples which confers a good potential to this technique. When applied to detrital quartz, though the bleaching process mechanism is not yet well understood, ESR has provided results from open sites in the northern part of Europe which could not be dated by other techniques. For example, in the Middle Loire Basin, two distinct phases of human settlements were evidenced around 1.1 Ma and 0.7 Ma, and particularly the Acheulean handaxe industries of La Noira, Brinay (Voinchet et al., 2010) (Figure 3). New applications were also performed on quartz coming from karstic environments at Atapuerca. The lowest levels of Gran Dolina were dated by ESR on quartz to more than 1 Ma (Moreno et al., 2015) in agreement with magnetostratigraphic data and other chronological evidence (Pares et al., 2018) providing to the ESR results with a good reliability. Recently, in the Philippines, hominin presence was estimated to be more than 0.7 Ma thanks to ESR dates obtained both on quartz and teeth pushing back the colonization of these islands by more than 600 ka (Ingicco et al., 2018). Presently, when old sites are not located in volcanic areas, the ESR method applied on optically bleached quartz, thanks to the good stability of Al center, is the only alternative able to provide ages as far as 2.5 Ma (Sahnouni et al., 2018).

The combined ESR/U-series (ESR-US) method applied on fossil enamel takes into account both ESR and U-series data, including radioelement contents, isotopic ratios, palaeodoses and external gamma-dose rate. It allows the reconstruction of the uranium uptake history in each dental tissue using a specific U-uptake parameter, p-value (Grün et al., 1988). The model cannot account for uranium loss. A recent model, called accelerating uptake model, AU-ESR, describes U-uptake into dental tissue as an accelerating process by the introduction of two parameters, the initial uptake rate and the acceleration of this uptake rate. It allows an extension for samples exhibiting a slight uranium leaching (Shao et al., 2012).

The combined approach allows the dating on herbivorous and/or human teeth during all the Middle Pleistocene period (Grün, 2006; Falguères et al., 2010). For the Lower Pleistocene Spanish sites, a review of the main difficulties using combined ESR/U-series methods applied to fossil enamel teeth was published bringing to light the difficulties to date such a period (Duval et al., 2012). The problem of uranium uptake (open system behaviour) in the different tissues of teeth is often influenced by specific geochemical and geological context, in some cases does not allow the calculation of a modelled age. In human teeth fragments, an underestimation of some palaeodoses was explained by the possible creation of unstable non–oriented CO_2^- radicals after artificial gamma irradiation and heating identified as a source of error in D_e assessment (Grün et al., 2008). The mathematical description of ESR dose response of fossil tooth enamel has been discussed recently showing that for D_e higher than 2000 Gy, a single saturating exponential (SSE) function could lead to some overestimation of the results (Duval and Grün, 2016). For D_e values lower than 2000 Gy, a single saturating exponential plus linear function (EXPLIN) better describes the growth curves. For Arago teeth dated to 530-300 ka, EXPLIN function was used to calculate De because presenting slight better r2 adjustment and smaller error range providing results lower from 1 to 12% than using SSE fitting (Falguères et al., 2015).

The limits of Luminescence methods applicability have been recently extended to 0.8 to 1Ma at Gran Dolina and Sima del Elefante by using techniques such as thermally transferred optically stimulated luminescence (TT-OSL) and post-infrared stimulated luminescence (pIR-IRSL) and contribute to better constrain the chronological framework of the Pleistocene period (Arnold et al., 2015) but remain still difficult to implement on samples older than 1 Ma.

3/ The oldest sites

Recently human presence in Western Europe before 1 Ma has been discussed (Muttoni et al., 2018; 2015). Bearing in mind the large uncertainties of absolute dating methods, these authors propose a critical assessment based on magnetic stratigraphy which favours the MIS22 period between the normal polarity Jaramillo subchron, 1.07- 0.99 Ma, and the Brunhes-Matuyama boundary, 0.78 Ma, for the earliest hominin settlements. During MIS22, it is argued an onset of increasing aridity in Sahara, combined with other climatic constraints, led herds to move from Africa to the southern part of Europe. On the other hand, some researchers support the idea that the first hominins arrived in Europe before the Jaramillo subchron considering a pool of data from several disciplines including those provided by dating methods whose large error ranges are constrained by results obtained by a multidisciplinary approach.

The site of Dmanisi which documents the presence of early *Homo* outside Africa at 1.8 Ma, represents more than 90% of the human remains found during the period ranging between 2.0 to 0.8 Ma. The study of an entire well preserved skull associated with his mandible suggests strong affinities with "the earliest known *Homo* fossils from Africa" (Lordkipanidze et al., 2013). The lithic assemblage ressembles the Oldowan tradition found at African sites which is referred to as Mode 1 tradition in Europe, and including core choppers, flakes and retouched flakes. It is associated with a large vertebrate fauna contemporaneous with a latest Pliocene-earliest Pleistocene age (Gabunia et al., 2000). Because of its antiquity and because human remains were found in a well-established stratigraphic sequence dated by Ar/Ar method coupled to magnetostratigraphic data, it is a key-site for the understanding of human dispersals in Eurasia and probably a starting point of human European settlements.

