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Hominins, deserts, and the colonisation and settlement of continental Asia

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ABSTRACT

Deserts are now extensive across continental Asia south of 45° N from Arabia and SW Asia to the Thar Desert of India, and north-eastwards through Central Asia to North China. Despite the potential importance of arid regions to human evolutionary studies, Palaeolithic records from areas that are now desert are generally poor, and the best information tends to be derived from springs and palaeolakes, partly because these are obvious taphonomic traps for archaeological, faunal and other environmental material, and partly because water would have been the most critical resource for survival. This paper provides an overview of what can currently be stated about the Palaeolithic record from areas of Asia that are now deserts, particularly in relation to Middle Pleistocene hominin evolution, the expansion in MIS4-3 of *Homo sapiens*, and the extinction of its competitors. It is suggested that among the reasons why *H. sapiens* was ultimately more successful than Neanderthals in MIS 3-4 in colonising continental Asia are that they were physiologically better adapted to high summer temperatures, and were probably more skilled in creating a viable resource base in semi-arid and arid landscapes. Neanderthals in Central Asia may have faced additional problems in dealing with low winter temperatures, large areas of salt deserts and sand seas, and non-potable water supplies. Nevertheless, even *H. sapiens* does not appear to have developed the means to survive habitually in Asian deserts until the terminal Pleistocene, and in most cases, the Holocene.

1. Introduction

At present, deserts cover ~6 million km^2 of continental Asia (Fig. 1), or an area almost 50% larger than the 4.3 million km^2 of the European Union. Overall, Asia contains ca. 32% of the global arid zone (Thomas, 2011). These deserts exist mainly because of two climate systems. In west Asia, the main precipitation occurs in winter and spring and derives from the Mediterranean and Black Seas. Most of this falls as rain in the Levant and in western Turkey, and little penetrates inland, apart from Eastern Turkey, the Caucasus and Zagros Mountains (which can receive heavy snow in winter). East of the Caucasus, most of the rain from the Caspian is drawn to the Elburz Mountains of northern Iran, so very little reaches the Iranian Plateau and Central Asia. In South and East Asia, most of the rain falls during the summer monsoon which brings rain from the Indian and western Pacific Oceans. Its northward penetration is blocked by the Himalayas and the Tibetan Plateau, and thus the "Northern Arid Area of China" (NAAC) is arid or hyper-arid. In winter, the cold, dry winds of the winter monsoon blow southward from Siberia and Mongolia, and further accentuate the aridity of northern China. The Arabian Peninsula misses out on most of the rainfall from both the Mediterranean and Indian monsoonal systems, with the exception of the Yemeni Highlands, which receive some rainfall from the summer monsoon. Human-induced activities over the past 10,000 years such as over-grazing and the gathering of shrub vegetation for fuel have doubtless increased the current extent of deserts, particularly by destabilising sand dunes, but are not a primary cause of desert formation.

Unlike northern Africa, which is dominated by the Sahara, Asia contains several deserts (Table 1). The smallest are the deserts of the Sinai Peninsula, Egypt, and the Negev, Israel. The largest in Southwest Asia is the Arabian Desert, which adjoins and grades into the Syrian and Mesopotamian Deserts. In Iran, the Iranian Plateau largely comprises the Dasht-i-Kavir (Plain of Sand) in the North, and the Dasht-i-Lut (Plain of Salt) in the south. To the east of the latter, Baluchistan and Sindh in southern Pakistan are desert, and further east, there is the Thar Desert of northwest India. Central Asia is dominated by the deserts of the Kara Kum and Kyzil Kum between the Caspian and the Pamirs. Eastwards of these and between the Tienshan and Kunlun Mountains lie the deserts of northern China – the Taklamakan, the Turfan Basin, the Gobi, Tengger, Badan Jarain, Ordos and Mu Us deserts. Much of the Tibetan Plateau and Mongolia

