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New views on an old move: Dispersal out of Africa

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FIRST PARAGRAPH: All current evidence points to Africa as the place where the human lineage originated. However, the questions of when humans first left the continent and where they went in Eurasia remain highly controversial [1-4]. Until the mid 1990's, most researchers would have accepted a date of about 1.2 Ma as a maximum for the first appearance of Homo erectus in Eurasia [5]. In western Eurasia the earliest human fossils were dated to 0.5 Ma, but archaeological discoveries within the past twelve years have reopened the question of the age of the first Europeans [6-8]. Findings in Atapuerca provided the oldest direct evidence for a human presence in Europe at around 1.2 Myr [9]. The most parsimonious interpretation of this finding in the Sierra de Atapuerca is that Western Europe was settled during the Early Pleistocene by a hominin population coming from the east. It has been suggested that this population may be related to the first demographic expansion out of Africa, currently represented by the Dmanisi hominins [9]. The validation of such hypothesis is hampered by the absence of an accurate chronostratigraphic context for early to Middle Pleistocene sites [1,4]. A solid knowledge of the chronology, biostratigraphy and geologic context of hominin sites would enable us to address important issues such as possible migration routes, whether there were several pulses of migration and the role of climate and/or technical-cultural selection on the expansion outside Africa.

出非洲记：老迁徙的新观点

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首节：现在所有的证据都指向非洲是现代人类的起源地。然而，何时人类第一次离开非洲，他们到达了欧亚大陆的哪些地方，这些问题还是很有争议[1-4]。直到十九世纪九十年代中期，大多数研究者已经接受，最早出现在欧亚大陆的直立人最多为120万年前[5]。在欧亚大陆的西部，最早的人类化石为50万年，但考古学家在过去12年来的发现，为最早的欧洲人的年代问题又提供了新的证据[6-8]。阿塔坡卡遗址的发现又提供了最古老的证据，证明约120万年前欧洲就有人类出现[9]。阿塔坡卡山的发现可以简单的解释为，在更新世早期就有来自东方的人群居住在欧洲西部。有证据显示，这个人群可能和德曼尼西人代表的第一次出非洲的人口膨胀有关。这个假说由于缺乏精确的更新世中期遗址年代地层环境而难以验证[1,4]。详细地了解年代学、生物地层学和地质环境将有助于我们解决一些重要问题，如可能的迁徙路线、是否有多次迁徙、气候的作用和科技文化对走出非洲扩张的选择。

Unfortunately, deposits with hominins or artifacts are often poorly dated outside regions containing volcanic or ash flows that can be dated using argon-argon dating. Thus, while the chronology of human evolution of the Lower Pleistocene sites in Indonesia, African and Western Asia is relatively well documented, there are vast regions in Europe, South Africa and China with little or no radiometric ages at all.

There are several key issues surrounding the debate about the first human expansion out of Africa, each of which requires an improved chronological and biostratigraphic framework for its resolution. These are as follows:

-Expansion of hominins in Eurasia: was there a single "pulse" or is it possible to distinguish several stages of expansion?

-Hominin remains in Dmanisi, at the gates of Europe, are significantly older than those found in central and southern Europe. Is such a gap simply an artifact of limited chronological data? Or has there been an essentially continuous expansion?

-Can we, with better chronological data, identify the triggering mechanism that led the first Africans into Eurasia (e.g., techno-cultural, climate).

-Is there a connection between hominin expansion and major climatic pulses within the Plio-Pleistocene?

The first two questions are closely related: Human remains from Dmanisi indicate that 1.8 Ma hominins existed at the gates of Europe. This site in the Caucasian Republic of Georgia has produced a set of human fossils and stone

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industries which now constitutes the oldest evidence of human occupation outside of Africa [10]. The chronology of the site is based on a combination of paleomagnetism and Argon dating of volcanic and sedimentary materials, and is estimated around 1.8 Ma.