2 000 km southward, in Jordan Valley, the site of Ubeidiya has yielded some human remains such as cranial fragments and teeth in association with lithic assemblages and abundant fauna. The Ubeidiya formation constituted mainly with fluvial sediments has indicated a reversed polarity and some faunal elements are biochronologically dated to 1.1 to 1.5 Ma (Belmaker et al., 2002). The lithic artefacts are constituted by choppers including "a small but distinctive group of crude bifaces" (Bar-Yosef and Goren-Inbar, 1993) suggesting that the hominins that left Africa and reached Dmanisi, did not acquire the bifacial technology, on the contrary of those who settled 300 ka later in Ubeidiya, reinforcing the idea of episodic settlements during that period even though the Southern Caucasus area was repeatedly occupied during the Olduvai subchron (Ferring et al., 2011).

Between Dmanisi and Ubeidyia, towards west, the Kocabas skull was found in the upper part of a long travertine sequence with a large late Villafranchian mammal assemblage. This formation is stratigraphically between two fluviatile levels dated by $^{26}Al/^{10}Be$ burial method to 1.1-1.6 Ma. The Upper fossileferous travertine shows a reversed polarity that becomes normal above but made on the basis of stratigraphic correlations suggesting a possible Cobb Mountain but most probably Jaramillo event at the top of the sequence if no stratigraphic gap occurred between both sections (Lebatard et al., 2014). This old sequence in Turkey containing one human skull associated with a lot of other faunal remains strengthens the idea that the Levantine corridor is the most probable African gate exit for Eurasia.

In Western Europe and particularly in Spain, some prehistoric sites such as Atapuerca Elefante and Dolina in the northern part, and others like Fuente Nueva 3 and Barranco Leon in Andalucia, have yielded human remains associated with large faunal assemblages and lithic artefacts indicating human presence before 1 Ma. Among these sites, three are dated to 1.4-1.1 Ma corresponding to the first human occurrence in Western Europe (Carbonell et al., 2008; Toro Moyano et al., 2013). They are dated either by methods such as cosmogenic and ESR and also by the association of biochronologic and palaeomagnetic data. The last two methods represent the major part of the chronological framework established according to the presence of some rodents such as *Allophaiomys lavocati* recorded together in Fuente Nueva 3 and Barranco Leon and in the lower level of the Sima del Elefante, TE9, strengthening the idea of a pre-Jaramillo period (Garcia et al., 2014). The Matuyama/Brunhes boundary is observed at Sima del Elefante between levels TE16 and TE17 (Pares et al., 2006) and corroborated by reliable OSL dates ranging between 724 and 864 ka (Arnold et al., 2015). These data provide a firm minimum age of 0.8 Ma to the human remains found in the lower TE9 level dated by $^{26}Al/^{10}Be$ nuclides to 1.1-1.3 Ma and by micromammal faunal assemblage (Carbonell et al., 2008; Cuenca-Bescos et al., 2013) and though the Jaramillo event was not found because of the probable discontinuous nature of such an infilling.

The fourth, Atapuerca Gran Dolina, has yielded more than 150 human remains (*Homo antecessor*) associated with a number of lithic tools and a large macrofaunal assemblage in a reliable stratigraphic context, dated to 0.8-0.9 Ma by combined ESR and U-series on herbivorous teeth and by luminescence and ESR on feldspar and quartz for the 2m thick TD6 horizon. These data are constrained by a clear reversed to normal polarity change in TD7 layer above the TD6 level, attributed to Brunhes-Matuyama boundary (Pares and Perez-Gonzalez, 1995; Falguères et al., 1999; Berger et al., 2008; Arnold et al., 2015; Moreno et al., 2015). This multi-method and multi-proxy approach makes of Gran Dolina the best-dated European site for the Early-Middle Pleistocene period and represents a remarkable point of reference for the chronology of European human evolution.

Other sites in France (Vallonnet, Pont-de-Lavaud, Bois-de-Riquet), in Italy (Monte Poggiolo, Pirro Nord), in Russia (Rodniki/Bogatyri/Kermek), exhibit faunal and/or lithic assemblages as evidence of an early human presence before or around 1 Ma. The chronology of Pirro Nord remains unclear ranging between 1.6-1.3 Ma by biochronology to 1 Ma by radiometric methods (unpublished results) showing the difficulties to date such a sedimentary infilling fissure. Bogatyri and Kermek sites are dated to the Early Pleistocene by a combination of geologic, biochronologic and paleomagnetic data but without dating methods (Shchelinsky et al., 2016). Other sites like Vallparadis and Barranc de la Boella in Spain and Kozarnika in Bulgaria, and Gesher Benot Ya'aqov (GBY) in Israel, belong to a period which can be constrained between 1 and 0.8 Ma. The first mentioned is dated by a combination of palaeomagnetic (reversed period) and biostratigraphic data correlated with a biozone defined at Atapueca Dolina between 600 and 800 ka (Cuenca Bescos et al., 2010). ESR-US age obtained on two herbivorous teeth and ESR ages obtained on quartz ranging between 0.8 and 0.9 Ma are in agreement with the previous data (Duval et al., 2012; 2015). La Boella located in Catalunia has provided a data set based on palaeomagnetic and cosmogenic analyses and palaeontologic assemblage by stratigraphic correlations of three sections. These data place the site at ca 1 Ma as one of the oldest Early Acheulean European sites even though no transition between Mode 1 and Mode 2 was clearly found (Mosquera et al., 2016). Kozarnika site has a long stratigraphic sequence in which an impressive faunal assemblage was found, is dated to 1.5 to 0.5 Ma (Sirakov et al., 2010). A recent palaeomagnetic study has reduced the duration of the sequence to the Middle Pleistocene period with the base of the infilling beginning with the Brunhes-Matuyama boundary at 0.78 Ma (Muttoni et al., 2017). GBY has yielded important environmental and cultural data in a chronostratigraphical framework bracketed by Ar/Ar dates and documented by magnetostratigraphic data, highlighting important climatic changes around the Brunhes/Matuyama boundary (Goren-Inbar et al., 2000; Proborukmi et al., 2018). After Ubeidiya at 1.4 Ma, another wave with biface technology leaves Africa at 800 ka.