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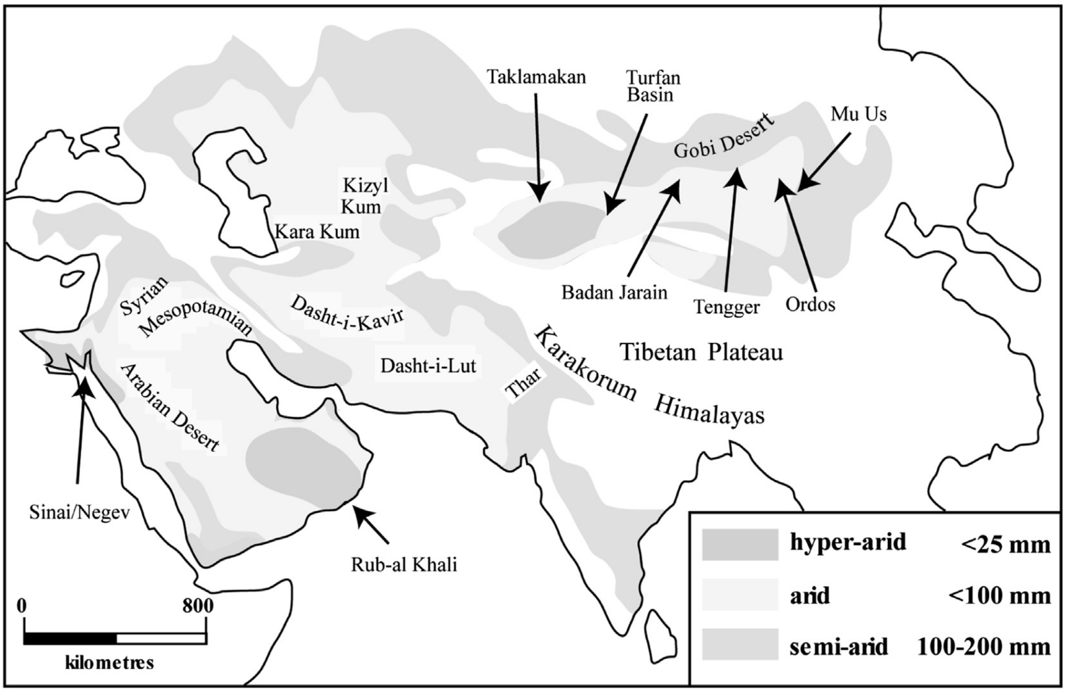

Fig. 1. The arid and semi-arid regions of Asia. (Source: the author).

can also be classed as desert, in terms of effective precipitation. The topography of these Asian deserts varies enormously, from mountain ranges nearly 4000 m high (as in Arabia), substantial dune fields, in which the highest dunes in the Badain Jaran of North China are over 450 m high (Yang et al., 2003), to desert pavements, extensive salt flats (as in the Dasht-i-Lut) and stony plains (as in the Gobi). Some Asian deserts are crossed by large perennial rivers that originate in less arid regions: examples are the Tigris and Euphrates in the Syrian and Mesopotamian deserts; the lower Indus in Sindh; the Oxus in the Kizyl Kum, and parts of north China, with the Huang He (Yellow River). These apart, the main source of potable water in most Asian deserts are lakes and springs.

2. The importance of the semi-arid zones adjoining deserts

The term "desert" is often used interchangeably (and sometimes imprecisely) with "dryland" and "arid zone", but the common underlying feature is moisture availability, or the balance between precipitation and evapo-transpiration. Arid environments are commonly classed as semi-arid, arid or hyper-arid, depending upon the (in)frequency and average amount of rainfall over a defined number of years. As approximate indicators, hyper-arid areas might record several consecutive months with no rainfall and averages over several years of 25–200 mm p.a., and arid and semi-arid areas usually have average precipitation levels of 200–500 mm p.a.

Table 1
The size and temperature regimes of Asian deserts.

Country/region	Desert	Area (sq. miles)	Area (km^2)	Mean winter and summer temperature range (°C)
The Arabian Peninsula	Arabian: includes:	888,030	2,300,000	2–40[a]
	Rub' al Khali	234,375	600,000	
	An Nefud	28,125	72,000	
Israel	Negev	4630	12,000	2–30[a]
Egypt	Sinai	23,350	61,000	2–30[a)]
Syria	Syria	200,000	518,000	10–46
Iraq	Mesopotamian	78,125	200,000	2–40[a]
Iran	Dasht-i-Kavir[b]	156,250	400,000	1–30[a]
Iran	Dasht-i-Lut[b]	78,125	200,000	2–30[a]
Central Asia	**Karakum***	189,190	490,000	−30–54
Central Asia	**Kyzyllkum***	78,125	200,000	−30–54
Northern China	**Taklamakan***	125,000	323,750	0 ± 18
Northern China	**Turfan Depression***	19,305	50,000	−10 ± 32
Northern China	**Tengger***	16,486	42,700	-2 ± 16
Northern China	**Ordos***	12,355	32,000	0 ± 20
India	**Thar***	82,625	214,000	−10 ± 32
Mongolia	**Gobi***	501,930	1,300,000	−18 ± 20
Total		2,453,526	6,343,450	

Note: Those in **bold** are cold deserts, with temperatures at or below freezing for at least two months each year. The largest recorded temperature extremes are probably those from the Turfan Basin (154 m below sea level), from +48.9 °C to −52.1 °C.
Sources: Stoppato and Bini (2003).
[a] Cooke and Warren (1973, Fig. 1.1).
[b] Naval Intelligence Geographical Handbook Series (1945) for Iran.

However, these "average" figures are very limited in value because of inter-annual variability in rainfall: whereas in temperate regions, year-to-year variability in rainfall is usually <20%, it may be as high as 80–150% in arid regions (Thomas, 2011, pp. 5–11). Consequently, "average" rainfall totals alone do not provide clear distinctions between semi-arid, arid and hyper-arid regions; instead, a combination of factors such as the infrequency, duration and intensity of rainfall, its inter-annual variability, and the likely size of area affected by a rainfall event are more meaningful indicators of aridity.

