Journal of Anthropological Archaeology 76 (2024) 101624

Contents lists available at ScienceDirect

Journal of Anthropological Archaeology

journal homepage: www.elsevier.com/locate/jaa

Hunting, Herding, and diet breadth. A landscape based approach to niche shifting in subsistence economies (Gobi Desert)

Lisa Janz

Department of Anthropology, University of Toronto Scarborough, 1265 Military Trail, Scarborough, ON M1C 1A4, England

ARTICLE INFO

Keywords:
Neolithic
Palaeolithic
Broad spectrum foraging
Core reduction
Spatial distribution
Mobility
Palaeoecology
Mongolia
China
Bronze Age pastoralism

ABSTRACT

Diet is fundamental and closely interconnected with land-use, technology, and economy. When societies undergo major diet shifts, the entire human niche shifts, including all interrelated aspects of social organization. As such, larger patterns in social organization can inform us about diet in the absence of direct evidence. This study focuses specifically on patterns of land-use in the Gobi Desert of China and Mongolia, a place where direct evidence of diet is scanty due to the poor preservation of organics. The purpose is to explore diachronic changes in the spatial distribution of sites and variation in intensity of site use in order to explore proposed changes in subsistence economies. Here, a reorganization of technology, raw material use, and settlement that began in the early to middle Holocene ("Oasis 2") supports the idea of diet breadth expansion between the Palaeolithic and Bronze Age. Strategies of land-use during all three periods are considered. The findings offer a foundation from which to build testable hypotheses about local land-use and subsistence, but also a model for exploring such transitions in other regions where direct evidence is scanty (e.g., forest landscapes, many arid regions and the very deep past).

1. Introduction to diet and land use

Significant changes in hunter-gatherer diet and land-use emerged world-wide during the late Pleistocene and Holocene though at very different tempos and with divergent trajectories. Understanding diet change is primarily associated with the study of faunal and botanical assemblages, as well as dietary isotopes (C/N). This means that reconstructing diet in regions with poor organic preservation – regions with high aridity, highly acidic soils (for fauna), or highly alkaline soils (for botanicals) – is extremely challenging. Such regions are largely excluded from high-level narratives of human prehistory and this undermines our ability to understand human adaptation within the full range of environmental settings and world regions, particularly in deserts and heavily forested areas. The implications of excluding large swaths of the planet from the human narrative are concerning, especially when we consider the importance of dietary studies to categorising major trajectories in social complexity and their role in characterizing the nature and pace of change, including capabilities for change and/or continuity across human society.

Mongolian archaeology is gaining increasing attention for groundbreaking studies on the emergence of nomadic pastoralism (Honeychurch 2013; Honeychurch and Makarewicz 2016) and has also been shown to have the potential to contribute to the study of early human migrations (Zwyns et al. 2019), broad-spectrum foraging (Janz 2016) and wild herd management/domestication (Brunson et al. Nd). The Gobi Desert is of particular interest in understanding trajectories of social and economic change because its geographic location historically divides settled farming societies from nomadic pastoralist ones (Fig. 1). Surface assemblages play a major role in archaeological interpretation here because the region is geologically characterised by low levels of soil accumulation and high levels of deflation (Fairservis 1993; Janz 2016; Janz et al. 2015; Maringer 1963; Odsuren et al. 2023). One of the earliest observations in the English literature about Gobi Desert archaeology is that habitation sites post-dating the Last Glacial Maximum (LGM) tend to be clustered around dune-field/wetland habitats and tend to contain technologies like pottery and grinding stones (Nelson 1926; Derevianko and Dorj 1992; Fairservis 1993; Maringer 1950, 1962; Okladnikov 1962). The lack of direct dates long made it impossible to know how old these sites were and how they might relate to contemporaneous environmental or socio-economic changes. This problem was largely resolved with the introduction of a three-phase date-based chronology for the end of the LGM until the adoption of pastoralism (Janz et al. 2015), allowing researchers to focus on more nuanced lines of inquiry (Dubreuil et al. 2022; Evoy 2019; Farquahar 2022; Janz 2016; Janz et al.

E-mail address: lisa.janz@utoronto.ca.

https://doi.org/10.1016/j.jaa.2024.101624
Received 6 March 2024; Received in revised form 30 August 2024;
Available online 25 September 2024

2020; Reis Cordeiro 2024; Rosen et al. 2019, 2022; Schneider et al. 2021; Pleuger et al. 2023).

Diet is foundational to and interrelated with many other changes such as the spread of pastoralism, tool manufacture and use, and relationships with neighbouring regions. For example, I previously argued that the use of dune-fields and wetlands during the early to middle Holocene are explicitly connected to diet breadth expansion: the more intensive use of plants and small prey. I further argued that this shift was driven by climatic amelioration (Janz 2016) not resource depression. This contrasts with the traditional explanation for late Pleistocene and Holocene diet breadth expansion, which is grounded in optimal foraging theory or prey choice model frameworks (Binford 1968; Stiner et al. 2000). Drawing on similar observations to Zeder (2012), showing numerous correlations between diet breadth expansion and resource abundance, I offered an explanation grounded in patch-choice models as a way to think about how large-scale shifts in landscape ecology might be connected to global changes in human diet, sedentism, and demography during the terminal Pleistocene and early-to-middle Holocene (Janz 2016). The implication is that humans adapted to fundamental changes in landscape ecology by eating differently and moving less (Zhao et al. 2021). These changes, specifically a greater reliance on highly concentrated and resilient resources (i.e., annual plants and animals with high reproductive rates), stimulated sedentism and reduced the prevalence of population crashes, which increased human population density (Binford 1968; Stiner et al. 2020).

The focus of this article is the Gobi Desert and the aim is to use museum collections gathered largely from surface contexts to understand fundamental changes in social organization. Here I analyse lithic-heavy surface assemblages as a means of studying diet change from a landscape-based perspective. This approach relies on the idea, outlined in Section 3, that changes in diet are necessarily linked to other specific organizational changes such as land-use and residential mobility (not to mention technology, intra- and intergroup relations, ritual practice, and demography, though these are not addressed herein).

2. A brief chronology of Post-LGM landuse and technology in the Gobi Desert

The Gobi Desert (Fig. 1), spanning southern Mongolia and Inner Mongolia, is a region where clear evidence for food production, in the form of herding, is encountered relatively late (2000–1500 BCE) compared to other regions in Eurasia (Stephens et al. 2019). Most of what is known of the regional archaeology is based on analysis of surface assemblages collected during the 1920 s and 1930 s (Maringer 1950; Fairservis 1993) and some later collection and excavation by Mongolian and Russian archaeologists during the Soviet period (Derevianko and Dorj 1992; Janz et al. 2017). These early researchers described partially and fully deflated scatters of lithics, pottery, and groundstone, most of which were recovered from the shores of dry lake basins within dune-field deposits (Maringer 1963).

Based on evidence from North China and Siberia, Late Upper Palaeolithic (LUP) completely replaced Early Upper Palaeolithic (EUP) blade-based reduction strategies beginning about 25,000 years ago (Gladyshev et al. 2010, 2012; Keates 2007; Kuzmin 2007; Qu et al. 2013: 42-45). Post-LGM lithic assemblages in the Gobi Desert represent a continuation and evolution of LUP assemblages in Northeast Asia. Volumetric blade cores likely provided a cognitive foundation for the microlithization of blade-based toolkits across Mongolia and rest of Northeast Asia (see Gladyshev et al. 2010). Due to a lack of LGM and early post-LGM sites in Mongolia, the local timing of this shift is unknown, but until proven otherwise we should assume it to be consistent with other parts of Northeast Asia.

There are currently very few archaeological sites in Mongolia dated between 23,000 BCE and 6500 BCE, likely suggesting lower population densities during and following the LGM. Those few sites that have been securely dated are consistently dominated by pressure- and percussion-flaked microcores, increased frequencies of microblades, the appearance of retouched flakes, and the complementary use of expedient flake technology (Gladyshev et al. 2010: 39; Janz et al. 2017; Zwyns et al. 2014). Expedient or less consistently structured flake cores were also

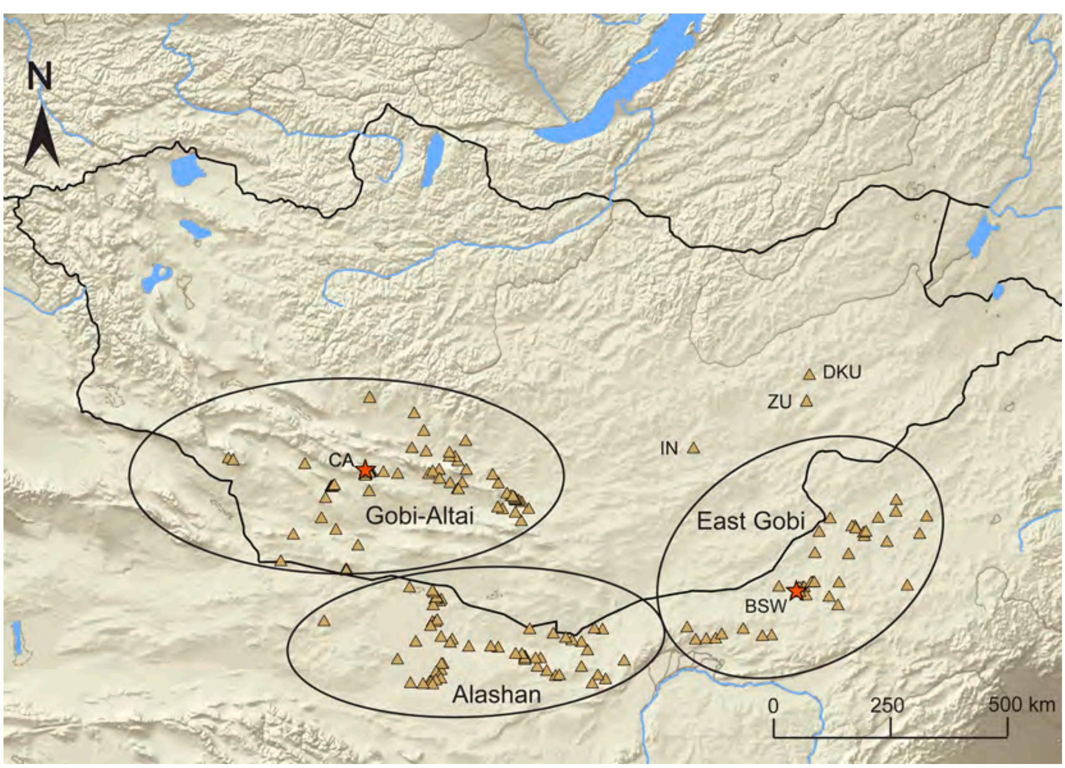

Fig. 1. Map of Mongolia, showing extent of subregion divisions and location of all sites analysed for this study. BSW: Baron Shabaka Well; CA: Chikhen Agui; IN: Ikh Nart; ZU: Zaraa Uul; DKU: Delgerkhaan Uul.

used to produce blanks for flake tools such as the characteristically small, round endscrapers known as “thumbnail scrapers” and bifacial projectile points, which were preceded by unifacially retouched microblade projectile points (Janz 2012; Janz et al. 2017: Fig. 19.11). A temporary shift away from formal reduction strategies has been noted in the southern Gansu Province, PRC, where hard hammer and bipolar reduction of massive crystalline quartzite cobbles interrupted formalised reduction strategies during the LGM (Barton et al. 2007; Morgan et al. 2011). Those authors argue that this was due to the circumscribed range of hunter-gatherers and the lack of local raw materials during this cold-dry interval. Raw material is abundant across the Gobi Desert proper and it is not known whether the trend observed in Gansu would be mirrored here.

I have argued that a greater variety of microblade cores was used in later periods, underlying a more flexible strategy of raw material reduction aimed at exploiting a range of stone nodules from secondary, in addition to primary sources (Janz et al. 2012, 2017). Evidence of technologies associated with intensive plant processing are very rare during the early post-LGM, but small fragments of low-fired pottery and grinding tools do occur in across North China, the Amur River Basin of the Russian Far East, and Japan (Elston et al. 1997, 2011; Jia 2007; Keally et al. 2003; Lu 1998; Popov and Tabarev 2008, 2017). The earliest pottery in the Gobi Desert is currently directly dated to 7733–7549 BCE (8604 ± 51 years BP [AA-89868]) (Janz et al. 2015). Technologies such as pottery and grinding stones proliferate and become ubiquitous after 6500 BCE (Janz et al. 2017; Janz et al. 2021) and co-occur with polished stone tools (Evoy 2019) and a shift towards highly coloured, fine-grained high-silicate metasedimentary cherts like jasper. Microblade technology became ubiquitous following the LGM and continued to be used during the Bronze Age and potentially far beyond (An 1992; Janz et al. 2012, 2017). Expedient, flake-based, assemblages were present across northeastern China through the early Holocene (Jia 2007; Lu 1998) but are not typical of the Gobi Desert and are likely tied to regional trajectories in techno-cultural diversity.