The archaeological sequence of Vallonnet site lies between two flowstones recently dated by U-Pb methods and correlated with palaeomagnetic results providing an age range older than the Jaramillo event around 1.2-1.1 Ma (Michel et al., 2017). However, the limited number of palaeomagnetic samples plus the similar ages obtained on both upper and lower calcitic formations do not support such a temporal resolution allowing an identification of a palaeomagnetic event of less than 30 ka duration. At Pont-de-Lavaud site, Creuse valley, a prehistoric settlement is attested by several archaeological pavements and numerous artefacts of archaic lithic industry (Mode 1). The fossil fluvial terrace at +90m (up to the present-day floodplain) in which the site was recovered, is dated by ESR applied on quartz to 1.1 Ma with an error range which does not allow a firm attribution to a pre Jaramillo period. But the dates are made in a regional context providing to the Middle Creuse valley with a fluvial history from the highest terrace dated to 1.8 Ma suggesting the beginning of the valley incision to the youngest fluvial formations (at +15-25m) dated to 200-300 ka in which bifaces were found (Voinchet et al., 2010). The chronology of the site of Bois-de-Riquet, at Lézignan-la-Cèbe, was discussed before the recent excavations allowed a better knowledge of the stratigraphic relation between the basalt dated to 1.57 Ma and the archaeological units deposited in a locus formed after a thermal retraction of the basalt at the end of the cooling phase. A small rodent assemblage yields an age ranging between 1.0 and 0.9 Ma based on the overlap of the biostratigraphic range of arvicoline species and compared with those found in other old European sites (Lozano-Fernandez et al., 2019).

The site of Happisburgh in England, thanks to a weak reversed polarity of the sediments and in spite of a strong normal polarity overprint due to iron mineral (greigite), and a rich documentation of fossil plants and vertebrate assemblage, demonstrates also that Early Hominins settled at latitude higher than 50° in northern Europe, at 1.0-0.8 Ma during a fully temperate climatic episode (Parfitt et al., 2010).

Today, the « key-fossils » contributing to the knowledge of human evolution in Western Europe are the oldest fossils found at Elefante and Barranco Leon, which are too fragmentary to be classified, *Homo antecessor, Homo heidelbergensis, Homo neandertalensis* and *Homo sapiens* (Stringer, 2012). One of the major paleoanthropological issues is to establish whether or not there is a phyletic relationship between the oldest fossils and *Homo antecessor* whose age, well constrained at Gran Dolina, Atapuerca, is older than 0.8 Ma and likely younger than 1 Ma belonging to the end of Early Pleistocene period (Bermudez de Castro et al., 1997). According to the Spanish authors, *Homo antecessor* and the European fossils were close to the African contemporaneous branch. This is the only one fossil that is well dated since the Dmanisi human remains and both are separated from 1 Ma. Today, the paucity of European human remains older than 1 Ma precludes a thorough comparative study between these fossils.

3/ The Middle Pleistocene period

Another important chronological gap of about 150-200 ka exists between the human fossils of TD6 Gran Dolina and *H. heidelbergensis* (Stringer, 2012). In other words, no fossil was found between 800 and 650 ka in Europe. The holotype mandible of Mauer has a reliable chronological framework provided by independent methods for which results of 0.6 Ma are in agreement, and corroborated by faunal arguments (Wagner et al., 2010). No lithic artifacts were found in the site. The Mauer mandible is coeval with the decidual human tooth unearthed from an archaeological layer at Isernia la Pineta, Italy, constrained with accuracy by $^{40}Ar/^{39}Ar$ analyses to 583-561 ka (Peretto et al., 2015), and with the human femur of Notarchirico constrained between 670 and 610 ka (Pereira et al., 2015). In both cases, $^{40}Ar/^{39}Ar$ single crystal laser fusion was applied to sanidines extracted from reworked volcanic effluents for Isernia layers and for which results are presented as probability diagrams on 4 units (Deino and Potts, 1990). For the U3 fluvial unit overlying the archaeological layer, a wide range of age is obtained from 709 to 576 ka. The youngest sanidine ages are the same than that of the basal calcareous tufa which is considered as a maximum age for the human remain (weighted mean age of 586 ± 1 ka). Isernia has yielded a great quantity of faunal remains similar to those found at Mauer, and has provided a large lithic assemblage without bifaces but documenting significant technical innovations of the Early Acheulean in Europe (Gallotti and Peretto, 2015). In Notarchirico, the comparison of $^{40}Ar/^{39}Ar$ ages with TL and ESR results on bleached quartz are in agreement and place the sequence between 670 and 614 ka. Bifaces associated with the hominin femur represent one of the oldest Acheulean assemblages in the southern part of Western Europe. These human fossils are contemporaneous with the marine isotope stage (MIS) 15 with concordant $^{40}Ar/^{39}Ar$ ages at the two sigma limit and with reliable Luminescence and ESR ages with one sigma error range for Mauer and Notarchiricho but not for Isernia which gave younger ESR-

US ages because of the difficulty to build the geochemical history of the t3 layer which consists in a dense bones accumulation with high uranium content due to the volcanic environment (Falguères et al., 2007; Shao et al., 2011). The apparent older introduction of Bifaces in Europe than the current chronological framework of *Homo heidelbergensis* questions about either the real older origins of that fossil or about another species bringing with it the Acheulian culture. Is the Mauer mandible representative as a *Homo heidelbergensis* holotype as written by Hublin in 2009?