Although the theme of the Middle Palaeolithic in the Desert conference was people and deserts, we need to widen the study of past arid and hyper-arid regions to include the semi-arid zone that borders them. There are three reasons for doing so. The first is that semi-arid regions probably contained the source populations that could expand into adjoining arid regions when either population levels allowed expansion and/or when climatic conditions were conducive to expansion. Secondly, the boundaries of deserts are not immutable: areas that are now arid might have been semi-arid in the past, and areas that are semi-arid today could have been arid during cool, dry phases of the Pleistocene. One good example is the Loess Plateau of northern China, much of which is now semi-arid. In the last glaciation, rainfall may have been reduced by up to 25% (Maher et al., 1994; Maher and Thompson, 1995), 30% (Florindo et al., 1999) or even 40–75% (Liu et al., 1995), with precipitation levels as low as 100–200 mm over the central part of the Loess Plateau during the last glacial maximum and previous stadial, which caused a significant southward extension of desert conditions. During the deposition of loess15 (a particularly thick and silty layer) ca. 1.15–1.24 Ma, it is estimated that annual average temperatures on the Loess Plateau were as low as 1.5–3.0 °C, and rainfall only 150–250 mm p.a. (Guo et al., 1998, 2002a), comparable to conditions experienced today in Northeast Inner Mongolia or on the Tibetan Plateau.

Conversely, in the last interglacial (and doubtless in previous ones), rainfall over the Loess Plateau may have increased by up to 20% (Liu et al., 1995) or even 80% (Maher and Thompson, 1995); either way, the desert margin would have contracted.

A third reason why we should not ignore the semi-arid regions that adjoin deserts is that these often have the best records of desert expansion and contraction. This is particularly true of North and Central China, and Central Asia. In both regions, cold dry periods were associated with reduced vegetational cover and increased dust deposition, blown in from neighbouring deserts, often in violent dust storms. The result is over 175 m of loess deposited in the last 2.5 Ma (in addition to an equivalent thickness of aeolian red clay before this time), and over 150 m in Tajikistan. During moist interglacials and interstadia, loess was still deposited, but surfaces stabilised with the formation of palaeosols; thus loess profiles typically show alternations of red bands denoting palaeosols with yellow loess denoting colder and drier periods. This record of loess and palaeosol deposition provide the most continuous and detailed terrestrial records of climate change in Eurasia over the last 22 Ma in the case of northern China (Guo et al., 2002b), and 2.5 Ma in the case of Central Asia (Dodonov, 2002). In both regions, the loess records show numerous mild and short shifts from dry to moist conditions in the Early Pleistocene, and six long and severe shifts in the last 600 ka (see Fig. 2; Liu et al., 1999). The same Middle Pleistocene signal is recorded right across Asia, from the South China Sea (see e.g. Chen et al., 2003) to Lake Baikal (Khursevich et al., 2001), and westwards into Europe.

3. The Pleistocene history of Asian deserts

Despite their size, we lack detailed accounts of the long-term, pre-Holocene history of many of the Asian deserts. What appears to be a common feature is the way they repeatedly expanded and contracted during the Pleistocene, with some becoming more extensive during the Middle Pleistocene (0.78–0.125 Ma). This is evident by briefly reviewing the desert histories of China, Central Asia, Arabia and India.