Based on direct dates from diagnostic pottery, three distinct phases were proposed for the sequence of post-LGM microblade producing groups: Oasis 1, 11,500–6000 BCE; Oasis 2, 6000–3000 BCE; and Oasis 3, 3000–1000 BCE (Janz 2012, Janz et al. 2015). Oasis 2 corresponds with the Holocene Climate Optimum and recent evidence from excavation suggests that it began by at least 6500 BCE (Janz et al. 2021; *contra* Janz 2012, Janz et al. 2015). The Holocene Climatic Optimum was a period of enhanced precipitation driven by the strengthening and resulting northward migration of the East Asian Summer Monsoon System (see Lee et al. 2013; Winkler and Wang 1993). Palaeoenvironmental proxies indicate the expansion of lakes, rivers, and wetlands, shifts towards desert-steppe and steppe ecosystems within the Gobi Desert, as well as the development of riparian and high elevation woodlands (Bazarova et al. 2019; Cermak et al. 2005; Felauer et al. 2012; Holguín and Sternberg 2018; Holguín 2019; Janz et al. 2017, 2021; Lee et al. 2013; Miehe et al. 2007; Rosen et al., 2019, 2022), and forest-steppe along the less arid southern boundary (Jiang et al. 2006; Wang et al. 2001; Wang et al. 2010; Zhao et al. 2023). The establishment of sedentary villages in northeastern China and pit-dwelling communities in the far eastern steppe of Mongolia were probably similarly facilitated by changed ecological conditions associated with increased precipitation (Janz et al. 2017; Liu et al. 2015; Odsuren et al. 2015; Zhao et al. 2021).

Oasis 1 (11,500–6500 BCE) broadly corresponds with what early Russian archaeologists referred to as the Mesolithic, but American archaeologists have also suggested using the term Epipalaeolithic (Farquhar 2022; Wright et al. 2019). The period was meant to distinguish a period of post-LGM recolonization of the Gobi Desert and spans massive fluctuations in climate, including the end of the Bølling–Allerød interstadial, Younger Dryas, and early Holocene. There are currently so few sites known to date to Oasis 1, however, that the temporal range of such a period is admittedly rather abstract. The best-dated is Chikhen Agui (Figure 1.1), a well-preserved, multi-layer cave site in the Gobi-Altai mountains (Derevianko et al. 2003), upon which the upper chronological limits of this period were based. It is during this time that people begin to preferentially select the more colourful jaspers, which in this region were formed through the volcanic metamorphosis of high-silicate sediments, producing fine-grained and homogenous cherts of high aesthetic appeal. There are rare occurrences of new cooking technologies such as pottery and milling or grinding stones alongside the continued emphasis on microblade-based toolkits (Elston et al. 1997, 2011; Han et al. 2024; Janz et al. 2015; Morgan et al. 2022). At its most essential, the period is characterised by an evolved microblade-based toolkit lacking pottery.

Oasis 2 (6500–3000 BCE) coincides with the Holocene Climatic Optimum (Janz et al. 2015) and, based on various palaeoenvironmental proxies, corresponds with widespread expansion of lakes, rivers, and wetlands, shifts towards desert-steppe and steppe ecosystems within the Gobi Desert, as well as the expansion of arboreal vegetation (Bazarova et al. 2019; Janz 2012; Janz et al. 2021). Oasis 2 sites show an emphasis on similar raw material types used in Oasis 1, but regularly contain chipped and/or polished adzes and axes, pottery, grinding stones, and small projectile points made on microblades or microflakes. The earliest projectile points tend to be unifacially, rather than bifacially, retouched with pressure flaking (Janz et al. 2017: Figure 5.4, 19.11). Amorphous or somewhat elongated flakes continue to be produced from microcores with sub-prismatic or even blocky and irregular shapes, including with multiple (2 +), expediently developed platforms.

Technological changes around food processing – namely, the widespread use of extractive technologies such as pottery and grinding stones – underscore the hypothesis of a major shift in plant use during this time (Dubreuil et al. 2022). Pottery, grinding stones, and polished stone tools are all associated with plant processing, among other tasks, and became widely used across Northeast Asia during the Holocene, having been discontinuously adopted across the region in geographically disparate regions such as the Russian Far East, Japan, and southern China soon after the LGM (Elston et al. 2011; Keally et al. 2003; Kuzmin and Orlova 2000; Kuzmin and Shewkomud 2003; Takashi 2012; Wu et al. 2012; Zhao et al. 2004). Early researchers noted the apparent relationship between the use of dune-field and wetland environments in the Gobi Desert (Maringer 1963), which may be related to the local amalgamation of these three technologies (pottery, grinding stones, and polished stone tools) into a Gobi Desert “Neolithic” (Okladnikov 1962; Derevianko and Dorj 1992; Janz 2016). The adoption of specialised plant processing technology would suggest that dietary changes during this period would have been significant.

Oasis 3 (3000–1000 BCE) assemblages are very similar to Oasis 2, but are characterised by distinct pottery types and a greater emphasis on highly local raw materials, including small chalcedony nodules. Oasis 3 represents the next phase of technological development and a transitional period between hunting and gathering and the adoption of pastoralism (Janz et al. 2015, 2017). Oasis 3 overlaps with the Bronze Age and culminates with large-scale cultural and economic shifts characterised by increasing interaction with Central Asian pastoralist communities. Region-wide economic changes are highlighted in the adoption of domesticated herd animals, dairying, the adoption of bronze-working and the bidirectional exchange of cereal crops (Brunson et al. 2020; Dodson et al. 2009; Dong et al. 2017; Filipović et al. 2020; Frachetti et al. 2010; Honeychurch et al. 2021; Jaang 2015; Janz et al., 2020; Jones and Li 2009; Li 2008; Peng et al. 2017; Wilkin et al. 2020; Yang et al. 2014). Dates on Bronze Age-style burial cairns from across Mongolia further indicate a major ideological shift in the centuries following 2000 BCE (Honeychurch et al. 2021; Taylor et al. 2019; Wright et al. 2019), and these elements become particularly intense across Northeast Asia after 1000 BCE (Dyakonov et al. 2019; Honeychurch 2015; Honeychurch et al. 2021; Janz et al. 2020; Rhee et al. 2021). It is clear that domesticated herd animals were fully incorporated into *some* East Asian subsistence strategies by no later than 3000 BCE

(Wilkin et al. 2020), but are so far only shown to have been present more broadly shortly after 2000 BCE (Honeychurch et al. 2021; Wright et al. 2019; Yang et al. 2014). In other words, the distribution of pastoralist economies may have been spatially limited to the far west and possibly central regions for a millennium or more (Janz et al. 2020). Provisional geoarchaeological and aDNA evidence offers room to postulate that some element of herding practices were embedded in local subsistence by at least the latter half of Oasis 3 (Brunson et al. Nd; Rosen et al. 2019). Dairy residues on potsherds have been directly dated to 1614–1439 BCE (3246 ± 39 years BP [AA-89878]) (Janz et al. 2020), though earlier dates are likely as research progresses. The incorporation of herd animals into local economies would have been fully accomplished, therefore, during Oasis 3.

We currently do not know how the above cultural changes impacted technological traditions, but it seems that changes in the nature of lithic production may have been minor (Farquhar 2022; Janz et al. 2017). Unifacially-flaked projectile points had completely disappeared by this time though awls made on microblades persisted. The range of bifacially-flaked tools also expands. Many of the carefully made "drills" likely belong to this period (and perhaps the end of Oasis 2) and are hypothesised to have been used in the production of stone beads (see Janz et al. 2020). A decline in the use of formal grinding stones, such as large saddle querns, is also likely but the scarcity of securely dated contexts makes this difficult to interpret (see Dubreuil et al. 2022). The onset of Oasis 3 corresponds better with large-scale socio-economic changes than with distinct environmental changes, though a slow trend towards aridification is often assumed (though not proven) to have driven the spread of East Asian pastoralism in the millennia after 3000 BCE.

Regional archaeology reveals that there were significant changes in technology, subsistence, and land-use in the Gobi Desert following the end of the LGM and leading up to a form of fully developed nomadic pastoralism characteristic of the Iron Age (including Slab Grave and Hunnu/Xiongnu periods). At the same time, despite a few stratified deposits in the more northern desert-steppe (Bazarova et al. 2019; Derevianko and Dorj 1992; Janz et al. 2021; Pleuger et al. 2023; Rosen et al. 2019; Tseveendorj and Khosbayar 1978; Tsydenova et al. 2012, 2015), most known habitation sites in the Gobi Desert are characterised by a proliferation of surface assemblages with few stratified sites and few to no organics remains such as bone or macrobotanicals that would be capable of providing direct evidence of diet. Can large-scale dietary changes alter the spatial patterning in lithic assemblages? I specifically consider the possibility that major changes in diet alter group organization and land-use in ways that are visible in the location of sites and organization of land-use. I present a detailed qualitative and quantitative analysis of regional lithic datasets in order to more fully test the hypothesis that wetland-centric logistical foraging was fundamental to the Gobi Desert Neolithic, and distinct from a more generalised pattern of high residential mobility during the late Pleistocene. I will also examine whether the onset of pastoralism can be recognised through landscape-based approaches to lithic analysis. Such an approach, when applied to securely dated assemblages would allow us to more accurately assess timing for the onset of pastoralism.

The primary goals of this study are to determine whether changes in subsistence are visible within large-scale patterns in land use, use trends in spatial patterning to build testable hypotheses for describing changes in subsistence economies, and suggest methods for testing these hypotheses. The secondary goal is to encourage researchers, particularly in regions with limited preservation, to find new ways (and revisit old ones) of more actively integrating studies of diet and land-use, including in relatively recent time periods.

2.1. The role of landscape studies in examining changes in the human ecological niche

Post-LGM changes among hunter-gatherer communities in the Gobi Desert are currently thought, as outlined above, to be represented by an expansion in diet breadth during Oasis 2, which was then superseded by the adoption of pastoralism by the end of Oasis 3. I adopt the concept of *niche shifting* as an interpretive tool to investigate these fundamental changes in diet at the end of and following the Pleistocene. *Niche shifting* is a known concept in ecology and stems from the idea that environmental changes can stimulate an individual species to change adaptive strategies rather than moving or adapting physiologically (*sensu* Jezkova et al. 2011). Niche shifting is a strategy distinct from, but not antithetical to, niche construction where an organism changes elements of an ecosystem in a way that modifies an existing niche (*sensu* Laland et al. 2000; Odling-Smee 1988). The process is couched in an evolutionary framework and is connected to long-term biological success and instinctive adaptive response; however, with regard to humans it necessarily also relates to agency in resource use and social organization. The term is introduced here as a way to succinctly categorize and describe what we already see in the archaeological record. I use the concept of niche shifting to create a unified terminology associated with archaeologically observed diet and land-use change, which may or may not involve intentional (or unintentional) niche construction. My intent is not to strip the importance of cultural and environmental context from a larger understanding of human land-use (i.e., I will not argue that these changes mean the same thing everywhere). I simply point out that changes in diet and land-use naturally co-occur, that each diet strategy requires distinct modes of land-use, and that one set of changes will naturally give clues to the other and allow us to generate a series of testable hypotheses.

One of the most notable examples of niche shifting in the evolution of human societies took place during the Late Pleistocene and Holocene. We know this transition varied across regions and was gradual, cumulative, and specific to the individual context; however, there are many characteristics that are shared by many world regions though they occur at different times. Major shared characteristics include reduced residential mobility or sedentism and diet breadth expansion. This shift has been archaeologically identified in a range of ways, including through ratios of *K*- to *r*-selected prey being consumed (e.g., Stiner et al. 2000), widespread changes in post-glacial land-use (Gamble 1986), and by the long-term impacts it fostered in social organization, demography, and intensity of land management (Hayden 1981, 1990; Zeder 2012). Of particular importance to this study is decreased residential mobility and logistical or central-place foraging, as classically outlined by Binford (1980), which should result in strict divisions between the types of sites represented, the environmental context of each site type, and corresponding variability in occupation intensity. The adoption of agriculture and domesticated animals, in contrast, arguably demonstrates another episode of niche shifting, where the integration of tame animals typically led to a decline in diet breadth.

Here I use the distribution and relative intensity of settlement occupation to guide a landscape-based approach to niche shifting. The broader spectrum diet evident in the Pleistocene-Holocene niche shift, essentially one that is more intensively focused on the exploitation of *r*-selected prey, requires a variety of organizational changes that potentially include modifications in the division of labour (Elston and Zeanah 2002; Elston et al. 2014; Kuhn and Stiner 2006) and redundant long term occupation of some localities and a corresponding decline in the use of others (Binford 1980, 1982; Elston et al. 2014; Marean 2016; Martínez et al. 2017; Ramsey and Rosen 2016; Testart 1982; Zeanah 2002). Interconnected with changes in land-use and group division of labour is the introduction of technologies (e.g., grinding stones, cooking vessels, traps, nets, weirs) that can increase the nutritional value and/or caloric intake of a species, while decreasing the cost of hunting and processing small prey and plant foods, facilitating a greater – and perhaps seasonal – emphasis on such resources (Adovasio et al. 1996; Bailey and Aunger 1989; Holliday 1998; Lupo and Schmitt 2002; Pike-Tay 1993; Revedin et al. 2015; Soffer 2000; Torrence 1989). Such changes have the potential to reorganize resource use at the landscape level and to be discerned through a combination of the spatial distribution of sites and the relative intensity of their use.