The first Acheulean evidence with Large Cutting tools assemblages (LCTs) like bifaces, cleavers and other large flakes, emerged in several European sites at c. 600-800 ka. The oldest sites yielding handaxes appear simultaneously in Central France such as La Noira dated to around 650-700ka (Moncel et al., 2013) and in southern Italy at Notarchirico between 610 and 670 ka as mentioned previously, and a climatic stage later in the lowest levels of Arago cave, France (Falguères et al., 2015). La Noira did not yield any faunal remains because of the acidic deposits. So, the ESR method was applied to optically bleached quartz grains on the fluvial sequence providing a weighted mean age of 665 ± 55 ka (Despriée et al., 2017). An age of 730 ± 210 ka was obtained by $^{26}Al/^{10}Be$ on quartz coming from the unit containing the lithic artefacts at the base of the stratigraphy (Shen et al., 2012). The large error range is essentially due to the relatively high aluminium content in the sediment. The result was proposed as preliminary one.

Several sites have yielded human remains that began to acquire Neandertalian features. Arago cave exhibits a thick archaeological sequence constituted by three stratigraphical complexes (Lumley de et al., 1984). Cold and arid conditions are observed at the base of the Middle Stratigraphical Complex, in levels in which human remains associated with lithic artifacts among them large handaxes, were found. This level (P/Q level) was recently dated to 550 ka by combined ESR/U-Th and associated with the MIS14 in agreement with the fauna found such as *Ovis ammon antiqua* and *Rangifer tarandus* indicating a cold climate. The top of the Middle Complex has provided more than 100 human remains in the G level for which a mean age of 440 ka suggests a development of this level during a cold stage (MIS12), at least at the base of the level (Falguères et al., 2004; 2015; Han et al., 2010). These fossils have been classified as *Homo erectus Tautavelensis,* showing affinities with Middle Pleistocene *Homo erectus* of Africa and Asia (Lumley de, 2015).

Another key-site for Middle Pleistocene period is La Sima de los Huesos, Atapuerca, Spain. The Hominin-bearing layer that yielded thousands of human remains was reassigned to a minimum age of 430 ka by using a multi-method approach (Arsuaga et al., 2014). A calcite raft taken directly on human skull has yielded and age of 434 +36 / -24 ka. Quartz grains were dated by TT-OSL and pIR-IR provided an age range of 428 to 441 for feldspar and f 396 to 429 ka for quartz. A ESR age of 443 ± 90 ka was obtained on quartz. Some much older age was obtained by ESR underlining the bad conditions of quartz bleaching in karstic sediments. The contemporaneity between the age of Arago (G level) and that of SH fossils does not fit well with their evolution degree in terms of neandertal apomorphies and raises the issue of one or two coeval human species. We find the same type of comparison in Africa with Kabwe skull recently dated by U-series (LA-MC-ICPMS, TIMS, Gamma-spectrometry) directly on the skull and bones and on calcitic crust yielding an age of 300 ka (Grün et al., 2020), similar to that obtained on Jebel Irhoud human remains (Richter et al., 2017) though they are morphologically different.

The Acheulean technology becomes standardized in many European sites at 300-400 ka with some essential evolution steps like the arrival of Levallois technique and fire control, and disappears at the end of Middle Pleistocene (ca 130 ka).

4/ The southern part of the Mediterranean Basin

When we look at the southern side of the Mediterranean Sea, in Northern Africa, Aïn Hanech site in Algeria has provided the oldest lithic artifacts from Maghreb probably at 1.7-1.9 Ma and recently Oldowan stone artifacts and cut-marked bones excavated from two nearby deposits at Aïn Boucherit were estimated to 1.9 Ma to 2.4 Ma (Sahnouni et al., 2018). The age range was obtained by magnetostratigraphic, Electron Spin Resonance, and mammalian biochronologic data. This raises the possibility that the Gibraltar strait was an eventual gateway for peopling Europe before 1.0 Ma (Bar-Yosef and Belfer Cohen, 2001; Pares et al., 2013). Thomas Quarry, Morocco, yielded also a rich Acheulean lithic assemblage including bifaces in level L1 which could be older than 1 Ma according to the faunal assemblage and taking into account the reversed polarity magnetostratigraphy observed in the sediments (Raynal et al., 2001; Gallotti et al., 2020).

In the same early Middle Pleistocene shoreline of the Oulad Hamida Formation, the "Grotte des Rhinoceros" has yielded the earliest evidence of human consumption and carcass processing at 700 ka in Acheulean context in a cave for North Africa (Daujeard et al., 2020). Combined ESR/U-series ages were obtained on herbivorous teeth and gave a range comprised between 690-720 ka and 520-550 ka from the base to the top of the archaeological sequence. The faunal assemblage appears to be younger than that of Tighennif, Algeria, but older than 500 ka by comparison with early Pleistocene extinct taxa and in agreement with radiometric dates. Tighennif has provided a human mandible associated with a large faunal assemblage placing the site at the Brunhes-Matuyama boundary and making of this site one of the best reference for Middle Pleistocene in North-Africa (Geraads, 2010).