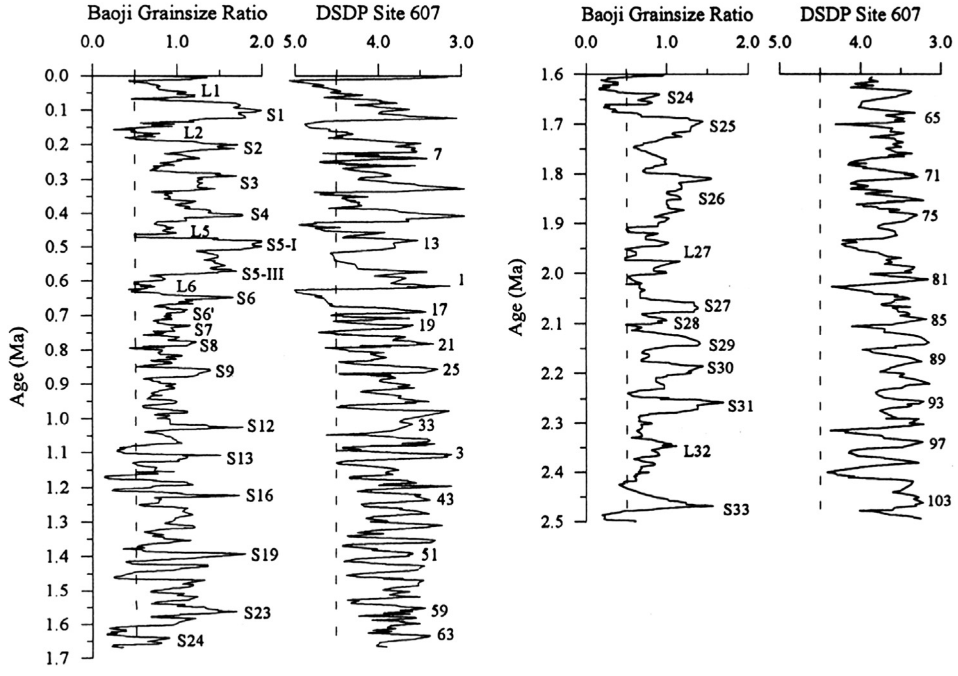

Fig. 2. The loess-palaeosol sequence from Baoji, China. L = loess, S = palaeosol. Note the numerous oscillations before 0.6 Ma, and the high-amplitude, low frequency climate shifts after 0.6 Ma. The loess-palaeosol sequences of China and Central Asia provide among the best proxy records of desert expansion and contraction. Source: Liu et al. (1999, Fig. 3).

3.1. China

The oldest Asian deserts are probably those of northern China, where (see above) desert formation began at least 22 Ma, and intensified from the late Miocene onwards. The main driving force in this process was probably the uplift of the Tibetan Plateau, particularly along its northern margin (Fort, 1996; Sun et al., 1998; Dettman et al., 2001; Liu and Yin, 2002) which experienced up to 3 km of uplift in the Pliocene and Pleistocene (Tapponnier et al., 2001; Wu et al., 2001) that would have blocked the moist summer monsoon and strengthened the dry winter monsoon. Aeolian dust deposition from desert sources began in the main part of the Chinese Loess Plateau by at least 7.6 Ma (Sun et al., 1998), and the deserts of the Tarim Basin and Taklamakan are at least 5.3 Ma old (Sun et al., 2008). The Tengger and Badain Jaran (and by implication, the Northwest Arid Area of China [NAAC]) were in place 850,000 years ago (Fang et al., 2002a; Guan et al., 2011). However, both desert development and Tibetan uplift in the last 3.5 Ma appears to have been complex and stepwise (see Li and Fang, 1999); thus the southern margin of the Mu Us Desert advanced southwards at 2.6 Ma, 1.2, 0.7 and 0.2 Ma, possibly because of a stepwise weakening of the summer monsoon brought about by either further uplift of the northern parts of the Tibetan Plateau or increased global ice volumes (Ding et al., 2005), and the Tarim Basin may have reached its present size ca. 500 ka following uplift of the Kunlun Mountains and Tienshan (Fang et al., 2002b). In northern Xinjiang, NW China, the earliest loess on the Tienshan occurred ca. 800 ka, followed by further aridification and desert expansion ca. 650 and 500 ka (Fang et al., 2002b).

3.2. Central Asia

The background to the aridification of Central Asia is the retreat of the Paratethys Sea in the late Oligocene and its increasingly continental climate. This process was complicated 3 Ma and 1.1 Ma when the Black Sea and Caspian Seas were linked north of the Caucasus, and even with the Aral Sea (Boomer et al., 2000). The progressive desiccation of the Aral Sea basin exposed clay soils that were vulnerable to wind erosion and thus loess deposition. In Tajikistan, loess deposition commenced ca. 2.5 Ma (Dodonov and Baiguzina, 1995; Dodonov, 2002). Although direct data is lacking, it is likely that most of the desert expansion in Central Asia occurred in the Middle Pleistocene. In Central Asia, and unlike in China, the increase in loess deposition was progressive, and increased from ca. 7.8 cm/1000 years between 1.77 and 0. 85 Ma to 12.1 cm/1000 years from 0.85 to 0.25 ka, when it rose to 20 cm/1000 years (Ding et al., 2002; Yang and Ding, 2006). This trend probably reflects the increasing aridity of this region, and the expansion of the Kara Kum and Kizyl Kum deserts.

3.3. Arabia

The Arabian Desert experienced substantial environmental change during the Quaternary (see Parker, 2009; Groucutt and Petraglia, 2012; Drake et al., 2013). For example, the interior of Arabia was once drained by at least three large, eastward flowing river systems (Al-Sayari and Zötl, 1978; Petraglia et al., 2012a,b), and lakes such as those in the now hyper-arid An Nefud desert of northern Arabia once supported pygmy hippopotamus (*Hexaprotodon* sp.), fish >1 m long, elephant, large bovids and horse (Thomas et al., 1998).