Shifting priorities in food acquisition constantly mediate choices of where to settle and for how long. There are two very specific changes that we can look for in the case of diet breadth expansion: 1) the more targeted use of ecosystems suited for the capture of *r*-selected prey (e.g., hare, birds, fish, nuts, grass seeds); and 2) longer stays due to the higher carrying capacity of an environment exploited for *r*-selected prey, which are naturally denser and less demographically vulnerable than *K*-selected prey such as large ungulates (i.e., Charnov 1976; Cannon and Meltzer 1998; Janz 2016; Kelly 1995). Therefore, the emphasis here is change in the range of locations used and the length of occupation (for discussion of changes in Gobi Desert technology see Cybiktarov 2002; Derevianko and Dorj 1992; Dubreuil et al. 2022; Janz et al. 2017, 2020). We tend to expect that declines in residential mobility will negatively impact access to large ungulates due to both overhunting and predator avoidance (Badenhorst and Driver 2009; Broughton et al. 2010; Jerozolimski and Peres 2003; Schollmeyer and Driver 2013; but see Butler and Campbell 2004 for deer); however, reduced residential mobility facilitates more efficient capture of small prey as it allows greater use of passive procurement technologies such as traps, snares, and weirs (Holliday 1998; Wadley 2010). Collection of plant foods is equally important and access to a variety of plant foods is likewise controlled by location and length of stay (Ramsey and Rosen 2016; Zeder 2012). Therefore, it is expected that a shift towards more intensive use of *r*-selected prey is interconnected with: 1) increased length of time spent in environments with high concentrations of *r*-selected prey; and 2) a shift towards logistical forays, especially in the pursuit of large herd animals (see Binford 1980).

We would also expect large-scale changes in land-use to be associated with the shift from broad spectrum foraging to pastoralism, wherein access to large ungulates was secure and highly controlled. The adoption of herd animals would thereby shift priorities from pursuit towards the care and keeping of ungulates: people would be more focused on providing graze than on intercepting unsuspecting prey at water holes or along migration corridors. Movement ensures the health of grazing ungulates and host grasslands by avoiding overgrazing, dispersing manure, and taking advantage of landscape-level changes in nutrient availability. Moreover, priorities for access to water could potentially shift slightly: ungulates need water, but they need it less often and can tolerate a higher bacterial load than humans; human companions, in turn, rely on milk products to stay hydrated when clean water is less readily available. Although hunting likely remained of some importance, the more important domesticated herd animals become the more people will prioritize their needs; the pastoralist shift in dietary niche should slightly presage access to graze over access to freshwater.

Group division of labour may also be affected. Historic and modern ethnographic studies in Mongolia demonstrate the importance of women's labour in dairying and men's labour in managing the movement of herds (Fernandez-Gimez 1999; Fijn 2011). If earlier hunter-gatherer women were engaged in securing and preparing plant foods and small game (*sensu* Elston and Zeanah 2002; Elston et al. 2014; Kuhn and Stiner 2006), a shift towards pastoralism could contribute to narrowed diet breadth, less intensive use of plant foods, and declining interest in associated niches such as wetlands. These expectations provide an example for how herding activity might be uniquely reflected in land-use, but it is important to bear in mind that actual behaviour is also moderated by local environment and decisions about the use of community lands. In Mongolia where urbanization remains low and land management favours open grazing, entire pastoralist households often tend to move with their herds rather than fissioning-off to engage in seasonal activities in different locales (Fernandez-Gimez 1999; Fijn 2011). This mode of land-use seems similarly well-suited to non-agriculture pastoralist populations unencumbered by state controls, as we assume of these early pastoralists. As such, I expect pastoralist land-use in this sample to be characterised by low variability between sites with the majority being small residential encampments complemented by radiating task sites (see Fijn 2011: 203, Fig. 9.1).

I will use the above inferences to interpret evidence for changes in subsistence economies through time. Oasis 2 is characterised by the introduction of new technologies such as grinding stones and pottery alongside a preponderance of wetland-based habitation sites and an increase in representation of small, fast prey. Since these peoples are thought to be the earliest groups engaged in broad spectrum foraging, their land-use should be characterised by decreased residential mobility in locations with access to high concentrations of r-selected prey a settlement pattern tethered to wetlands with an emphasis on long-term campsites. Domesticated herd animals are present in East Asia by 3300 BCE (Honeychurch et al. 2021; Jaang 2015; Peng et al. 2017). They may be widespread by 2000 BCE (Rosen et al. 2019). Dairying is evident in the Gobi by at least 1600 BCE (Janz et al. 2020). Therefore, we must consider the presence of herding as a certainty as least during the end of Oasis 3. There are several possible subsistence strategies that Oasis 3 peoples might have followed (e.g., committed pastoralists, mixed hunting and gathering with herding, or a mix of hunter-gatherers and food producers). For the purposes of this study, I will begin with the premise that they were all pastoralists, meaning that I expect land-use to be characterised by a focus on pasture and the use of short-term campsites with radiating task sites. Long-term campsite were likely to have remained important, but only during winter months.

Quantitative analysis of patterns in lithic reduction strategies will be used to assess relative length of site occupation and spatial patterns in landscape distribution to assess prioritisation of land-use. These two measures will test the viability of a landscape-based approach to lithic analysis in identifying niche shifting within the archaeological record. Based on the patterns of group organization and resource prioritisation outlined above, I expect the lithic assemblages to present evidence of: 1) reduced residential mobility in Oasis 2 and Oasis 3 compared to the Palaeolithic and Oasis 1; 2) highest intensity of wetland use during Oasis 2, with an emphasis on logistical foraging; and 3) an emphasis on grasslands over wetlands during Oasis 3.

2.2. History of studied collections and research challenges

The material analysed for this study includes more than one hundred individual archaeological site assemblages housed in two museums: the American Museum of Natural History (AMNH), New York and the Ösasiatiska Museet (Museum of Far Eastern Antiquity) branch of the Världkulturmuseerna, Stockholm (Frieman and Janz 2018; Janz 2012). At the time of analysis, the collections were largely unstudied but associated with abundant archival data outlining landscape context and collection strategies. Materials were collected across the desert regions of Mongolia and the Inner Mongolia Autonomous Region, People's Republic of China (PRC) by Nels C. Nelson in 1925 and Alonzo Pond in 1928 for the Central Asiatic Expeditions, and Folke Bergman in the 1920 s and 1930 s for the Sino-Swedish expeditions. These expeditions were major multi-disciplinary scientific expeditions that included research not only by archaeologists but also geologists, climatologists, botanists, wildlife biologists, and palaeontologists (Hedin 1943). Original field notes frequently indicate which team members discovered the sites and under what conditions (Bergman 1945; Maringer 1950; Nelson 1925; Pond N.d., 1928).

The combined geographic range covers much of the Gobi Desert and a variety of environments were explored with equal rigour. These characteristics improve the reliability of site distribution analysis. One major challenge is that many localities contain artefacts from multiple phases of occupation and many were undifferentiated surface scatters collected from dune-field margins (e.g., Maringer 1950: 152). Some sites in the collection did, nevertheless, feature distinct clusters of artefacts around a central hearth while other site assemblages were even partially excavated (Fairservis 1993; Maringer 1950; Nelson 1925; Pond N.d). Chronological challenges were somewhat mitigated through extensive radiocarbon and luminescence dating and assemblage seriation through which the period of primary site occupation was assessed and multiple periods of occupation, when they occurred, were identified (for details on methods see Janz 2012; Janz et al. 2015). Resulting data on each site is recorded in appendices A to D of Janz 2012 and is summarised here in Table S1.

The covered geographic area can be divided into three broad regions based on similarities in environment and collection strategy (Fig. 1). Each of these regions is ecologically and geologically distinct. The Gobi-Altai assemblages were collected by Nelson, and include sites from the modern provinces (*aimag*) of Bayankhongor, Ömnögov', and Gobi-Altai. I used additional published data from the Gobi-Altai region to improve the representation of Palaeolithic sites, which were poorly represented in my own sample (Derevianko et al. 1996, 1998, 2000; Derevianko 2000). The Alashan Gobi material was collected under the supervision of Bergman, including sites from across the Gurnai Depression and Alashan Desert of Inner Mongolia. Material analysed from the East Gobi includes assemblages from north of the Yinshan range and from the Hushandake Sandy Land, collected primarily by Pond and Bergman, with a few sites collected by Nelson.

There are a number of challenges or limitations to this study. First, in most cases, only vague descriptions of the spatial extent of lithic scatters were offered. This study, therefore, relies exclusively on artefact counts rather than spatial extent or artefact density. Another analytical challenge is lack of clarity about how heavily most of these assemblages were culled during and following collection. The main exception is material from Shabarakh-usu (now called Bayandzak). The presence of all artefact types in these assemblages, including large quantities of unretouched and/or unused flakes (both microblade and generalised) are promising and do suggest that attempts were made in all cases to accurately sample these scatters. Nelson's notes were uniquely detailed and sometimes include exact numbers of artefact types that were maintained and discarded, showing that cores were usually retained while "ordinary" or "raw" flakes were often discarded (Nelson 1925: 51c-51 s). Flake tools were also sometimes discarded, including formal types. Nelson's field notes, as well as Pond's (Pond N.d.) support the idea that the largest sites were most heavily culled, but that balanced representations of types were maintained. Based on Nelson's field notes, it seems likely that cores were seldom discarded and so this analysis focuses primarily on variation in cores. Farquhar (2022) used a similar approach to analyse of surface collections, but the material was collected under her direction, which made it possible for her to employ a wider range of artefacts in the analysis.

3. Methods

As described above, the primary focus of data collection and analysis was to distinguish temporal change in the distribution of sites and intensity of occupation across the five ecozones defined below. Each site was assigned to a site type (e.g., task site, short-term residential site, long-term residential site) based on both the relative number of artefacts and a suite of criteria connected to activity (i.e., function of artefact). Site types were used as a proxy for intensity of occupation under the premise that longer-term occupation will result in a greater number of activities represented. The validity of this proxy was independently tested by measuring the relative intensity of lithic reduction represented across the site types. In other words, I used a number measurements associated with conservation of toolstone, or lack thereof, in order to independently test whether my categorizations of short-term and long-term residential sites were statistically valid.

3.1. Site distribution: Identifying spatial patterning across ecosystems

Based on the arguments outlined above, I anticipate that changes in the distribution of sites across the larger landscape should highlight changes in the prioritisation of resources from the Palaeolithic to Oasis 3 (as outlined in Section 3). Based on knowledge of Gobi Desert landforms and previous interpretations of land-use in arid Northwest China (e.g., Bettinger et al. 2007) we can expect significant variation in the use of five distinct terrains: dune-field, lake, steppe, mid-elevation (e.g., mesas, hillslopes, plateaux), and mountainous terrain. Based on variation in modern floral and faunal distribution, four separate environmental factors are important in delineating ecozone categories: elevation, topography, water source, and presence/absence of sand or dune-fields (Allen 1938; Jigjidsuren and Johnson 2003; Batsaikhan et al. 2010). Data on elevation (metres above sea level [m a.s.l.]) was sometimes recorded in field journals, but I more often determined elevation by locating each archaeological site on the expeditions' topographical base maps. Environmental context (e.g., hydrology, dune-fields) was determined based on site descriptions in the original expedition notes and publications (Maringer 1950; Nelson 1925; Pond 1928) or otherwise plotted on 1:200,000, 1:500,000, and 1:1,000,000 scale topographic maps (Army Map Services, Corps of Engineers, U.S. Army, Washington, D.C., 1949, 1950, 1954; Bureau of Geological Investigation, Geological Survey of Mongolia 2003a, b, c, d; Hill n.d.; Hill and Roberts n.d.; Norin and Montell 1969; Norin 1978; Roberts et al. n.d.). In order to determine which environmental parameters were most relevant to archaeological locations, Pearson's chi-square was used to assess potential significance in the distribution of sites based on elevation, topography, water, and sand, as well as the natural juxtaposition of these environmental parameters (Janz 2012: 224-225, Table 4.2). Results showed natural relationships between elevation, topography, water, and sand, with a broad natural division in hydrology and sand above and below 1200 m a.s.l. Preliminary observations on the association of sites with each parameter over time suggested that the most productive results would come from a classification system that combined elevation and hydrology.

Five ecozones classifications were derived from this analysis: lowland dune-field lake, lowland river/spring, lowland dry, upland with water source, and upland dry. These parameters largely circumvent the problem of ecological change through time as most palaeoshorelines in the region lie below 1000 m a.s.l., suggesting that higher elevations were typically exposed throughout millennia of wetting and drying. Lowlands were locations below 1200 m a.s.l., while uplands were those above 1200 m a.s.l. Hydrological classifications were often based on cartographic data. I made determinations based first on proximity (within 5 km) of a palaeolake basin or within 1 km of a major river. When field-notes described a nearby spring or well, the site was only classified as "lowland river/spring" if there was no clear evidence of a former lake. In one instance, a rather large site (Site 29) was located near a well on the hillslope of a valley. Despite the low elevation (~1075 m a.s.l.) the site was categorised as "upland." It is possible that this site was originally associated with a spring and/or river. Lowland lakes in the Gobi Desert are typically associated with dune-fields. There have not been any major changes in topographical variation during the past 40,000 + years of human occupation in the region, so despite some changes in surficial hydrology, including a degree of basin infilling (Janz et al. 2021, Rosen et al. 2022), Holocene lake basins should reliably map Pleistocene lake basins.