It is clear from the above that further development of dating methods and multi-proxies and/or multi-method approaches are critical to improving the chronology of this evidence of early human occupation and to highlight dispersal continuity or discontinuity, and better understand the routes by which our ancestors dispersed by Africa.

6/ Conclusions

Figure 1 suggests that several possible paths could have been taken by the first hominins to reach Western Europe between 1.8 and 1.0 Ma and the main terrestrial way is the Levantine corridor giving an access to Europe by Turkey or by the northern shores of the Black Sea. We cannot forget that the Gibraltar strait offers an opportunity for hominins to cross from Africa to Europe in spite of all the difficulties inherent in the strength of the currents and to the distance to cross and though no evidence in terms of megafauna nor lithic assemblage allows one to support such a crossing. A similitude between specific large flake Acheulean techniques observed at Tighenif, Algeria and present in some Spanish sites would support a North-African origin for the Acheulean in Spain (Sharon, 2011). The comparison between the human fossils found at Thomas Quarry, Morocco, Tighenif, Algeria and those found at Atapuerca, for instance, would certainly provide a number of valuable information on the eventual morphological affinities between these hominins at the end of Early Pleistocene and on their filiation. The exceptional richness of Early Pleistocene sites in Spain for this period (4 sites older than 0.8 Ma) could be an argument in favor of an early peopling of the Iberian Peninsula by Gibraltar.

The Turkish path is probably the easiest route to take from Africa to Europe. Turkey offers a potential of sites such as Kocabas and probably many others yet to be discovered even though currently only Middle Pleistocene sites are known like Yarimburgaz (Howell et al., 1996). On the other bank of the Bosphorus, Kozarnika, Rodniki Bogatyri and Kermek sites are witnesses of another possible path north to Black Sea.

Again it can be argued that radiometric dates, compared with palaeomagnetic and biostratigraphic data, added to faunal constraints due to climatic and environmental changes with dates for the first or the last occurrence of species, are vital to reconstruct the chronological framework of human evolution in Europe. On the other hand, the nature and heterogeneity of archaeological sequences often perturbed by posterior events (draining phenomena, diagenetic processes) and discontinuous sedimentation process render difficult the interpretation of paleomagnetic data.

The first presence of hominins without bifaces is observed at Dmanisi and Aïn Boucherit/Aïn Hanech at more than 1.5 Ma. Another "wave" of settlements shows that Levantine and African sites like Ubeidiya and Thomas Quarry have bifaces at a period ranging between 1.4 to 1.0 Ma while their contemporaneous western European sites like Pirro Nord, Barranco Leon, Elefante or Pond-de-Lavaud show a Mode 1 industry. The Acheulean handaxe industries appear in Western Europe around 0.7 Ma suggesting that the technique was used before the emergence *of Homo heidelbergensis*, though the scarcity of human remains in Europe between 1.5 and 0.6 Ma emphasizes the difficulties in understanding human evolution and behavior. So, before the arrival of Acheulean assemblages around 600-700 ka, it seems difficult to consider a continuity of peopling Europe. Probably the scarce first settlements that reached Europe and particularly in the Iberian peninsula did not succeed in terms of demography to provide a stable and a continuous human peopling. When looking at the range dates at figure 4 and table 1, Hominins settled in Europe before 1 Ma in the Mediterranean basin. The knowledge of the oldest wave of human arrivals, after that of Dmanisi, still remains fragmentary since the only human remains belonging to this first implantation come from sites in Spain and at Ubeidyia and Kocabas.

Currently, only three sites in Spain one in England and one in France are coeval with the end of the Lower Pleistocene. The high altitude (around 1000m) for the TD6 and the latitude higher than 50° for Happisburgh suggest that the human occupations settled during temperate and humid phases while controlled fire was not yet present. The Middle Pleistocene period was marked by a succession of cold periods with severe climate interspersed by shorter temperate and humid episodes. These contrasts contributed mainly in the hominin settlements of Western Europe from 800 to 130 ka (Denell et al., 2011). From this point of view, *Homo antecessor,* found in a well constrained stratigraphy associated with large faunal and lithic assemblages, is of paramount importance because it represents the only human fossil making a link between the first waves of settlement and the people who brought bifacial culture to Europe.

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Figure caption

Figure 1: The main possible paths for peopling Western Europe from Africa between 1.8 and 0.8 Ma. The sites in blue contain human remains.

Figure 2: The main dating methods used in Prehistory and their range of application. The grey areas correspond to a normal polarity (+) while the white parts are reversed polarity (-). H.H. is *Homo Heidelbergensis*.

Figure 3: Large Cutting Tools, LCT, classified as Acheulean industry from La Noira site found in layer dated older than 650 ka (Moncel et al., 2013).

Figure 4: Chronology of the main sites with their age range (in green, sites with human remains) versus palaeomagnetic data, marine oxygen isotopes (Lisiecki and Raymo, 2005). The oldest sites in Europe appear at around 1.4 Ma. Sites in green have human remains and those with a star have bifaces.