Extreme aridity appears to have set in during the late Middle Pleistocene. One of the best indicators is the record of dust deposition offshore in the Indian Ocean, as shown by ODP 722, showing three main peaks in the last 200 ka (Emeis et al., 1995). However, we need to be careful as at times of low sea level, the Arabian/Persian Gulf would have been dry land and an additional source of dust, so this has to be accounted for; nevertheless, it is evident that offshore dust deposition increased after 200 ka. Desert conditions intensified in Arabia in the late Middle Pleistocene. Speleothem records from Oman and Yemen show that speleothem growth (indicating higher rainfall) was restricted over the last 330 ka to short (5–10 ka) periods of growth, during peak interglacial periods, corresponding to the early to middle Holocene, MIS 5.1, 5.3, 5.5, 7.1, 7.5 and 9 (Burns et al., 2001; Fleitmann et al., 2003, 2011), indicating that the summer Indian monsoon moved offshore of southern Arabia during arid glacial episodes. This finding is supported by evidence of extensive sand dune development in the United Arab Emirates (UAE) and southern Oman during MIS 6 between 140 and 160 ka (Preusser et al., 2002) when the floor of the present-day Arabian/Persian Gulf was exposed as a source of aeolian dust, precipitation was lower, and vegetation cover was reduced. Glennie and Singhvi (2002) suggest that during periods equivalent to high-latitude glaciations, the winter shamal winds that blow from the northwest down the Arabian/Persian Gulf and then southwards across the Rub al Khali Desert of southern Arabia would have been more dominant than today, and the southwest Indian summer monsoon would have been weaker, and further offshore. The overall inference from these studies is that parts of the Arabian Peninsula were even drier than today throughout much of the Middle Pleistocene, but were suitable for colonisation during interglacial and inter-stadial periods, as indicated by the recent sequence of archaeological assemblages in lake shoreline deposits at Jubbah, and the frequent association of Palaeolithic sites with extinct water courses (Petraglia et al., 2011; Groucutt and Petraglia, 2012). As Fleitmann et al. (2011, p.786) point out, there were at least three time slots for *Homo sapiens* to disperse into Arabia: 130–123, 105–100 and 80–78 ka BP.

3.4. Thar Desert

The Thar Desert has a long and complex history that has been investigated over several decades (see e.g. Misra et al., 1982; Misra and Rajaguru, 1989; Misra, 1995; Singhvi et al., 2010). Recent summaries are provided by Dennell (2009) and Petraglia et al. (2012a,b). As with Arabia, its history includes several periods when rainfall was higher than today's. Today, much of the Thar Desert is covered by sand dunes, especially in its north and northwest. The area around Didwana contains three geological formations, the Jayal, the Amurpura, and, most recently, the Didwana. The Jayal Formation is an uplifted palaeochannel (Blinkhorn, 2013) exposed for over 50 km as a low, undulating ridge up to 50 m above the surrounding plains, and is a 20–60 m-thick, poorly sorted, clast-supported, coarse quartzitic gravel deposited by a strong but shallow braided stream that originated in the Himalayas, and is assumed to be Early Pleistocene in age. The climate was probably hot and humid, as evidenced by the presence of ferricretized iron. After the Jayal Formation, the drainage weakened, and aeolian processes became important. The Amurpura Formation lies over or against the Jayal Formation; it comprises calcareous loam, marl, and kankar (caliche) and is extensively exposed in low lying areas. The upper part has a calcrete layer up to 2 m thick, which contains Acheulean and late Middle Palaeolithic tools. Although the Amurpura Formation is undated, the presence of Lower Palaeolithic to late Middle Palaeolithic tools is interpreted as indicating a long period of deposition in the Middle Pleistocene, under a semi-arid climate and weakened drainage system of small, braided streams that flowed through wide plains, with many lakes and pools. Gradually, as the climate deteriorated, the drainage of the Thar shifted increasingly to the north and west, and eventually it lost all its perennial rivers. During the Middle Pleistocene, strong aeolian activity under increasingly arid conditions resulted in the formation of extensive linear and longitudinal dunes on relict flood plains. Their history is shown by profiles at Chamu (Dhir et al., 2010) and the 16R dune near Didwana (Singhvi et al., 2010). At the latter, three lithounits are recognised: Unit I (Holocene; 4.9-m-thick loose sand); Unit II (Late Pleistocene; 3-m-thick, light grey, loose and moderately sorted loamy sand); and Unit III, a 10-m-thick sequence of brown to pale red sands which contains both Middle and possibly Lower Palaeolithic assemblages. The lower part of this sequence is dated by TL to 130–160 ka, but the upper part extends into the Holocene (Misra and Rajaguru, 1989; Raghavan et al., 1989; Singhvi et al., 2010). Numerous palaeosols indicate that dunes were often stabilised under intermittent periods of higher rainfall, and at least sixteen calcrete bands in units II and III show periodic fluctuations in the water table. As in Arabia, conditions in the Thar Desert varied from extreme aridity in parts of MIS 6, 4 and 2, to moister periods (as in MIS 5 and parts of MIS 3) when it contained riverine corridors and lakes and sufficient resources to support human colonisation (see Blinkhorn, 2013).