Wetlands, including marshes and floodplains, are essential to procurement of plant foods and the capture of *r*-selected prey in desert environments (Ramsey and Rosen 2016). They are likely to have been exploited throughout all these periods; however, substantial expansion in diet breadth would have prioritised more regular and/or prolonged use of wetlands as such environments offer higher biodiversity than other ecotones within the arid landscape (Elston and Zeanah 2002; Elston et al. 2014; Keddy 2000; Nicholas 1998; Pankova 2008; Ramsey and Rosen 2016). Based on the enhanced biodiversity and productivity of small game around wetlands, we should expect that lowland dune-field lake and rivers were used during all periods, but uniquely emphasised above all other environments for longer-term occupations during Oasis 2.

The number of Palaeolithic sites represented in museum assemblages was very low and may underrepresent the presence of such occupations in the Gobi Desert. An exceptional amount of additional data on the distribution and nature of Palaeolithic sites has been collected for the Gobi-Altai region through the efforts of Joint Mongolian-Russian research and the Joint Mongolian-Russian-American Archaeological Expedition (JMRAAE), whose primary objectives included the discovery of Palaeolithic sites. This data is not completely comparable; however, the periodization and classification of site types is very similar (see Derevianko 2000). In addition to the data that I had previously collected from museum assemblages, I selected all sites whose detail on location and nature was sufficient to determine ecozone and characterize them broadly as Palaeolithic, Oasis 1 (i.e., "Mesolithic"), or Oasis 2/Oasis 3 (i.e., "Neolithic"). In order to avoid inflating the number of Palaeolithic sites, which were exponentially dominant in this sample, for each locality I included only one site for each time period and site type represented despite the fact that several localities (e.g., Tuin gol, Nariin gol left bank, Shabarakh-usu/Bayandzak) included many distinct site assemblages. Raw data is reported in Table S4.

3.2. Site type: Identifying variation in site use over time and space

Choices about diet affect where and for how long people settle. Temporal change in the distribution of sites reflects changes in land-use as well as diet. Binford's (1980) seminal work categorising hunter-gatherer settlement took a systematic approach to site categorization that is still highly relevant for broadly categorising generalised patterns of hunter-gatherer land-use. Within this framework, forager and collector aggregation sites are known respectively as *residential bases* or *base camps*. Short-term procurement locales or task sites are used by both groups and referred to as *locations*. *Field camps* are sites where long-ranging task groups are maintained away from the collector base camps. Binford's categories of *caches* and *stations* are not relevant to this particular study. I simplified Binford's original categorizations, using the general designation of *residential sites* to encompass residential bases, base camps and field camps. Residential sites were divided into two categories based on differences in two interdependent variables: number of artefacts and levels of intra-assemblage variability. *Residential A* sites represent the larger, more varied end of the spectrum while *Residential B* sites are the smaller and more homogeneous (the validity of these categories will be independently tested below). *Task sites* account for the remainder of site types and their use is less actively addressed here, but it is important to note that such sites are highly variable in artefact composition and as a group they represent a range of activities such as expedient tool manufacture, food acquisition and raw material procurement.

Site type classification followed the formal methodology summarised in Table 1 and explained below, with results summarised in tables S1 and S2. Table 1 outlines the criteria used to classify each site. All "necessary" criteria needed to be met for a site to classified as Residential A, Residential B or a Task site. "Likely" were secondary criteria that should typically be met, but were negotiable because they were more prone to bias (e.g., potential variability in preservation, or in range of artefact types present in early time periods – for example evidence of cooking is unlikely to have been preserved in an open-air site prior to the introduction of pottery and grinding stones). Each site was evaluated individually based on the established criteria.

Table 1
Criteria used for site type classification.

Site type	Necessary	Likely
Residential A	• > 100 artefacts • > 20 cores • 3 or more activity types	• > 1000 artefacts • cooking • more than 2 types of specialised tools
Residential B	• 2 or more activity types	• 101–1000 artefacts • > 5 cores • cooking
Task site	• no evidence of cooking (or extremely limited, i.e. 1 sherd) • 1 or 2 activity types	• < 100 artefacts • < 5 cores • no more than 1 specialised tool type

Artefact counts serve as a rough proxy for site size due to a lack of information on the spatial extent of most sites. I relied on broad ranges of artefact counts: < 10, 11–100, 101–1000, and > 1000. Bin size was based on exponential increases in artefact counts. Task sites will typically also have fewer artefacts and tend to be characterised by < 100 artefacts and < 5 cores. This was a secondary criterion because the types of activities taking place may influence sheer artefact counts (e.g., quarrying of toolstone and primary reduction may produce many individual artefacts, but does not reflect length of occupation). The number of cores was given greater consideration than total artefact counts because this category of tools is less vulnerable to collection biases; they are one of the primary artefact categories collected from lithic assemblages (see Schiffer 1987: 354-355) and Nelson's field notes support the idea that they were rarely discarded in these collections (see above). Higher core counts were taken as a proxy for residential occupation (i.e., > 20 cores = Residential A) because more occupants and longer periods of time result in more intensive tool production and exhaustive use and discard of cores.

Residential A and B sites should contain evidence of cooking. Cooking was determined based on evidence of hearths, reports of fire-cracked rock, and/or the presence of food processing equipment such as pottery and grinding stones. Both technologies may be used for non-culinary purposes, but those other activities (e.g., carrying water, boiling tar, grinding ochre) similarly occur in residential locations. Cooking was not considered a necessary criterion for early sites as Palaeolithic and Oasis 1 largely pre-date the use of pottery and grinding stones, making evidence of cooking difficult to distinguish. The likelihood that open-air hearths and fire-cracked rocks would be preserved also declines with time, especially in primarily surface contexts.

The range of activities and specialised tool types was also considered. The number of activities that take place at a site is closely tied to who is present and for how long. A greater range of activities are expected to take place at base camps than on logistical forays (but see Binford 1982). Task sites, where only a few group members are staying for a relatively short period of time, are defined by the narrow range of activities carried out there (e.g., kill/butchery, raw material procurement, retooling). Residential sites represent longer term occupations where the larger group is present and multiple activities take place. Residential A sites are considered to have been occupied by the most people for the longest period of time. They are also likely to have been reoccupied multiple times and may have been provisioned for future visits (Binford 1979; Nelson 1991; Torrence 1989). Residential A sites should, therefore, have the most diverse record of activity (Binford 1980, 1982; Schiffer 1975, 1987: 281-282) and were expected to meet a threshold of at least three different activities. Only one or two types of activity should be represented at task sites and they should have many fewer artefacts (⟨100). Residential B sites, assumed to be shorter term base camps or residential bases were required to have two or more types of activities represented. I did not use traditional diversity indices because of the lack of reliable artefact counts.

Activity categories included cooking, manufacturing (scrapers, adzes/axes, needles, awls/drills, grooved slabs), lithic reduction (cores, unretouched flakes), hunting (projectile points), and ornament manufacture (drills, grooved slabs [Janz et al. 2020], beads, decorative stone nodules, ostrich eggshell). These categories are therefore relatively robust for a number of reasons. Activity categories were purposefully kept broad (e.g., manufacturing, cooking) and I did not use the categories assigned in publication or museum catalogues. Each tool was individually inspected and categorised according to function (e.g., core, projectile point, scraper, awl/drill) based upon morphology and the location, angle and extent of retouch and macrowear. "Scrapers", for instance, had a continuous and steeply retouched edge and often evidence of thinning or hafting wear opposite the used edge. Many of the adzes and axes underwent systematic macro- and micro-usewear analysis (Evoy 2019) and most were shown to have been associated with woodworking at some point in their life history. These categories are, therefore, very robust.

I gave special attention to highly specialised tools, in contrast to more generalised forms. Specialised tools are expected to occur in contexts where the associated activity recurs frequently. This may be a Task site dedicated to one activity or a Residential site where the activity is intensively undertaken alongside a range of other tasks. Specialised activities would include beadmaking, hunting (i.e., small projectile points suitable for arrow or dart heads), processing foods in or constructing ceramic vessels (i.e., pottery), and grinding flour (i.e., large formalised milling stones such as saddle querns and knob-headed rollers – see Dubreuil et al. 2022; Reis Cordeiro 2024). This criterion is secondary and naturally biased towards Oasis 2 and Oasis 3 as there is very little evidence of special-purpose tools during the Palaeolithic and Oasis 1. The diversity of specialised tools was one of the last categories considered and only used to make final decisions on later period sites that were otherwise difficult to categorize.

With respect to the Gobi-Altai data, I followed the same protocols outlined above. Original site type classifications were given as locality, workshop, occupation site – workshop, long-term and seasonal sites (Derevianko 2000: 241-243). These were classified as task site, task site, Residential B, and Residential A, respectively (Table S4).

3.3. Raw material conservation: Core reduction as a key to recognising reduced residential mobility versus recurrent occupation

Transport limitations, time allocation, risk, variation in quality of raw material, and distribution networks can all influence decisions about how tools are made and how extensively they are used (Aubry et al. 2012; Bamforth and Bleed 1997; Blades 2002: 10-21; Conard and Will 2015; Knutsson et al. 2016; Kuhn 1995; Manninen 2016; Morales 2016; Nash et al. 2016; Peña and Wadley 2017; Phillipps et al. 2016; Torrence 1983), but most researchers have adopted the general rule that the curation and efficient use of raw material is most closely tied to limitations on availability: tool stone will be used more conservatively when it is less readily available (Bamforth 1986; Bleed 1986; Goodyear 1989; Kelly 1988; Kuhn 1995; Parry and Kelly 1987; Shott 1986). A knapper will regularly make more efficient use of the material on hand when it is impossible or inconvenient to acquire more raw materials for tool manufacture and if raw material is readily available, he/she will be less inclined to reuse tools or to reduce cores in a conservative manner. Mobility is, therefore, expected to directly affect the relative importance of expedient and formal reduction strategies: highly mobile hunter-gatherers may not encounter tool stone for long periods so they tend to organize technological systems around the curation of artefacts, while decreased residential mobility is usually related to the use of less standardised and more expedient tools as raw materials can be more easily stockpiled (Bleed 1986; Kuhn 1995; Parry and Kelly 1987; Phillipps and Holdaway 2016; Torrence 1989). A reduction in residential mobility is associated with more expedient tools and cores, a lower degree of raw material conservation, and lessened emphasis on reliability (Bleed 1986; Clark and Barton 2017; Kuhn 1992, 1994, 1995; Parry and Kelly 1987; Peña and Wadley 2017; Wallace and Shea 2006).

Deposits of high-quality cryptocrystalline stones are abundant and widely distributed across the Gobi Desert. This is reflected in the archaeological assemblages which are almost uniformly rich in high quality cherts. Raw material is widely available, but access to high quality toolstone is by no means even in any landscape. The three regions were considered separately as there are distinct differences in landscape-wide availability: high quality toolstone is most widely available in the Gobi Altai and patchier in the Alashan Gobi.

The ubiquity of quality raw materials indicates that access to or procurement of stone was highly prioritised. Since toolstone is never evenly distributed across a landscape, we should expect that provisioning is the main controlling factor determining availability. Provisioning is most convenient under conditions of radiating logistical mobility – where group members are regularly leaving to and returning from different locations across the landscape. A residential base or base camp associated with radiating logistical mobility should be well-provisioned in a landscape where high-quality toolstone is widely distributed. Under such conditions of land-use (radiating mobility) and toolstone availability (widely spread), raw material availability will increase when length of occupation increased and raw material conservation will likewise decline. These considerations are implicit in the analysis described below.

In order to test whether the categories of Residential A and Residential B hold up under scrutiny of independent criteria, I evaluated variation in the intensity of core reduction across site types to test whether these two categories statistically represent different populations. The goal was to determine whether conservation of toolstone varied between Residential A and Residential B sites (i.e., that toolstone was systematically more available at one type of site than the other). Recurrent differences in proximity to raw material sources (i.e., the possibility that all "Residential A" sites were those adjacent to raw material sources) are irrelevant here since many localities contained both types of sites. Palaeolithic and Oasis 1 sites were excluded from this analysis because the collections did not include Residential A sites for those periods.

Cores are particularly important for measuring raw material conservation because they are foundational in tool kit production and are one of the few artefacts that has the potential to occur in all types of sites (Douglass et al. 2018; Phillipps and Holdaway 2016; Wallace and Shea 2006). The available evidence also suggests that they were the most likely artefacts in these assemblages to have been retained and curated. I used intensity of microblade core reduction as the primary proxy for raw material conservation. Oasis 2 and Oasis 3 toolkits are dominated by the production of microblades from formally prepared cores (Fig. 2). Flake tools are sometimes also produced from microblade cores, for example small "thumbnail" scrapers are often made on platform rejuvenation spalls, while projectile points, awls, and drills were often made on microblades. Less formally prepared flake cores (Fig. 3) were also frequently used to produce rounded, amorphous, or elongated flakes that could be used as expedient tools or to make thumbnail scrapers and bifacial projectile points. Researchers typically characterize the production of formal cores and extensive reduction prior to discard as indicators of conservative approaches to core reduction (Clarkson 2013; Douglass et al. 2018; Kuhn 1994; Shott 1996).