Table 1: The oldest sites in Europe and Northern Africa (Mediterranean Basin) presented with radiometric, biochronologic and palaeomagnetic data, and the relevant references. B/M corresponds to Brunhes/Matuyama, M/G to Matuyama/Gauss and O to Olduvai.

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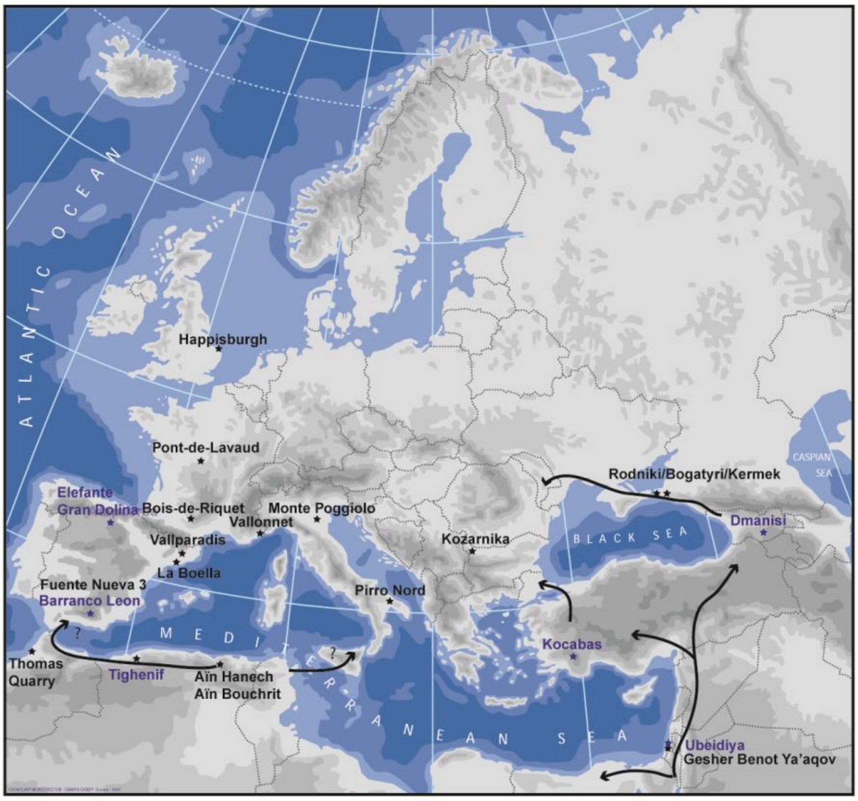
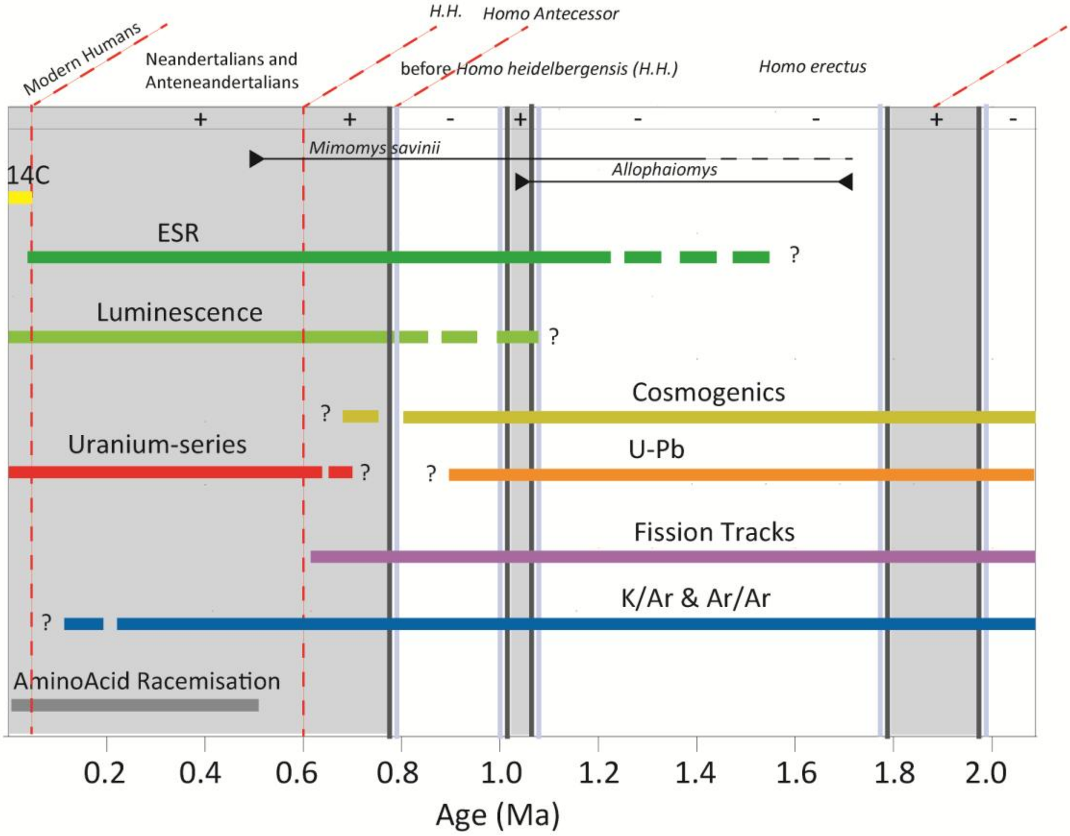
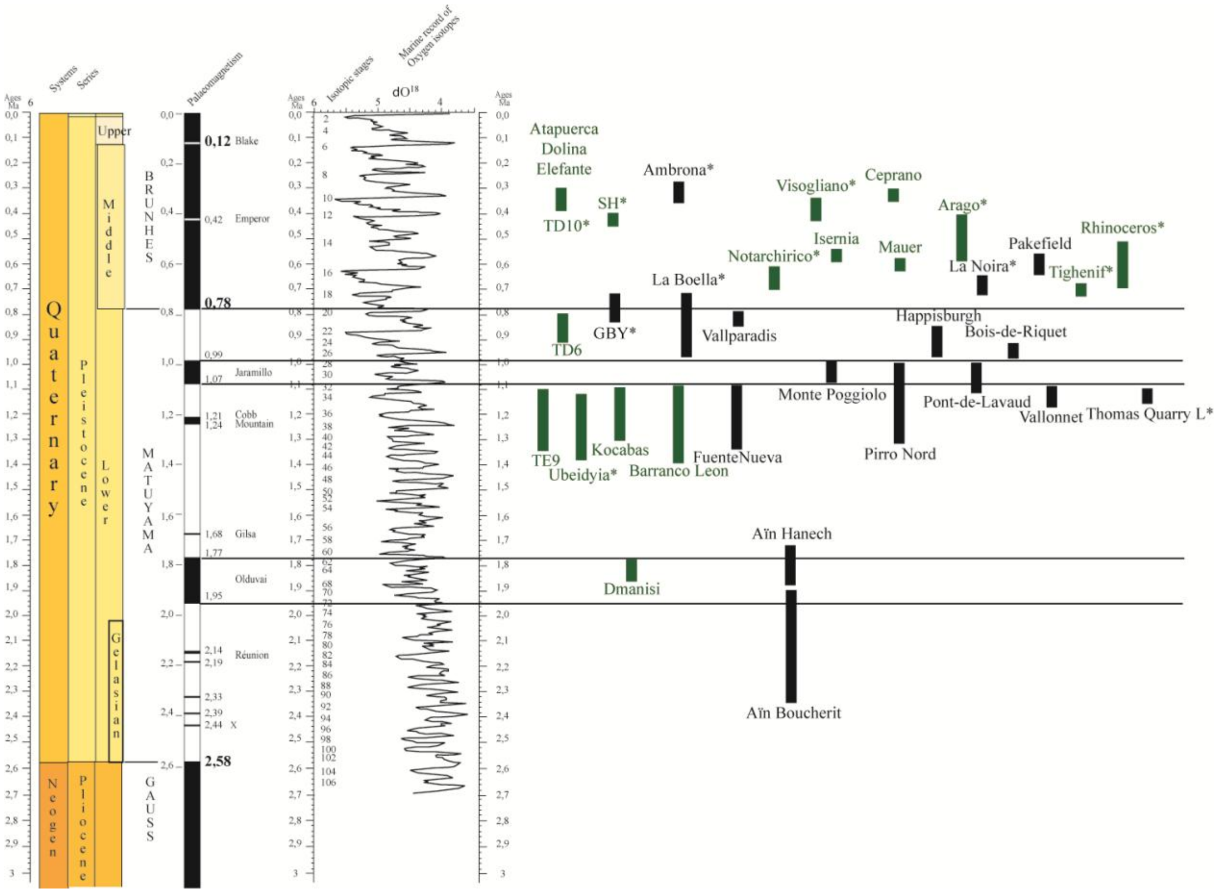
Sites	Countries	Layers	Ages (Ma)	Dating Methods	Palaeomagnetism	Biochronology	Human remains	Fauna	Lithic artefacts	References
Oriental Mediterranean area										
Dmanisi	Georgia	Mashavera Basalt	1.85 ± 0.01	$^{40}Ar/^{39}Ar$	(+)					(Gabunia et al., 2000)
		layer VI - A1	1.81 ± 0.05	$^{40}Ar/^{39}Ar$	(+)	Villafranchian	Skulls, mandibles, postcranial	x	x	(Garcia et al., 2010; Lumley et al., 2002; Ferring
Ubeidiya	Israel	Lake and fluvial sediments	1.8-1.1		(-)		cranial fragments and teeth	x	x	(Belmaker et al., 2002; Verosub and Tchernov, 1
Gesher Benot Ya'aqov (GBY)	Israel	Lake sediments	1,20-0,66	$^{40}Ar/^{39}Ar$	B/M	Micromammals		x	x	(Goren-Inbar et al., 2000; Proborukmietal., 201
Kocabas	Turkey	Upper Travertines	1.3-1.1	$^{26}Al/^{10}Be$ burial age	(-) and (+)	late Villafranchian	fragmentary skull	x		(Lebatard et al., 2014)
Rodniki/Bogatyri/Kermek	Russia	Breccia			(-)	Early Pleistocene, Early Biharian		x	x	Shchelinsky et al., 2010; Dodonov et al., 2008)
Kozarnika	Bulgary	Layers 13-11			(+) / (-)	Middle Villafranchian		x	x	(Sirakov et al., 2010; Muttoni et al., 2017)
Western Europe										
Monte Poggiolo	Italy	marine and detritic sediments	> 0.78	ESR quartz	(-)				x	(Gagnepain et al., 1998; Peretto, 2006; Muttoni
Pirro Nord	Italy	conglomerated sandy-clay sediments	1.3 - 1.7		(-)	Late Early Pleistocene		x	x	(Arzarello et al., 2007; Arzarello et al., 2016)
Pont-de-Lavaud	France	Fluvial deposits	1.1 ± 0.1	ESR quartz	(+)				x	(Despriée et al., 2018)