However, the site with the closest antiquity to Dmanisi, Sima del Elefante at Atapuerca, has an age of about 1.2 Ma [9]. It is somewhat paradoxical, therefore, that the two oldest Paleolithic sites – Dmanisi and Sima del Elefante – are found at geographically disparate locations, that is at the boundary between Asia and Europe and in the “cul-de-sac” of Europe, the Iberian Peninsula. Furthermore, it is intriguing that there is an apparent lack of hominin presence in this region in the time window of 1.8-1.2 Ma, as we discuss next.

Throughout the circum-Mediterranean area there is a number of Palaeolithic sites containing evidence of hominin presence (fossils or stone industry) whose ages are around 0.8 to 1.4 Ma (Ubeidiya, Pirro Nord, Pont-de-Lavaud, Lunery, Lézignan-la-Cèbe, Le Vallonnet, Monte Poggiolo, Fuente Nueva III, Barranco León, Kozarnika). However, the ages of the fossils and artifacts from these localities are either very imprecise, based on non-radiometric methods (Pirro Nord, Ubeidiya, Fuente Nueva III, Barranco León, Kozarnika) or lack important details about the analytical methods employed (Le Vallonnet, La Boella). Regardless, at present, the hominin record of the circum-Mediterranean region reveals an apparent gap between the ages of Dmanisi and Atapuerca.

The key question is whether this gap represents a genuine hominin absence (at least at discovered sites) during that time range. If so, what was the cause? Alternatively, is this gap an artifact of imprecise or inadequate dating of the archaeological sites? Put in other words, was there an uninterrupted human expansion starting at 1.8 Ma from west to south? Or else, did these occupations cluster around certain periods or pulses of expansion? The key to these questions lies in establishing more accurate and precise chronologies for the deposits of these important sites. An improved chronological framework is also key to understanding the routes and patterns of early hominin dispersal. In particular, is it plausible, given modern mammalian dispersal and migration patterns that multiple dispersals of small groups occurred periodically and that the fossil hominins in the Early Pleistocene outside of Africa came from different source populations [11]. As these latter authors conclude, some of the hominins that left Africa could have stayed in new localities while others moved further on.

The third question refers to the mechanism and causes behind the expansions out of the African continent. There are basically two theories in this regard [12]. Some authors proposed an interesting hypothesis coined "technical selection". According to this hypothesis, the first exit and dispersal of hominins out of the African continent occurred as a result of a population increase in the groups that developed an industry type Mode 2 (Acheulean). Mode 1, or Oldowan, refers to a technique consisting of very rudimentary elaboration of utensils, used for the first time in Africa 2.5 Ma ago. Mode 2, or Acheulean, also originates from Africa, and its manufacture and expansion was a decisive step in hominin technological progress.

However, since the early 90’s there have been numerous studies that suggest a connection between global climate changes and expansion of humans out of Africa into Europe and Asia [13-15]. There are essentially three competing hypotheses: (1) the “savanna hypothesis”, in which a relative shift toward cooler and drier conditions causes a change from more forested to more open vegetation; (2) the “turnover pulse hypothesis”, which relates broad-based faunal turnovers to climatic events; and (3) the “variability selection hypothesis”, which focuses on the repetitive nature of environmental oscillations through time. More recently, however, an alternative hypothesis has been put forward, which suggests that the emergence of hominids corresponds to periods of extreme climatic variability, coinciding with maxima of orbital eccentricity [16]. These maxima would have produced the highest amplitude in insolation cycles, causing an alternation of monsoonal conditions between very strong and very weak cycles. In East Africa, these periods of extreme variability would have translated to episodes in which lake levels oscillated with largest amplitudes. In the Sahara-Arabian desert belt, the eccentricity maxima are evidenced by long-term periods when desert and “green Sahara” conditions alternated. The ultimate, putative climate mechanism driving hominin evolution would be the insolation-driven monsoon, as suggested by the systematic link between speciation events and out of Africa expansions with eccentricity maxima. The periods of formation of large lakes and simultaneous “green Sahara”