Relatively large cores and high levels of remnant cortex are both expected at sites where large amounts of raw materials are stockpiled because greater access to raw materials allows cores to be discarded at an earlier stage of reduction, and primary reduction occurs on-site more frequently under such conditions (Dibble et al. 2005). Together core size and cortical surface provide the best insight into how procurement and reduction interact and are two important variables for measuring reduction intensity (Dibble et al. 2005; Douglass et al. 2018; Fontes et al. 2015; Wallace and Shea 2006). Volume and cortex can be misleading for individual artefacts if discard happens at an early stage, perhaps due to raw material flaws or mis-strike, but as a whole the assemblage should indicate a particular pattern of raw material use and curation (see Kuhn 1995; Surovell 2009). Several studies have attempted to develop more precise methods of tracking the progress and intensity of reduction for individual artefacts and within larger assemblages (Dibble et al. 2005; Douglass et al. 2018; Morales et al. 2015; Morales 2016); however, this study is concerned primarily with identifying consistent and statistically significant variation at the final stage of discard across an expansive geographic range. I used two assemblage characteristics to assess differences in raw material conservation: the relative importance of formal

Fig. 2. Examples of the range of formal microblade cores represented in Gobi Desert assemblages.

to expedient manufacturing techniques and the extent of core reduction prior to discard.

Percentages of formal and expedient core types are also considered as a proxy for mobility based on the assumption that formal prepared cores are volumetrically and strategically designed to reliably produce high numbers of standardised blanks, which minimizes risk, and extends the potential for curation and the use life of raw materials (Andrefsky 1987; Clark 1987; Wallace and Shea 2006). Relative frequency of expedient to formal cores in each site assemblage was expressed as a percentage for each category of core type. Formal cores are essentially equivalent to microblade cores. I classified a variety of more spontaneously planned and less heavily reduced cores as "expedient" or "informal" (Fig. 3). Since many of the same tools can be produced on debitage derived from microblade production, it may be that such cores are more often used when raw material is readily available. The analysis explores the possibility that relative frequency of informal core types corresponds with other measures of raw material conservation.

Remnant cortex and core size were only measured on microblade cores as such cores are more standardised, while informal flake cores are larger, more variable, and less intensively prepared (i.e., more likely to retain cortex). The purpose was to determine whether microblade cores from Residential A sites retained significantly higher levels of cortex than those from Residential B sites. Degree of remnant cortical surface, or how much of the entire surface area of each core was covered by cortex, was measured on an ordinal scale of percentages: 1 = 0 %, 2 = 1–25 %, 3 = 26–50 %, 4 = 51–90 %, 5 = 91–100 %. The purpose was to compare the relative frequency of cores with very high retention of cortex and I chose to quantify two overlapping bins: more than 25 % and more than 50 % remnant cortex. The production of microblade cores requires extensive core preparation so that 25 % remnant cortex is quite high, but still possible on a core that has been used enough to have a well-developed shape and a well-used striking platform. More than 50 % is exceptional in formal microblade cores and is more typical of a piece that has been only briefly used before discard. The total percentage of cores falling into each of these two categories was calculated for each site and presented in Supplementary Table S2. These frequencies were used to generate a separate mean for Residential A and Residential B sites in each of the three regions.

Core volume was likewise used as a proxy for extent of reduction prior to discard and three dimensions were measured for each

Fig. 3. Examples of informal flake cores from Gobi Desert assemblages.

microblade core: height and two perpendicular platform measurements which were typically the shortest and longest platform measurements. The use of 3D imaging technology has recently become popular in reduction intensity studies and for measuring core volume (Clarkson et al. 2013; Li et al., 2015; Morales et al. 2015), but is time intensive and requires access to specialised equipment that was not available at the time of study. I used simple volume calculation for rectangular prism (L x W x H) with width and length measured by perpendicular measurements on the core platform. Original measurements were taken in mm, but core volume was recorded in cm^3 for ease of analysis. Mean core volume and mean platform surface area were generated for each site assemblage.

I also collected data related to intensity of retouch on scrapers. The original analysis used Kuhn's (1990) reduction index for unifacial tools (t/T or vertical thickness of flake at termination line of retouch scars, divided by maximum medial thickness of the flake). The results (Janz 2012: 282) followed the same pattern observed below, but were insignificant (p = 0.28). They are not reported here as observations of core reduction were more robust and better supported.

According to the expectations outlined above, *if Residential A assemblages were derived from longer term occupations, the results should show that Residential A and Residential B sites are drawn from separate populations with consistent differences in degree of raw material conservation.* Reduction strategies at Residential A sites will be *less conservative of raw material, combining higher frequencies of informal cores, higher percentages of remnant cortex on microblade cores, and larger core volumes.*

According to the expectations outlined in the background and theoretical sections, we should see more lowland dune-field occupations of longer duration during Oasis 2. This should be expressed as a significantly greater number of Residential A sites in lowland dune-field wetlands during Oasis 2 compared to other periods. A shift to pastoralism is predicted to present an increase in residential mobility from Oasis 2 and a lessened emphasis on dune-field wetlands due to the prioritisation of grazing over *r*-selected prey (i.e., lowland riverine and lowland dry ecozones in the summer and upland ecozones in the winter). This could be expressed as a more even distribution of residential sites across ecozones, or perhaps a shift from lowland dune-field wetlands to lowland riverine habitats. Residential B sites should increase in relation to Residential A sites during Oasis 3, but residential sites should still be more common than task sites. It is expected that Oasis 1 sites will be more similar to Palaeolithic than Oasis 2 and 3 sites (Janz 2016, Janz et al. 2017), but we currently know very little about the period.

4. Results

4.1. Site distribution

Absolute numbers for the distribution of Upper Palaeolithic, Oasis 1, Oasis 2, and Oasis 3 sites are presented in Table 2 and frequency distributions illustrated in Fig. 4. The two-tailed test was used throughout this study and allows for visualization of effects in both directions (i.e., greater or fewer sites than expected). Pearson's chi-square was used to evaluate these distributions (Table 2), but individual cell counts are too low (70 % < 5) to make the *p*-value reliable. For that reason, Fisher's Exact Test (1000 simulation runs) was used to calculate probability of observed occurrences under the assumption of equal proportions; the resulting *p*-value of 0.004 voids the null hypothesis that the samples were drawn from the same population and supports the interpretation of a significant change in land-use over time. Expected count and standardised residual (z) were calculated for each cell. Significance is measured at $Z_{0.025}$ (97.5 %) with values $\leq$ -1.96 or $\geq$ 1.96 considered significant.

All significant values were associated with Palaeolithic land-use, including fewer lowland dune-field lake sites (z = -3.69), more lowland dry (z = 3.39) and more upland dry sites (z = 2.68) than expected (Table 2). This shows that land-use during the Palaeolithic was very different from Oasis 2 and Oasis 3. Occupations were focused more in upland than lowland environments. They appear to have also been less closely tied to a stable source of water, but this idea is tentative as there have been major post-glacial changes in hydrological features and their visibility on the landscape. Fig. 4 shows the relative frequency of ecozones inhabited during each period and highlights the unique quality site distribution during Oasis 1, which is most similar to Oasis 2 and Oasis 3, but still more upland-oriented than those later sites. It is possible that the statistical significance of Oasis 1 settlement patterning was overwhelmed by the high number of later sites and their strong divergence from the Palaeolithic.

The dominance of Oasis 2 and Oasis 3 sites within this sample is a major point of importance because it means these sites are the primarily determinant of sample parameters: in other words, the distribution of

Table 2
Absolute numbers for the distribution of sites for each ecozone according to period.

Ecozone	Palaeolithic	Oasis 1	Oasis 2	Oasis 3
Lowland, dune-field lake	1	6	26	38
expected	6.98	6.4	23.86	33.75
st. residual	**−3.69**	−0.26	0.83	1.56
Lowland, river/spring	2	1	3	5
expected	1.08	0.99	3.7	5.23
st. residual	0.97	0.01	−0.47	−0.14
Lowland, dry	3	0	1	2
expected	0.59	0.54	2.02	2.85
st. residual	**3.39**	−0.79	−0.9	−0.71
Upland, any source	2	4	8	7
expected	2.06	1.89	7.06	9.98
st. residual	−0.05	1.76	0.48	−1.43
Upland, dry	4	0	3	6
expected	1.27	1.17	4.37	6.18
st. residual	**2.68**	−1.2	−0.85	−0.11

*X^2 = 28.708, df = 12, *p*-value = 0.0003. Fisher's Exact Test, *p* = 0.0043.

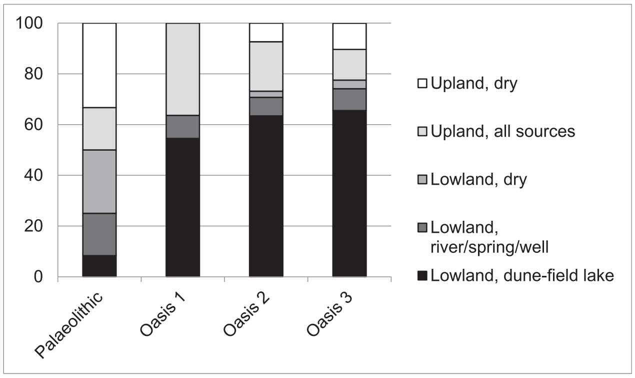

Fig. 4. Percentage of sites within each ecozone according to period.

Table 3
Absolute numbers for the distribution of Gobi-Altai sites for each ecozone according to period.

Ecozone	Palaeolithic	Oasis 1	Oasis 2 and 3
Lowland, dune-field lake	3	3	13
expected	11.14	3.29	4.57
st. residual	**−4.2**	−0.19	**5.01**
Lowland, river/spring	15	4	6
expected	14.66	4.33	6.01
st. residual	0.16	−0.2	0
Lowland, dry	5	0	1
expected	3.52	1.04	1.44
st. residual	1.26	−1.15	−0.43
Upland, any source	27	7	4
expected	22.29	6.58	9.13
st. residual	1.95	0.23	**−2.45**
Upland, dry	11	4	1
expected	9.38	2.77	3.85
st. residual	0.89	0.88	−1.81

*X^2 = 30.22, df = 8, *p*-value = 0.0002. Fisher's Exact Test, *p* = 0.0002.

such sites will influence expected values for the entire sample. The reverse pattern is seen in the Gobi-Altai sample below (Table 3), where the sample was dominated by Palaeolithic sites and these determined sample parameters (note that Oasis 2 and Oasis 3 were combined here because it they were not distinguished in the published dataset). The results confirm that lowland dune-field lake sites are significantly fewer during the Palaeolithic and more numerous than would be expected for Oasis 2 and Oasis 3. Lowland sites during the Palaeolithic tend to focus on riverine environments. The results for Oasis 1 tend to follow expectations for random distribution within these sample parameters, meaning that they are inconclusive; however, it is notable that there are no Oasis 1 sites identified in the entire sample from dry lowland contexts (tables 2, 3). Oasis 1 sites may have been underrepresented if they are conflated with sites from other periods (Late Palaeolithic or Oasis 2/3).

4.2. Site type

Site classifications and supporting information are presented in Table S1. The frequency of distributions is illustrated in Fig. 5. Since counts are fewer than five in 33 % of the cells (see Table 4), I used the Fisher Exact Test (1000 simulation runs) to calculate the exact probability of the observed occurrences based on expected distributions under the assumption of equal proportions. The resulting *p*-value of < 0.001 allows us to reject the null hypothesis that the distribution of site types is consistent between periods. Based on the residuals from expected distributions, there are significant deviations ($Z_{0.025} \geq 1.96$ or ≤ -1.96) as follows: there are fewer Residential A (N=0) and more task sites than expected for the Palaeolithic and Oasis 1; there are more Residential A sites for Oasis 2; and there are more Residential B and fewer task sites during Oasis 3 (Table 4, Fig. 5). One interpretation of the data is that land-use during the Palaeolithic and Oasis 1 emphasised task-focused occupations complemented by small residential sites, whereas Oasis 2 and Oasis 3 emphasised larger residential sites. During Oasis 3, there are a greater than expected number of Residential B sites and notably fewer than expected Task sites, suggesting some kind of organizational shift.

Table 4
Number counts of site types by period.

Period	Residential A	Residential B	Task Site
Palaeolithic	0	3	9
expected	3.47	4.76	3.77
st. residual	**−2.33**	−1.09	**3.43**
Oasis 1	0	2	8
expected	2.89	3.97	3.14
st. residual	**−2.11**	−1.32	**3.45**
Oasis 2	17	13	11
expected	11.86	16.26	12.88
st. residual	**2.18**	−1.28	−0.78
Oasis 3	18	30	10
expected	16.78	23.01	18.21
st. residual	0.49	**2.6**	**−3.22**

* X^2 = 31.847, df = 6, *p*-value = <0.0001. Fisher's Exact Test *p* = <0.001.