Vallonnet	France	stalagmitic floor	1.2-1.1	U-Pb, ESR calcite	(+)	Epivillafranchian		x	x	(Michel et al., 2017; Yokoyama et al., 1988)
Bois-de-Riquet	France	basalt containing archaeological sediment	1.1-1.4	$^{40}Ar/^{39}Ar$		arvicolines (1.0-0.9 Ma)		x	x	(Lozano-Fernandez et al., 2019)
Happisburgh	United Kingdom	Channel sediments	1.0-0.78		(-)	Early Pleistocene		x	x	(Parfitt et al., 2010; Ashton et al., 2014)
Iberic Peninsula										
Barranco Leon	Spain	Sandstones, calcareous silts	1.02-1.73	ESR quartz	(-)	Early Pleistocene	tooth	x	x	(Toro Moyano et al., 2013)
Fuente Nueva-3	Spain	Clays and sands	1.2 ± 0.2	ESR-US	(-)	Early Pleistocene		x	x	(Duval et al., 2012)
Trinchera Dolina	Spain	TD7	0.78		B/M					(Pares and Perez Gonzalez, 1995)
		TD6	0.78 - 0.86	ESR-US, OSL, TL		Late Early Pleistocene	150 cranial and post cranial re	x	x	(Falguères et al., 1999; Arnold et al., 2015; Berg
		TD4-TD3	> 0.86	ESR quartz	(-)			x	x	(Moreno et al., 2015)
		TD1	>1.0	ESR quartz	(-)					(Pares et al., 2018)
Trinchera Elefante	Spain	TE9 - TE16	> 0.78		B/M	Early Pleistocene		x	x	(Pares et al., 2006)
		TE9	1.1 - 1.3	$^{26}Al/^{10}Be$ burial age			mandible and teeth	x	x	(Carbonell et al., 2008)
Terrassa, Vallparadis	Spain	10 et 12	0.8	ESR quartz ; ESR-US	(-)	Late Lower Pleistocene		x	x	(Martinez et al., 2010; Duval et al., 2015)
La Boella	Spain	Unit II	1.0	$^{26}Al/^{10}Be$ burial age	(-)	Late Lower Pleistocene		x	x	(Mosquera et al., 2016)
Southern Mediterranean area										
Aïn Boucherit	Algeria	Muddy gravel deposits	1,9-2,4	ESR quartz	M/G, O	x		x	x	(Sahnouni et al., 2018)
Aïn Hanech	Algeria	fine-grained sediments	1.7-1.9		(+)	Early Pleistocene		x	x	(Sahnouni et al., 2004)
Tighenif	Algeria	Sandy sediments	0.7		(+)	Early Middle Pleistocene	mandible	x		(Geraads et al., 1986)
Thomas Quarry	Morocco	L level	1.0		(-)	Late Lower Pleistocene		x	x	(Raynal et al., 2001)