4. The Palaeolithic record of deserts

The Palaeolithic record from Asian deserts is highly variable: some, such as those in Central Asia and Northwest China, have very sparse records, partly perhaps because little fieldwork has occurred, and recent dune fields may have covered earlier surfaces, and possibly because they were rarely utilised in the Palaeolithic. Others, such as Saudi Arabia, have a very rich record (see Petraglia, 2003; Petraglia and Alsharekh, 2003; Groucutt and Petraglia, 2012), which doubtless reflects the number of surveys that have taken place (see e.g. Whalen et al., 1983, 1988, 1989), but also may indicate that when rainfall was higher than today, it was an attractive area for occupation. The best records from arid and semi-arid areas (i.e. those that would at times have been arid) are those from palaeolakes, such as Nahal Zihor, Negev (Ginat et al., 2003), the An Nefud and Jubba, Arabia (Thomas et al., 1998; Petraglia et al., 2011, 2012a,b); the Azraq Basin, Jordan (Garrard, 1998; Cordova et al., 2013), Kashafrud, NE Iran (Ariai and Thibault, 1977); we can also add from areas now semi-arid ’Ubediya (Bar-Yosef and Goren-Inbar, 1993) and Gesher Benot Qa’qov, Israel (Goren-Inbar et al., 2000), and the Nihewan Basin, North China, with a record now 1.6 Ma long of hominin occupation (Zhu et al., 2004), even if likely intermittent (Dennell, 2013). There are also oases, such as el-Khowm, Syria, with a superb Palaeolithic sequence (Jagher and Le Tensorer, 2011); and dune sequences, such as that from 16R in the Thar Desert, already mentioned, showing intermittent occupation during moist episodes. The palaeolakes and oasis records are clearly the main source of information because potable water would have been a key resource, and because they are ideal taphonomic traps, with periods of rapid and gentle accumulations of fine-grained deposits. Other sources should also be mentioned: wadi sequences, as in Yemen, from recent work by Anne Delagnes and her group at Shibat Dhiya (Delagnes et al., 2012), and from open sites, such as the detailed loess-palaeosol records of the last 900 ka in Tajikistan (Ranov, 1995; Ranov and Dodonov, 2003).

4.1. Arid or semi-arid adaptation?

Arguably the most important question to ask about Palaeolithic evidence from areas that are now desert is whether this indicates an adaptation to a desert environment, or an extension of a semi-arid lifestyle into a desert when it became semi-arid. There are two reasons why the latter is more likely. First, those Palaeolithic sequences from desert regions that can be integrated with a detailed climatic framework indicate that occupation is limited to episodes of increased precipitation. Several examples are offered in this volume of occupation during MIS 3 or MIS 5, but not during the arid parts of MIS 6, 4 or 2. Second, the Palaeolithic records from semi-arid regions show a similar pattern, indicating that even here, hominins were constrained by the rainfall. An excellent example is the Tajik record which shows that throughout the last 900 ka, hominin occupation is always associated with palaeosols which formed during moist (and warmer) interglacial and inter-stadial periods (see Ranov, 1995). As argued below, adaptation to year-round life in a desert environment is probably unlikely before the terminal Pleistocene at the earliest, and in most instances, the Holocene.

4.2. How moist are “moist” episodes in deserts?

As noted above, rainfall in deserts is extremely variable, and is often erratic, intense, ephemeral and localised: the “average” annual total may fall within a few hours, and conversely, there may be several consecutive months with none. Consequently, it is necessary to consider what is meant by a “moist” or “arid” episode in a desert environment, particularly because climatic change has been seen as a powerful factor that drives or inhibits human dispersals in the Pleistocene. When considering arid regions, care needs to be taken in distinguishing between long periods (of several centuries or millennia) and very short-term events (of perhaps only a few days or weeks) because of the magnitude of rainfall variability. As an example, it was estimated that at Sodmein Cave, Egypt, over a period of ca. 7800 years, there were probably only two rainfall events a century of sufficient magnitude to leave a record in the cave sediments (Moeyersons et al., 2002). Thomas and Burrough (2012) point out the importance of local variability and short-term events: a single, intense episode of intense rain or extreme drought might leave a geomorphological signature that might be dated, but it would not be valid to conclude that “wet” or “dry” conditions prevailed as the “average” condition within the error of margin of those dates. Still less would it be justified to assume that a dry or moist period in northern latitudes is automatically replicated in an arid region, or demonstrated by a single indication of a dry or moist event.

5. Deserts and human evolution: the colonisation of Asia

The location and varying extent of deserts are likely to have had major impacts upon hominin populations across Asia. Because deserts were less prevalent than today during the Early Pleistocene (see above), latitudinal dispersals across Asia would have been easier then than later (Dennell, 2004). Barriers to dispersal became much more serious after ca. 500 ka. Besides reducing the size of areas that hominins could inhabit, the growth of deserts placed major barriers that impeded or prevented the dispersal of hominins across Asia. There was thus a reduction in hominin mobility as well as of the space that they could inhabit. As shown in Fig. 1, the expansion of these deserts created a more or less continuous belt that was difficult to inhabit or cross between the Arabian Peninsula and North China. Particularly important barriers to hominin movement were the deserts of inland Southwest Asia, Central Asia, the Thar Desert of Northwest India, and those along the northern edge of the Tibetan Plateau and North China. Additionally, the expansion of deserts in the Middle Pleistocene blocked the corridors between Southwest Asia and East Africa and terminated faunal exchange between Africa and Asia after 700 ka (Tchernov, 1992; O’Regan et al., 2005). This point impacts directly on both the assumption that the Neanderthals’ ancestors left Africa ca. 500–

300 ka (Krause et al., 2010), and on assessments of whether *Homo heidelbergensis* should be regarded as a West Eurasian, East and West Eurasian (i.e. including Chinese specimens), or an Afro-Eurasian population (see Martinón-Torres et al., 2011; Stringer, 2012). Dispersals between Central Asia and northern China are also likely to have been severely restricted during the Middle Pleistocene because of the formation of the Northern Arid Area of China after 850 ka, and the increasing desertification of Central Asia, as reflected by the marked increase in aeolian dust deposition (see above, and Dennell, 2009).