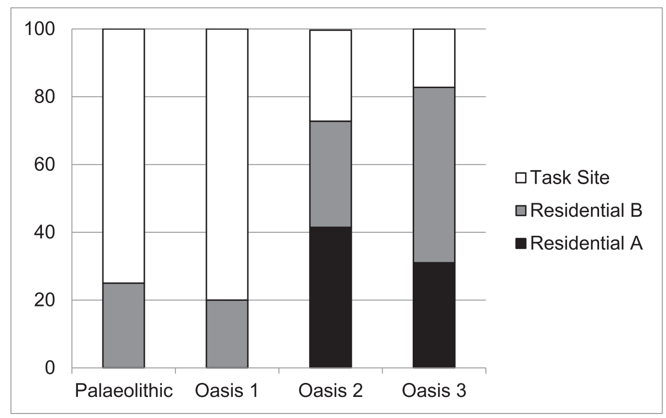

Fig. 5. Percentage of site types represented for each period.

The Gobi-Altai sample mirrors the Gobi-wide results here as well (Table 5). They confirm that Residential A sites are significantly more common than sample parameters would predict for Oasis 2 and Oasis 3, whereas task sites from those periods are fewer. Task sites are more common than expected for the Palaeolithic sample. The results for Oasis 1 are, as above, inconclusive.

As outlined at the beginning of this article, it was expected that we would see both more lowland dune-field occupations during Oasis 2 and an emphasis on Residential A sites in this ecozone. Table 6 and Fig. 6 show the combined distribution of different site types across ecozones during Oasis 2 and Oasis 3. Additional Gobi-Altai data was included to broaden the sample. Despite the greater homogeneity of the sample, which includes only Oasis 2 and Oasis 3 sites, the *p*-value for Fisher's

Table 5
Number counts of site types by period for Gobi-Altai region.

Period	Residential A	Residential B	Task Site
Palaeolithic	3	21	38
expected	5.31	25.39	31.3
st. residual	−1.64	−1.77	**2.66**
Oasis 1	0	8	10
expected	1.54	7.37	9.09
st. residual	−1.43	0.33	0.47
Oasis 2 and 3	6	14	5
expected	2.14	10.23	12.62
st. residual	**3.16**	1.75	**−3.49**

* X^2 = 17.817, df = 4, *p*-value = 0.001. Fisher's Exact Test *p* = 0.002.

Table 6
Distribution of each site type for Oasis 2 and Oasis 3 according to ecozone (includes additional data from Gobi-Altai region).

Site Type	Lowland, dune-field lake	Lowland, river/ spring	Lowland, dry	Upland, any source	Upland, dry
Residential A	25	4	0	2	0
expected	21.67	4	1.33	5.67	3.33
st. residual	1.39	0	−1.44	**−2.05**	1.17
Residential B	31	5	4	6	1
expected	29.49	5.44	1.81	7.71	4.54
st. residual	0.59	−0.27	**2.24**	−0.38	−1.69
Task site	9	3	0	8	2
expected	13.84	2.55	0.85	3.62	2.12
st. residual	**−2.32**	0.33	−1.06	**2.3**	**1.96**

*$X^2 = 17.558$, df = 8, $p = 0.02479$. Fisher's Exact Test, $p = 0.02298$.

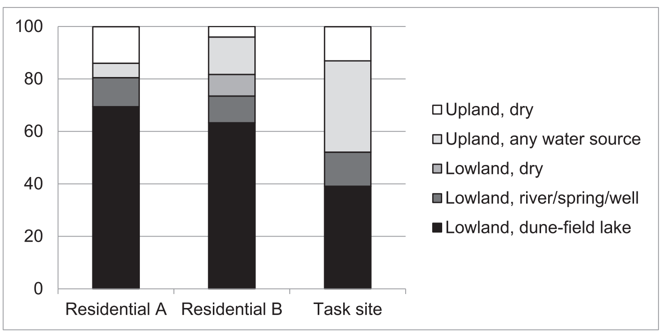

Fig. 6. Percentage of site types represented in each ecozone for Oasis 2 and Oasis 3 combined (includes additional data from Gobi-Altai region).

Exact Test is significant at 0.02298. Results indicate that residential sites tend to be focused in lowlands, while sites in uplands were task-oriented. Residential B sites were distributed over a wider range of environments; significantly more of these were present in dry lowland settings than would be expected within a random sample.

I further proposed that if local inhabitants moved towards specialised herding economies, we should expect to see a slight preference towards desert pastures (i.e., riverine lowland, lowland dry) over oases (i.e., lowland dune-field lake) combined with increase residential mobility (i.e., reduction in Residential A in favour of Residential B sites) associated with the need to find graze for herds. Table 7 compares the distribution of site types between Oasis 2 and Oasis 3, while Table 8 compares the distribution of all residential sites across ecozones. Survey data from the previously published Gobi-Altai dataset was excluded because it was impossible to distinguish Oasis 2 from Oasis 3. There is a greater than expected emphasis on Residential B sites in Oasis 3, but the combined results are not sufficiently significant to reject the null hypothesis that sites assigned to these two periods were drawn from the same population. There is no evidence of a change in the overall distribution of sites across ecozones between Oasis 2 and Oasis 3 (Table 8).

Table 7
Number counts of Oasis 2 and Oasis 3 site types.

Period	Residential A	Residential B	Task Site
Oasis 2	17	13	11
expected	14.49	17.81	8.7
st. residual	1.07	**−1.98**	1.15
Oasis 3	18	30	10
expected	20.5	25.19	12.3
st. residual	−1.07	**1.98**	−1.15

* $X^2 = 3.996$, df = 2, p-value = 0.1356.

4.3. Raw material conservation

The final component of this analysis was to test whether the site types, as they were classified, truly represent significantly different populations or whether characteristics such as greater numbers of cores or a wider range of specialised tools and activities, are a symptom of increased diversity with increasing sample sizes; did site classifications identify real differences in populations, or create imaginary distinctions? Are Residential A sites simply denser palimpsests of a similar nature to Residential B sites. Task sites were excluded from the analysis due to small sample size (most contained < 5 cores).

The Shapiro-Wilks test for normality indicated a non-normal distribution of percentages within the sample ($p > 0.05$) so I used the Wilcoxon Rank Sum test to compare Residential A and Residential B sites. The null hypothesis is that Residential A and Residential B sites are drawn from the same population. The results, presented in Table 9, clearly show that – at least when we consider the entire sample – the null hypothesis must be rejected for each variable ($p \leq 0.01$). Cores from Residential A assemblages show, without exception, higher percentages of informal cores, lower percentages of microblade cores, higher percentages of remnant cortex, larger mean core volume, larger mean core length, and larger mean platform surface area. The significance is weaker at the regional level, particularly in the Gobi-Altai region where raw material is most widely available. Regardless, each region consistently shows the same trend for each variable, with Residential A sites presenting less evidence for conservative use of raw material. The only exception to this trend is higher mean platform surface area for Residential B sites in the Gobi-Altai region. Raw material is abundant and distributed relatively evenly in this region. Reliable landscape-wide access to raw material could account the lack of evidence for raw material conservation.

Such consistent results across regions and variables are unlikely in a random sample and strongly support the probability that different raw material reduction strategies were consistently practiced between Residential A and Residential B sites. This pattern is consistent with the idea that Residential A sites were actively provisioned with raw material in anticipation of lengthier stays. Since both types of residential site assemblages were recovered from the same locality (usually within 1–2 km of each other), it is unlikely that differences in access to raw material were related to local availability.

Consistent and statistically significant levels of remnant cortex, along with larger core sizes and a greater emphasis on informal core types at Residential A sites indicate that core reduction was less intensive (i.e., raw material use was less conservative) than at Residential B sites. Similar patterns in retouch frequencies are noted for Palaeolithic sites in western Eurasia, where the frequency of retouched pieces is negatively correlated with artefact density (Barton and Riel-Salvatore 2014; Clark 2008; Kuhn 2004, 2013). According to Barton and Riel-Salvatore (2014), based on the results of computational agent-based modelling, this pattern of low intensity of raw material use (based on intensity of retouch) and high artefact densities is most extreme for the base camps of logistically mobile groups (*collectors* or *central-place foragers*). These results reflect the importance of provisioning strategies among logistically mobile groups and reinforce the interpretation of Residential A sites as base camps.

5. Discussion

Based on the current state of knowledge for post-LGM land-use and environment in the Gobi Desert, I set forth three expectations around diachronic change in distribution of residential and task sites: 1) residential sites would have been focused on lowlands during Oasis 2 and Oasis 3, but not during the Palaeolithic and Oasis 1; 2) Oasis 2 sites would present the highest *intensity* of wetland use, with an emphasis on logistical foraging; and 3) Oasis 3 residential sites will more often map to riverine and dry lowland environments. Change in the distribution of

Table 8
Distribution of residential sites according to ecozone for Oasis 2 and Oasis 3.

Site Type	Lowland, dune-field lake	Lowland, river/spring	Lowland, dry	Upland, any source	Upland, dry
Oasis 2	26	3	1	8	3
expected	26.5	3.31	1.24	6.21	3.73
st. residual	−0.21	−0.23	−0.29	1.02	−0.52
Oasis 3	38	5	2	7	6
expected	37.49	4.69	1.75	8.79	5.27
st. residual	0.21	0.23	0.29	−1.02	0.52

*$X^2 = 1.268$, df = 4, $p = 0.867$. Fisher's Exact Test, $p = 0.9081$.

sites by at least 6500 BCE reinforces the first expectation that Oasis 2 represents a novel shift towards the use of lowland wetlands. This interpretation is reinforced by the following results: 1) there are fewer than expected Palaeolithic sites in lowlands (<1200 m a.s.l.); and 2) there are a greater number of Palaeolithic task sites than expected. During Oasis 2/3, significant and consistent variation in core reduction intensity between Residential A and Residential B sites support the interpretation of two distinct tiers of residential settlement intensity. The smaller Residential B sites may represent satellite camps, variation in seasonal mobility, or perhaps even interannual changes in response to droughts – a question whose answer will require more targeted research.

Uplands versus lowlands: There appears to have been some preference for upland environments (classified here as > 1200 m a.s.l.) during the Palaeolithic. Sites were more evenly distributed across ecozones than during Oasis 2 and Oasis 3. Large residential sites may occur during the Palaeolithic, but systematic lithic analysis is needed at such sites to determine whether they were used more intensively and for longer, or simply more often (*sensu* Barton and Riel-Salvatore 2014; Clark 2008; Kuhn 2004, 2013). I have previously argued (Janz 2016) that there may be an early trend towards the use of lowland wetlands beginning in Oasis 1. The current results suggest that Oasis 1 sites are smaller and less intensively occupied, but found in a similarly broad range of environments as Oasis 2/3. There are, however, two few securely dates sites from this period to test that hypothesis. It is critical that there be careful analysis and dating of early microblade deposits post-dating the Upper Palaeolithic.

High versus low intensity residential sites: Another important point that arises is the likelihood that distinguishing differences between high (Residential A) and low (Residential B) intensity sites is an important key to understanding the nature and extent of diet breadth, including how land-use was organised to facilitate food acquisition. Residential A and Residential B sites often co-occur in the same locations. This suggests contemporaneous (within an archaeological timescale) variation in the nature of lowland dune-field residential sites – two components of a larger system that were both largely confined to lowland oases. Mobile task groups appear to have exploited upland environments and lowland settings farther from water. The implication is that land-use during Oasis 2 and Oasis 3 was characterised by lowland-dwelling groups using upland environments in a logistical pattern: longer term seasonal base camps (Residential A) centred on dune-field/wetland environments, complemented by radiating field camps (Residential B) and task sites (Janz 2012). Residential A sites appear to have been provisioned with raw materials and inhabited for longer, as evidenced by less conservative approaches to raw material reduction. The use of large, heavy formal grinding technology (Janz 2012) further suggests that Residential A sites were provisioned for planned reoccupation during seasons when resources such as tubers and/or seeds were being processed for immediate or delayed consumption (Dubreuil et al. 2022; Reis Cordeiro 2024).

Seasonality: Another possibility is that Residential A and Residential B sites represent seasonal variation in mobility within and across oases. Analyses of faunal and microbotanical remains at Zaraa Uul tend to suggest a winter and/or early spring occupation (Janz et al. 2021), while survey of the landscape around neighbouring Delgerkhan Uul (~50 km distant) suggests that smaller, more seasonal basins were regularly exploited but under conditions of high residential mobility (i.e., characterised by low-density scatters) (Odsuren et al. 2015; Pleuger et al. 2023). Denser occupational intensity characteristic of Residential A sites could be explained by reduced residential mobility during the harshly cold winter months. Reduced mobility in the winter is likely to have been dependent on the ability to preserve and store foods. This could explain the ubiquity of pottery and grinding stones in such contexts. Another possibility is that Residential A and Residential B sites represent decadal- or centennial-scale fluxes in resource availability and mobility – where the former residential sites relate to periods of higher occupational intensity due to resource abundance and the latter map high mobility during periods of resource decline. More site-specific types of research are required to address such questions.