ATLANTIC OCEAN
Happisburgh
Pont-de-Lavaud
Elefante
Gran Dolina
Bois-de-Riquet
Monte Poggiolo
Vallonnet
Vallparadis
La Boella
Fuente Nueva 3
Barranco Leon
Thomas
Quarry
Tighenif
Aïn Hanech
Aïn Bouchrit
MEDITERRANEAN SEA
Pirro Nord
Kozarnika
Rodniki/Bogatyri/Kermek
CASPIAN
SEA
BLACK SEA
Dmanisi
Kocabas
Ubeidiya
Gesher Benot Ya'aqov


Modern Humans
Neandertalians and
Anteneandertalians
H.H.
Homo Antecessor
before Homo heidelbergensis (H.H.)
Homo erectus
Mimomys savinii
Allophaiomys
14C
ESR
Luminescence
Cosmogenics
Uranium-series
U-Pb
Fission Tracks
K/Ar & Ar/Ar
AminoAcid Racemisation
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
Age (Ma)


Ages Ma
Systems
Series
Palaeomagnetism
Isotopic stages
Marine record of Oxygen isotopes
dO18
Quaternary
Neogen
Pleistocene
Pliocene
Upper
Middle
Lower
Gelasian
BRUNHES
MATUYAMA
GAUSS
0,12 Blake
0,42 Emperor
0,78
0,99
Jaramillo
1,07
1,21 Cobb
1,24 Mountain
1,68 Gilsa
1,77
Olduvai
1,95
2,14 Réunion
2,19
2,33
2,39
2,44 X
2,58
Atapuerca
Dolina
Elefante
TD10*
SH*
Ambrona*
Visogliano*
Ceprano
Arago*
Rhinoceros*
Isernia
Mauer
Pakefield
Notarchirico*
La Noira*
Tighenif*
La Boella*
GBY*
TD6
Vallparadis
Happisburgh
Bois-de-Riquet
Monte Poggiolo
Pont-de-Lavaud
Vallonnet
Thomas Quarry L*
TE9
Ubeidyia*
Kocabas
Barranco Leon
FuenteNueva
Pirro Nord
Aïn Hanech
Dmanisi
Aïn Boucherit