6. Deserts and the colonisation of Asia by *H. sapiens* and Neanderthals

I ended my recent book on the Palaeolithic of Asia (Dennell, 2009) by proposing that in the Upper Pleistocene, there was what I termed "a scramble for Asia" by both *H. sapiens* and Neanderthals. A good starting point is to look at hominin settlement in continental Asia during the most arid parts of MIS 6, ca. 140 ka. MIS 6 appears at times to have been as severe as the most severe parts of the last glaciation: most of interior Asia was exceptionally arid and probably largely uninhabited (Dennell, 2009, 477; Hetherington and Reid, 2010). With the last interglacial, a warmer and especially moister climate provided opportunities for colonisation by both Neanderthals and *H. sapiens*.

6.1. H. sapiens and deserts

On the assumption that *H. sapiens* originated in East Africa, the obvious point of entry would have been the Arabian Peninsula or the Levant. Although woefully documented, there appears to have been an initial expansion eastwards across southern Asia, from Arabia to Australia (Boivin et al., 2013; Dennell and Petraglia, 2012). On this trajectory, humans were in the New Guinea highlands by 50 ka (Summerhayes et al., 2010), and in Tasmania when Neanderthals were still extant in Gibraltar.

As much of the terrain between Arabia and India is now desert, a relevant question is whether *H. sapiens* avoided or traversed desert regions. Two hypotheses can be considered.

6.1.1. The coastal route

One popular theory is that hominins were adapted to exploiting marine resources (shell-fish, sea mammals, in-shore fish) by the last interglacial, and thus colonised southern Asia coastally, following a lowered coastal line during MIS 4, and thus bypassed deserts and inland areas, and reached SE Asia by 40 ka (Stringer, 2000; Macaulay et al., 2005). In support, it is claimed that the Andaman Islanders have a genetic history extending back 60 ka (Thangaraj et al., 2005), and are thus the oldest extant population in south Asia, and the oldest Asian population adapted to exploiting marine resources. Against this theory one can suggest a) that the evidence for marine exploitation across southern Asia is overwhelmingly Holocene, and dependant on boats and fine nets; b) there is no evidence that the Andaman islands were occupied before 2000 years ago (Cooper, 2002); and c) it is not clear that shell-fish were especially abundant along much of the Iranian and Indian coastlines. For these reasons, an overland route through areas now deserts is perhaps as likely.

6.1.2. The inland route, and deserts

An alternative view is that the deserts of southern Asia, from Arabia though southern Iran, Sindh, the Thar, were used as corridors during moister episodes. Many such opportunities would have existed during MIS 5, 3, and even parts of MIS 4. Additionally, if we assume that our species originated in the tropics, a light body frame would have been advantageous in coping with high summer temperatures.

Although deserts can be viewed as corridors for hominins rapidly dispersing between two non-desert regions, they should also be viewed as potential semi-arid regions where hominins settled, at least as long as conditions permitted. One should therefore expect evidence of lithic and material traditions that were idiosyncratic, and not simply those used by a migrating population that used a desert as a corridor. Examples are Arabian Middle Palaeolithic assemblages that show African (Rose, 2004; Armitage et al., 2011; Rose et al., 2011) or Levantine (Crassard, 2009) affinities, but also exhibit their own distinctive characteristics (see e.g., Delagnes et al., 2012, 2013). There may also have been refugia in areas where occupation was possible throughout dry periods; examples might be the Red Sea coastal plain of SW Arabia, the Yemeni Highlands and the exposed floodplain of the Arabian/Persian Gulf at times of low sea level (see Rose and Petraglia, 2009, Fig. 2). One would also expect evidence of long-distance networks for procuring and exchanging scarce materials (and by implication, mates and information). As often with populations in areas where resources were sparse and vulnerable to short-term climatic or environmental change, those that settled in deserts would have been unstable, and unlikely to persist when conditions became too arid (i.e. <100 mm p.a. over a generation). One can further predict that there would have been a rapid turnover of populations, and high rates of extinction and abandonment. Because re-colonisation following arid periods could have come from several directions, one would expect also a diverse range of cultural traditions, depending upon the location of the source populations, and little genetic time-depth in modern inhabitants because of repeated immigration (as seen in modern Yemen; see Ridl et al., 2009). These are what I would term "sink" populations, dependant on "source" populations to provide recruitment (see Dennell et al., 2011) that would usually have been outside in adjacent semi-arid regions.