Oasis environments and diet breadth expansion: The data presented here demonstrates the integrated nature of patterning in the human ecological niche; here, increased diet breadth is interconnected with visible decreases in residential mobility and more specialized use of oasis environments. These findings are further supported by ongoing research in eastern Mongolia (Farquhar 2022; Janz et al. 2021; Pleuger et al. 2023; Rosen et al. 2019; Tsydenova et al. 2012, 2015), previous observations about the restricted distribution of grinding stones during Oasis 2 (Dubreuil et al. 2022; Janz 2016), and new research showing the incorporation of diverse small fast species such as hare and waterfowl (Janz et al. 2021). Lowland wetlands in the Gobi Desert are typically associated with dune-fields, but such ecological systems are far less prominent landscape features in the desert-steppe. Results from recent fieldwork at Ikh Nart Nature Reserve of Dornogov' *aimag*, in the desert-steppe region of eastern Mongolia, suggests that we can conceive of oases differently according to the environmental setting (Farquhar 2022; Schneider et al. 2021). Compared with lakeshores (1049–1141 m a.s.l.) and lowlands (1133–1204 m a.s.l.), residential sites were more often located in upland (1153–1268 m a.s.l.) settings where rocky outcrops, freshwater springs, and plant and animal species abundance and diversity were highest (Farquhar 2022, see pp. 266–268 for environmental summaries of site locations). A high diversity of plant and animal species would have been present at the juncture of multiple ecozones, including arboreal and shrub vegetation, freshwater marshes and lakes, and open desert pastures (see Janz et al. 2021). Oasis 2 is most accurately characterised by intensifying use of environments in *ecotonal settings* (i.e., access to multiple distinct ecozones) with reliable freshwater.

Where the Holocene represents a period when such environments appear to have supported recurrent longer-term settlement (Janz 2016), it is likely that Palaeolithic peoples were also drawn to Pleistocene versions of "oasis" settings. The location and nature of oases, the way people used them, and probably people's perceptions of oases, would have changed during the Pleistocene-Holocene transition due to major epochal shifts in animal and plant communities (Guthrie 1984), the location of potable surface water (Janz et al. 2021), and changes in the structure of the human ecological niche. Residential bases centred upon wetlands was a common Holocene approach both in the Gobi Desert and globally, and some researchers have argued that this was due to climate-mediated changes in the relative abundance of *r*-selected animals and plant foods compared to the availability of large herbivore prey (Gamble 1986; Janz 2016).

Table 9
Results of Wilcoxon rank-sum test for Residential A and B lithic data sets. Combined mean values are included as an additional point of reference.

Variable		All sites (Res. A=30) (Res. B=45)	East Gobi (Res. A=9) (Res. B=8)	Gobi-Altai (Res. A=14) (Res. B=11)	Alashan Gobi (Res. A=7) (Res. B=26)
% informal cores	Res. A mean	37.35	47.5	38.8	16.2
	Res. B mean	19.82	31.78	33.62	7
	Mean of sites	27.99	41.76	42.47	8.621
	w =	499	58.5	22	63.5
	p =	**<0.01**	0.287	0.825	0.086
% microblade cores	Res. A mean	56	48.7	57.12	72
	Res. B mean	72.59	58.89	63.25	84.24
	Mean of sites	64.46	50.76	54.89	82.86
	w =	221.5	42	30	16
	p =	**0.01**	0.838	0.875	0.11
Mean % cores with remnant cortical surface (25 %+)	Res. A mean	32.5	38.2	33.3	17.25
	Res. B mean	14.16	8.94	22.62	12.94
	Mean of sites	21.46	26.9	31.5	11.21
	w =	524	90	28	42
	p =	**<0.001**	**<0.001**	0.27	0.476
Mean % cores with remnant cortical surface (50 %+)	Res. A mean	14.42	14.8	21	5.25
	Res. B mean	4.191	1.722	9.75	2.882
	Mean of sites	8.434	7.82	20.53	2.5
	w =	542	86	32	56
	p =	**<0.001**	**<0.001**	0.089	**0.021**
Mean microblade core volume (cm^3)	Res. A mean	116.1	113.53	121.9	115.26
	Res. B mean	71.64	56.25	120.25	59.76
	Mean of sites	87.6	82.74	114.16	79.27
	w =	486	82	16	56
	p =	**0.001**	**<0.01**	0.87	**0.05**
Mean microblade core platform (cm^2)	Res. A mean	34.19	32.99	34.27	37.12
	Res. B mean	24.17	22.18	35.3	20.64
	Mean of sites	26.79	26.8	32.95	23.92
	w =	477	77	22	54
	p =	**<0.01**	**0.01**	0.514	0.081
Mean microblade core length (cm)	Res. A mean	31.71	31.67	32.88	30.35
	Res. B mean	26.65	25.6	32.8	24.67
	Mean of sites	28.74	28.92	32.85	26.68
	w =	448	88	19	47
	p =	**0.01**	**<0.001**	0.87	0.263

*$p \leq 0.05$.

Pastoralism and Oasis 3 landuse: This study did not produce especially strong evidence to support the third expectation that Oasis 3 sites should be located outside lowland dune-field lake systems. The ecological distribution of Oasis 3 sites in this dataset is statistically indistinguishable with Oasis 2. A slight increase in Residential B sites provides only weak support for an increase in residential mobility during Oasis 3. Farquhar (2022) found a similar pattern at Ikh Nart, where occupation of key locations continued into the Bronze Age, though greater mobility is suggested by heightened conservation of raw materials. Both studies suggest some possibility of increased mobility during Oasis 3, but additional data is required to develop a better understanding of the timing and nature of changes such as the adoption of herding.

One of the major challenges in this study is the reliance on diagnostic technology to periodize sites. The similarity of core types and other basic components of Oasis 2 and Oasis 3 lithic assemblages proved challenging for firmly distinguishing such sites or recognizing possible differences in the nature of occupations spanning multiple periods. This study largely assumed that Residential A sites spanning Oasis 2 and Oasis 3 were used similarly in both periods. This may not have been the case. Many localities were used during both periods and the materials were often mixed. While a good understanding of diagnostic types reduced the possibility of *not recognizing* elements of Oasis 2 or Oasis 3 within larger assemblages, we can not be certain that such sites were used in the same way during both periods. The above-outlined challenges to distinguishing and categorising site use may have been a factor that masked statistical significance in this sample.

Luckily, field-based research is beginning to shed some light on the complexity of the transition from hunting and gathering towards pastoralism. Mongolian and Russian researchers during the twentieth century identified a period of increased mobility well before the adoption of pastoralism (Cybiktarov 2002; Derevianko and Dorj 1992; Dorj 1971; Sériadès 2006) and research in eastern Mongolia is beginning to verify the idea that there were substantial changes in land-use after 4500 BCE (Janz et al. 2021; Zhao et al. 2021). Within the 1,225.44 ha survey area of Ikh Nart, there is an abrupt and significant shift away from wetland ecosystems by 3500 BCE and perhaps as early as 4200 BCE (Farquhar 2022: 115-137, 233). Wetlands were not abandoned though. Their use at Ikh Nart continues on some scale until the Xiongnu period (Farquhar 2022: 115-137, 233). Such habitats were ephemerally used through historic and into modern times for winter campsites. Diagnostic artefacts from the Khitan period (10-12th c. AD) frequently occur in and around Oasis 2 and Oasis 3 wetland habitation sites (Janz 2012), suggesting a rise in the intensity of wetland use at that time. Despite possible continued use of wetlands, burial sites associated with the earliest confirmed pastoralist peoples, Prone Burial cultures that typically post-date 1800 BCE, are often located on terraces or hillslopes above rivers or plains, many far from oasis habitats, suggesting a conscientious, intentional, and highly visible claim upon upland habitats and associated plains (see Wright et al. 2017, 2019). The current chronology simply does not fully account for changes in land-use leading up to the adoption of pastoralism.

Palaeolithic, Oasis 1, and associated challenges: This study represents a coarse-grained approach to identify potential patterns in land-use related to major changes in subsistence during the Pleistocene-Holocene transition. The work covered a massive temporal and geographic range and there are a number of obvious limitations. With regard to the Palaeolithic, there was no distinction made between Palaeolithic periods, which spans an enormous breadth of time. The majority of known Palaeolithic surface assemblages in Mongolia do date to between 45–30 kya, which somewhat reduces statistical errors in grouping, but it remains that the resulting characterisation of Palaeolithic land-use compared to later periods is too essentializing. For example, it is plausible that the equitable distribution of sites across ecozones is an artefact of temporal depth. The idea that Palaeolithic sites are largely focused on upland settings is compelling, however, and supported by recent excavations at Otson Tsokhio/Zaraa Uul in the eastern desert-steppe of Sükhbaatar *aimag* (Odsuren et al. 2023). Geoarchaeological research suggests a connection between upland use and high lake levels during MIS 3 (Odsuren et al., 2023; Rosen et al. 2022).

As already noted, the characterisation of Oasis 1 sites was likewise difficult due to the paucity of dates and lack of identifiable sites from this period, which is interrelated with a poor understanding of diagnostic artefacts and the precise timing of post-LGM changes in settlement and technology. Preliminary analysis suggests that Oasis 1 may have maintained similar patterns of land-use to preceding periods, but there are simply too few such sites to advocate in any one direction. The existing chronology (Janz et al. 2015) merely presents a broad outline that must be refined as research progresses.

Testable hypotheses: Despite the challenges, the results of this analysis refine our current interpretations and provide a series of testable hypotheses. The results reinforce the interpretation of a marked shift towards reduced residential mobility and the centralised use of lowland wetlands which was underway by the beginning of Oasis 2 and continued into Oasis 3. Smaller residential sites also tend to be focused in these environments and it is recommended that we begin targeted inquiry into whether these functioned as shorter length occupations during certain seasons or years, whether they were part of radiating logistical foraging camps, or perhaps a mix of both. Task sites were often located in upland environments, suggesting specialised procurement of special foods and/or raw materials. One testable hypothesis is that local groups were semi-sedentary during part of the year and more mobile during another part of the year, with both modalities of land-use focused on lowland wetlands but supported by short forays into the uplands. Another testable hypothesis is that there was a shift towards Residential B and Task sites during Oasis 3 (Table 7). Despite the lack of statistical support presented herein, field-based research does support this as a possibility. Many questions remain.

6. Recommendations for directions in future research

The purpose of this study was to use analyses of settlement distribution and intensity of core reduction sequences to interpret changes in subsistence economies at the scale of region-wide land-use, and to develop testable hypotheses for future research. Twentieth century theoretical and ethnoarchaeological research has established that different modes of land-use are connected to different food procurement strategies. Researchers have frequently used the distribution and density of stone tool scatters to speculate about economic activities of early hominids (Pope and Roberts 2005). This approach also has potential for application in more recent periods. Where preservation of *in situ* material is rare it allows us to develop testable hypotheses about subsistence strategies, including predictive models that enhance our ability to find better preserved deposits. Mongolia is a region that has high potential for this kind of research. Decades of systematic field survey carried out by Mongol-American research expeditions in central and eastern Mongolia (Amartushvin and Honeychurch 2010; Wright et al. 2019, 2023) have produced many lithic assemblages and this study demonstrates the importance of using such datasets to map large-scale changes in land-use over the millennia of human occupation. Farquhar's (2022) results similarly reinforce the importance of continuing to investigate variation in residential sites through combined field survey and traditional lithic analysis.

The most notable result of this study is strong support for the idea that the use of lowland dune-field lake systems (and other ecotonal environments) became increasingly important during the late Pleistocene and culminating around 6500 BCE during the Holocene Climatic Optimum. This resulted in the emergence of provisioned longer-term Residential A sites. The practice of provisioning places indicates prolonged, recurrent, and likely seasonal site use (Barton and Riel-Salvatore 2014; Kuhn 1992, 1995; Nelson 1991). Previous research has shown that these changes in land-use are correlated with diet breadth expansion (Janz et al. 2021), and that specialized activities like intensive plant processing (Dubreuil et al. 2022; Reis Cordeiro 2024) and woodworking (Evoy 2019) occurred in many Residential A contexts. These combined findings highlight the exciting potential for more targeted research on regional land-use, interconnectivity of oases, diet and seasonality, which require fine-grained site-specific research such as chronometric dating and the use of faunal and botanical analyses.

Oasis 3 (3000–1000 BCE) begins with the settlement of western and central Mongolia by pastoralists (Honeychurch et al. 2021; Taylor et al. 2019) and the rise of Prone Burial cultures across the Gobi Desert and eastern Mongolia (Burentogtokh et al. 2019: 58-60; Tumen et al. 2014; Wright et al. 2019). The majority of research on this period has been dedicated to excavation of Bronze Age burials. The only clear record that we have for changes in the ecological niche of early pastoralists comes, infact, from the distribution of monumental burial sites (Wright et al. 2007, 2019). This is counter-intuitive to understanding a transition that was already far advanced by the time it is expressed in the burial culture.