might have favored hominin expansions within, and out of, Africa and might also have provided more abundant protein-rich food, basic for the evolution of the hominin brain. Interestingly enough, the results of Trauth [16], based on records of terrigenous dust flux from marine sediments of the Mediterranean and Arabian Sea,reveal the existence of three eccentricity maxima in the Pliocene-Pleistocene, at 2.6 Ma, 1.8 Ma and 1.0 Ma. The first is coincident with the emergence of Mode 1, and faunal shifts that show an expansion of grasslands accompanied by greater environmental instability in East Africa. The maxima at 1.8 Ma matches the earliest expansions outside of the African continent, as well as faunal turnover observed in East Africa. There is a number of archaeological sites in the time range 0.8-1.2 in the circum-Mediterranean region, but the lack of precise ages prevents determining if there is a correlation between the occupation of these sites and the eccentricity maxima, and hence whether expansion of hominins outside of Africa can be linked to such climatic events.

Lower Paleolithic sites such as Ain Hanech and Ain Boucherit (Algeria), and Ain Beni Mathar and Gafeit Basins (Morocco) are of particular interest due to their strategic location along the northern margin of Africa. In the Algerian deposits, current preliminary chronologic data suggest an age around 1.8 Ma, which would link this important Olduwan lithic site with a maximum of eccentricity and a faunal turnover in East Africa. At present, however, the chronological data are too scarce to formulate a solid hypothesis.

Despite the above described climatic and techno-cultural dispersal hypotheses, the basis for improved understanding of the causes of hominin migration out of Africa ultimately lies with constraining the timing of climatic, faunistic, geologic, and cultural key events.

可惜，通过氩氩测年法对古人种或器物的沉积测年通常不准确，而外周带有火山灰或火山灰流的区域的测年会相对准确些。因此，印度尼西亚、非洲和西亚的下更新统遗址的人类进化年代测定相对较好，但在欧洲、南非和中国的大部分地区放射测年很少或几乎没有。

关于走出非洲的第一次人口扩张的争论有几个关键问题，每个都需要提高年代和生物地层框架的精度才可解决。如下：

—欧亚大陆古人种的扩张：扩张过程只有一拨人还是可以鉴别出几个阶段？

—留在欧洲的入口处德曼尼西的古人种比中欧和南欧的人类显著古老。这种差异仅仅是研究误差或者测年数据不足，还是真的存在连续扩张？

—依据更好的年代数据，我们能够鉴别第一批非洲人进入欧亚大陆的诱因吗？(例如技术文化，气候)。

—上新世和更新世时期古人种扩张和气候大波动有关系吗？

前两个问题非常相关：德曼尼西遗址的人类遗骸揭示了180万年前欧洲入口存在古人种[10]。该地位于高加索地区的格鲁吉亚共和国，出土了一系列的人类化石和石器，这些是人类走出非洲的证据。基于古磁学和火山与层积物质的氩测年法，德曼尼西遗址的年代学鉴定约为180万年前。

然而，与德曼尼西年代最近的遗址阿塔坡卡的埃勒芬特裂谷遗址大约是120万年[9]。这有点自相矛盾，两个最古老的旧石器时代遗址，德曼尼西遗址和埃勒芬特裂谷遗址，在地理上相去甚远，分别在亚洲和欧洲的边界上和欧洲的尽头-伊比利亚半岛。因此，如我们下面讨论的那样，在180-120万年前，该地区明显缺乏古人种。在地中海周围的区域有很多旧石器时代的遗址，包括古人种的遗骸(化石或者石器)，他们的年代在80万到140万年前(尤贝蒂亚、北毗若、拉瓦德蓬、卢内瑞、勒兹南-拉-采贝、勒瓦隆纳、阳台山、新源头 III、狮子谷、 科扎尼卡)。然而，这些地方的化石和器物，或基于放射测年法而不太精确(如北毗若、尤贝蒂亚、新源头 III、狮子谷、 科扎尼卡)，或缺少分析方法的重要的细节(勒瓦隆纳、拉波拉)。不管怎样，目前，地中海周围区域的古人种揭示了德曼尼西和阿塔坡卡两个遗址年代间的明显断层。