6.2. Neanderthals and deserts

A point too often overlooked it that by the time of their extinction ca. 30 ka, most of the Neanderthal range was in Asia, not Europe. Also too often overlooked is the point that Neanderthals expanded their range eastwards in the Upper Pleistocene, just as did *H. sapiens* (Howell, 1999).

If taken at first value as a generous way of drawing boundaries around a small number of widely-spaced sites, Neanderthals in MIS3 in Asia were inhabiting substantial areas of southern Siberia, and large parts of SW Asia, notably the Zagros, Iran, the Levant, and Central Asia. The limits of their southern range are currently unclear. Petraglia (2011) places their southern limits north of Saudi Arabia, although it is not impossible that when conditions were favourable, they may have occasionally ventured further south (see e.g. Stewart and Stringer, 2012; Boivin et al., 2013, Fig. 1). The recent discovery of Neanderthal remains at Denisova cave, Transbaikalia, Siberia (Krause et al., 2007), places them closer to Beijing than Moscow, raising the possibility, even if remote, that they may have reached the Pacific. In Siberia at least, Neanderthals appear to have been conspecifics with Denisovans, so far identified from ancient DNA analysis of a phalange and molar (Krause et al., 2010; Reich et al., 2010). As their DNA signature is also detected in modern populations in SE Asia and Melanesia, their distribution may have extended across East Asia during the late Pleistocene.

It is likely that the distribution of Neanderthals in Asia was patchy rather continuous across continental Asia because of the types of deserts they would have encountered. Here, they experienced far greater constraints than those faced by *H. sapiens* in southwest and south Asia. Although the deserts of Central Asia and

North China share similar landforms with the deserts of for example Arabia or Iran, the critical differences lie in their winter temperatures (see Table 1). These are routinely sub-freezing, and often −20 °C., excluding wind chill. In the Tarim Basin, which at −154 m below sea level is the second lowest place on earth, winter temperatures as low as −50 °C have been recorded. As the highest temperatures at +50 °C, it has one of the greatest temperature ranges on the planet. Further east, on the North China Plain, January temperatures average −10° to −20 °C. Although the rugged skeletons and probable greater fat reserves than we have gave Neanderthals an extra degree or two advantage in enduring cold conditions, it is hard to see how they could have coped in areas not only defective in food and fuel, but also cripplingly cold in winter. At least in the wooded part of southern Siberia, there were better provisions of fuel, and wider range and greater amounts of food.

An additional problem would have been the lack of potable water, especially in summer, as in Central Asia, most of the rainfall is winter and spring. In spring, the main source is melt-water from high altitude snowfields in the Pamirs or Tien Shan – thus lakes become less saline in spring, but more so in summer. Although many lakes are recorded in North China and Central Asia, these are often highly saline (Yang et al., 2003), and that too needs to be considered when discussing Palaeolithic settlement. (On the other hand, saline lakes often support a rich and varied bird life, so their value as a resource should not be ignored providing that potable water was available nearby for hominins.)

7. True desert adaptations in Asia: a largely Holocene phenomenon?

Overall, it is unlikely that humans routinely lived year-round in arid and hyper-arid Asian deserts under conditions as arid as today (i.e. <100 mm) before the terminal Pleistocene and Holocene. There may be exceptions where there were networks of oases or lakes that provide a dependable, year-round supply of mammals, birds and perhaps fish, but these situations are likely rare in Palaeolithic Asia. Adaptations needed for successful and prolonged desert life include domestic livestock (sheep and goat especially, but also camel) for meat, milk and wool, and often horse, donkey, pony and/or camel for transport. In many cases across Asia, desert communities depend upon and are intimately linked with urban communities in semi-arid regions which provide markets, commodities and capital for investment, risk-buffering, and infrastructure such as wells and (in Iran) qanats for irrigation. The reciprocity involved in these transactions is usually positive, but can be negative (as with raiding, or the Mongol invasions of urbanised areas). The Palaeolithic record of occupation in deserts in Asia is likely to have been restricted to periods of higher rainfall that converted an arid desert into a semi-arid region, rather than an adaptation to life in an arid region.

8. Conclusions

Deserts in Asia profoundly affected the course of hominin evolution in Asia, and the nature of hominin settlement. The increasing aridification of much of continental Asia in the Middle Pleistocene would have led to the isolation of *H. erectus* s.s. in China from its counterparts in Central Asia, and the cessation of faunal exchange between SW Asia and East Africa would have isolated Eurasia from Africa. Both points are relevant to assessments of whether *H. heidelbergensis* was restricted to western Eurasia, or extended into sub-Saharan Africa and East Asia. In the Upper Pleistocene, Neanderthal expansion east and north of Iran was adversely affected by the prolonged sub-freezing winters in the deserts of Central Asia and north China. *H. sapiens* was less adversely affected by the deserts of southern Asia, but nevertheless likely restricted to periods (such as MIS 5 and 3) when these briefly became semi-arid. Such issues deserve more attention than they have so far received.

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