关键问题是这个断层是否代表了在这个时间区段内古人种的缺失(至少在发现的遗址中)。如果是这样的话，这是由什么导致的呢？换句话说，这是开始于180万年前人类不间断的从西向南的扩张吗？或者，这些人类的定居集中在某些年代或某几次的扩张事件中。这些问题的关键在于更准确和更精细地确定这些重要遗址的沉积物的年代。一个更好的年代框架是理解这些路线和早期人类扩散模式的关键。尤其，参考现代哺乳动物扩散和迁移模式，可能有小群体周期性的多次扩散和更新世早期化石人类来自非洲不

同的人群。如这些后来的作者的结论，走出非洲的人类可能一部分留在新的定居点，而另一部分继续迁徙[11]。

第三个问题涉及到走出非洲大陆的扩张机制和原因。在这点上有两个基本的理论[12]。一些作者提出一个有意思的假说叫做“技术选择”。根据这个假说，第一次走出非洲和人类扩散是该群体的种群的增加，这个增加也发展了一种第二模式生产技术，即阿舍利文化。第一模式，或者说奥尔德沃文化，涉及到一种将器具精细化的基本技术，这种器具的第一次使用是在250万年前。第二模式，或者说是阿舍利文化，也起源于非洲，它的生产和扩张也是人类技术进步决定性的一步。

然而，自从90年代早期出现了大量的研究揭示全球气候变化与人类走出非洲进入欧洲和亚洲有关[13-15]。出现了三种重要的假说：(1)“热带假说”，较冷和较干燥的状况出现导致草木丛生到草木稀少的变化。(2)“流动批次假说”，与气候事件导致的动物广泛流动有关。(3)“可变选择假说”，着眼于自然环境的周期性重复变化。然而，最近又提出了另外一种假说，揭示古人种的起源和极度的气候变化在时间上是一致的，与地球轨道反常的极点也恰巧一致[16]。这些极点导致周期中最高强度的日照，这些日照导致季风状况在非常强和非常弱的状态间周期转换。在东非，这些周期性极端变化引发了周期性的湖泊水位大幅度变化。在撒哈拉-阿拉伯沙漠带，沙漠和撒哈拉绿洲长周期的变换证明了反常极点的存在。物种形成时间和出非洲扩张中的反常极点间有系统关联显示，驱动人类进化的气候机制可能就是日照驱动的季风。大湖泊的形成和 “撒哈拉绿洲”产生可能有利于人类在非洲内外的扩张，同时也提供了蛋白更丰富的食物(这是人类大脑进化的基本营养)。有趣的是，Trauth等[16] 基于地中海和阿拉伯海的海底沉积物的泥土波动的记录，揭示了上新世和更新世的三个古怪极点的存在，即260万年前、180万年前和100万年前。第一个极点与第一模式的时间一致，动物区系的改变显示东非环境改变伴随的大草原的扩增。180万年前的极点与走出非洲的人口扩张一致，此时也观察到东非动物区系的更替。在80~120万年前这段时间在地中海周边的区域有大量的考古遗址，但由于缺少精确的年代，不能决定这些遗址出现的时间和反常极点是否有关联，因而也不能确定古人种走出非洲的扩张是否和这些气候变化事件有关。旧石器时代早期遗址，如阿尔及利亚境内的艾因哈奈什遗址和艾因波肖瑞遗址和摩洛哥境内的艾因贝尼玛塔和伽非盆地遗址，由于在非洲北部边缘系统性意义的位置而备受关注。现在初步的年代资料显示在约180万年前，在阿尔及利亚的一些沉积物中，奥尔德沃石器遗址和最大的反常与东非的动物区系更替相关。目前，年代的数据太少以致不能形成可靠的假说。虽然有上述的气候和技术文化扩散假说，理解人类走出非洲的原因最终还需依赖于对气候、动物区系和文化关键事件更加准确地年代测定。(袁媛 译)

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