I have suggested that future research engage more directly with Oasis 3 settlement in order to understand the nature of wetland use during the transition to pastoralism. Declining wetland use after 4500 BCE is probably related to increasing aridity (Felauer et al. 2012; Herzschuh 2006; Janz 2012; Lee et al. 2013; Rosen et al. 2022) and while later shifts away from wetlands might also have been influenced by shrinking freshwater lakes and marshes, I argue here that, in practice, this represents a prioritisation of grazing over broad spectrum foraging strategies. Such a shift could as easily be motivated by largely unrelated cultural changes (e.g., Janz et al. 2020). We currently have very little understanding of when hunter-gatherers first adopted herd animals or to what extent those species influenced established behaviours. Disentangling the pace and nature of these changes will require landscape-level analysis of clearly distinguished, and more firmly-dated, Oasis 2 and Oasis 3 habitation sites. Only then can we have fruitful discussions around how herding may have been incorporated into hunter-gatherer economies, the nature of hunter-herder interactions, and the ways that people balanced care of both managed herds and wetland ecosystems.

Finally, I propose that researchers working in the Palaeolithic compliment their robust study of typology with systematic studies of raw material reduction and site distribution in order to test the hypothesis that land-use was focused on upland environments with more task-specific use of lowlands. Understanding the evolution of Pleistocene lake basins in the region will be critical to this undertaking as high lake levels in the many local basins necessarily restricted movement and the types of available foraging opportunities. Understanding the chronology of early microblade assemblages, especially following the LGM and leading into Oasis 2, is equally critical. This analysis suggests that land-use in Oasis 1 may have been more similar to the Palaeolithic than to Oasis 2 and Oasis 3, but the finding is weakly supported due to limitations of the study. Developing a set of diagnostic features for LGM and post-LGM lithic assemblages will require careful dating and analysis of *in situ* sites – few of which are currently known. Survey and excavation of oasis sites should include greater attention to the possibility of such early sites around potential relict lakeshores from the Bølling Allerød and Younger Dryas (see Morgan et al. 2022).

For all of these questions, it is critical that future research focus on the excavation of buried and stratified sites in order to better understand specific changes between periods, including diet and technology. This is especially challenging considering the difficulty in locating *in situ* deposits in an environmental setting where both extensive deflation and massive aeolian redeposition provide challenging conditions for the recovery of buried sites, but the results of this study can be used to guide the development of predictive models aimed at identifying high probability locations (see Holguín 2019; Holguín and Sternberg 2018). The first stages of such work are currently being carried out in desert-steppe transitional zone of north-eastern Mongolia (Farquhar 2022; Janz et al. 2021; Odsuren et al. 2015; Rosen et al. 2019, 2022; Schneider et al. 2021) and by researchers in the sub-boreal reaches of northern central Mongolia. Hopefully, increasing interest in this period will lead to an improved understanding of post-LGM technology, diet, and land-use, which will in turn inform our understanding of variation in human organization across Northeast Asia and at the global scale during the Pleistocene-Holocene transition and as well as shifts towards food production.

Funding.

This work was supported by the Asian American Alumni, Staff, and Faculty Association at the University of Arizona; the Department of Anthropology, University of Arizona; SSHRC Doctoral Fellowship (752–2005-0035); ACLS/Henry Luce Foundation fellowship for East and Southeast Asian Archaeology; and the Roberta Bondar Postdoctoral Fellowship in Northern and Polar Studies, School for the Study of Canada, Trent University.

CRediT authorship contribution statement

Lisa Janz: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

James Conolly provided insightful comments on the statistical analysis and Steven Kuhn supervised the initial lithic analysis. Jacqueline Meier and Kate Dougherty provided comments on an early version of the text. This work was supported by the Asian American Alumni, Staff, and Faculty Association at the University of Arizona; the Department of Anthropology, University of Arizona; SSHRC Doctoral Fellowship (752-2005-0035); ACLS/Henry Luce Foundation fellowship for East and Southeast Asian Archaeology; and the Roberta Bondar Postdoctoral Fellowship in Northern and Polar Studies, School for the Study of Canada, Trent University.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaa.2024.101624.

References

Amartuvshin, Ch., Honeychurch, W., 2010. Дүндговъ АйМагт Хийсэн Археологийн Судалгаа: Бага Газрын Чулуу Dundgobi Aimagt Hiisen [Arkheologiin Sudalgaa: Baga Gazaryn Chuluu]. [archaeological Research in the Middle Gobi: Baga Gazaryn Chuluu]. Studia Archaeologica Insituti Archaeologici Academiae Scientarum Mongolicae, XXVII. Mongolian Academy of Science, Institute of Archaeology, Ulaanbaatar.

An, Z., 1992. The Bronze Age in eastern parts of Central Asia. In: Dani, A., Masson, V.M. (Eds.), The Dawn of Civilization, Earliest times to 700 BC, History of Civilization of Central Asia, Vol. 1. UNESCO, Paris, pp. 319–336.

Andrefsky Jr., W., 1987. Diffusion and innovation from the perspective of wedge shaped cores in Alaska and Japan. In: Johnson, J.K., Morrow, C.A. (Eds.), The Organization of Core Technology. Westview Press, Boulder, pp. 13–44.

Army Map Services, Corps of Engineers, U.S. Army, Washington, D.C., 1949. "Kuei-Sui" [map]. 1:1,000,000. In: Norin, E., Montell, G. (Eds.), 1969, Sven Hedin Central Asia Atlas. Reports from the Scientific Expedition to the North-western Provinces of China under the Leadership of Sven Hedin, Sino-Swedish Expedition Publication, Publication 47. Statens Etnografiska Museum, Stockholm, NK 49.

Army Map Services, Corps of Engineers, U.S. Army, Washington, D.C., 1950. "Dalan Dzadagad" [map]. 1:1,000,000. In: Norin, E., Montell, G. (Eds.), 1969, Sven Hedin Central Asia Atlas. Reports from the Scientific Expedition to the North-western Provinces of China under the Leadership of Sven Hedin, Sino-Swedish Expedition Publication, Publication 47. Statens Etnografiska Museum, Stockholm, NK 48.

Army Map Services, Corps of Engineers, U.S. Army, Washington, D.C., 1954. "O-Chi-Na Ho" [map]. 1:1,000,000. In: Norin, E., Montell, G. (Eds.), 1969, Sven Hedin Central Asia Atlas. Reports from the Scientific Expedition to the North-western Provinces of China under the Leadership of Sven Hedin, Sino-Swedish Expedition Publication, Publication 47. Statens Etnografiska Museum, Stockholm, NK 47.

Aubry, T., Luís, L., Mangado, J., Matias, H., 2012. We will be known by the tracks we leave behind: Exotic lithic raw materials, mobility and social networking among the Côa Valley foragers (Portugal). Journal of Anthropological Archaeology 31, 528–550.

Badenhorst, S., Driver, J.C., 2009. Faunal changes in farming communities from Basketmaker II to Pueblo III (A.D.1–1300) in the San Juan Basin of the American Southwest. Journal of Archaeological Science 36, 1832–1841.

Bailey, R.C., Aunger Jr., R., 1989. Net hunters vs. archers: Variation in women's subsistence strategies in the Ituri forest. Human Ecology 17, 273–297.

Bamforth, D.B., 1986. Technological efficiency and tool curation. American Antiquity 51, 38–50.

Bamforth, D.B., Bleed, P., 1997. Technology, flaked stone technology, and risk. In: Clark, G.A., Barton, C.M. (Eds.), Rediscovering Darwin: Evolutionary Theory and Archaeological Explanation. Archaeological Papers of the American Anthropological Association 7. American Anthropological Association, Arlington, Virginia, pp. 109–140.

Barton, L., Brantingham, P.J., Ji, D., 2007. Late Pleistocene climate change and Paleolithic cultural evolution in northern China: Implications from the Last Glacial Maximum. In: Madsen, D.B., Chen, F.H., Gao, X. (Eds.), Late Quaternary Climate Change and Human Adaptation in Arid China. Developments in Quaternary Science, Vol. 9. Elsevier, Amsterdam, pp. 105–128.

Barton, C.M., Riel-Salvatore, J., 2014. The formation of lithic assemblages. Journal of Archaeological Science 46, 334–352.

Bazarova, V.B., Tsydenova, N.V., Lyaschevskaya, M.S., Khenzykhenova, F.I., Tumen, D., Erdene, M., 2019. Reconstruction of paleoenvironmental conditions of ancient people habitation in the Togootyn Gol River valley (eastern Mongolia). Quaternary International 503, 105–114. https://doi.org/10.1016/j.quaint.2018.10.017.

Bergman, F., 1945. Travels and archaeological field-work in Mongolia and Sinkiang – a diary of the years 1927-1934. In: Hedin, S. (Ed.), History of the Expedition in Asia 1927-1935. Reports from the Scientific Expedition to the North-western Provinces of China under the Leadership of Sven Hedin, Sino-Swedish Expedition Publication, Publication 26, Part IV. Statens Etnografiska Museum, Stockholm, pp. 1-192.

Binford, L.R., 1979. Organization and formation processes: looking at curated technologies. Journal of Anthropological Research 35 (3), 255–273.

Binford, L.R., 1980. Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. American Antiquity 45 (1), 4–20.

Binford, L.R., 1982. The archaeology of place. Journal of Anthropological Archaeology 1 (1), 5–31.

Binford, L. R. 1968. Post-Pleistocene Adaptations. In: Binford, S. R., Binford, Lewis R. (Eds.), New Perspectives in Archaeology. Aldine, Chicago, pp. 313-341.

Blades, B.S., 2002. Aurignacian Lithic Economy: Ecological Perspectives from Southwestern France. Kluwer Academic Publishers, New York.

Bleed, P., 1986. The optimal design of hunting weapons: maintainability or reliability. American Antiquity 51 (4), 737–747.

Broughton, J.M., Cannon, M.D., Bartelink, E.J., 2010. Evolutionary ecology, resource depression, and niche construction theory: applications to Central California hunter-gatherers and Mimbres-Mogollon agriculturalists. Journal of Archaeological Method and Theory 17, 371–421.

Brunson K., Witt K.E., Monge S., Williams S., Peede D., Odsuren D., Bukhchuluun D., Cameron A., Szpak P., Amartuvshin C., Honeychurch W., Wright J., Pleuger S., Erdene M., Tumen D., Rogers L., Khatanbaatar D., Batdalai B., Galdan G., Janz L., ND. Ancient Mongolian aurochs genomes reveal sustained introgression and management in East Asia. bioRxiv [Preprint]. 2023 Aug 10:2023.08.10.552443. doi: 10.1101/2023.08.10.552443.

Brunson, K., Lele, R., Xin, Z., Xiaoling, D., Hui, W., Jing, Z., Flad, R., 2020. Zooarchaeology, ancient mtDNA, and radiocarbon dating provide new evidence for the emergence of domestic cattle and caprines in the Tao River Valley of Gansu Province, northwest China. Journal of Archaeological Science Reports 31, 102262. https://doi.org/10.1016/j.jasrep.2020.102262.

Bureau of Geological Investigation, Geological Survey of Mongolia, 2003a. "Orog nuur" [map]. 1:500,000. Mongol Uls, L-47-Г. Ulaanbaatar.

Bureau of Geological Investigation, Geological Survey of Mongolia, 2003b. "Ongi" [map]. 1:500,000. Mongol Uls, L-48-B. Ulaanbaatar.

Bureau of Geological Investigation, Geological Survey of Mongolia, 2003c. "Urt" [map]. 1:500,000. Mongol Uls, K-47-Б. Ulaanbaatar.

Bureau of Geological Investigation, Geological Survey of Mongolia, 2003d. "Dalanzadgad" [map]. 1:500,000. Mongol Uls, K-48-A, B. Ulaanbaatar.

Bureau of Geological Investigation, Geological Survey of Mongolia, 2003e. "Baruuncuu" [map]. 1:500,000. Mongol Uls, K-48-Б, Г. Ulaanbaatar.

Burentogtokh, J., Honeychurch, W., Gardner, W., 2019. Complexity as Integration: Pastoral Mobility and Community Building in Ancient Mongolia. Social Evolution & History 18 (2), 55–72. https://doi.org/10.30884/seh/2019.02.03.

Butler, V.L., Campbell, S.K., 2004. Resource intensification and resource depression in the Pacific Northwest of North America: a zooarchaeological review. Journal of World Prehistory 18, 327–405.
Cannon, M.D., Meltzer, D.J., 2008. Explaining variability in Early Paleoindian foraging. Quaternary International 191, 5–17.
Cermak, J., Opgenoorth, L., Miehe, G., 2005. Isolated mountain forests in Central Asian deserts: A case study from the Govi Altay, Mongolia. In: Broll, G., Keplin, B. (Eds.), Mountain Ecosystems: Studies in Treeline Ecology. Earth and Environmental Science, Part 4. Springer, New York, pp. 253–273.
Charnov, E.L., 1976. Optimal foraging, the marginal value theorem. Theoretical Population Biology 9, 129–136.
Clark, J., 1987. Politics, prismatic blades, and Mesoamerican civilization. In: Johnson, J. K., Morrow, C.A. (Eds.), The Organization of Core Technology. Westview Press, Boulder, pp. 259–284.
Clark, A.E., 2008. Changes in Occupation Intensity During the Lower and Middle Paleolithic at Tabun Cave, Israel. Department of Anthropology, University of Arizona. Unpublished Master's Thesis.
Clark, G.A., Barton, C.M., 2017. Lithics, landscapes & la longue-durée – Curation & Expediency as expressions of forager mobility. Quaternary International 450, 137–149.
Clarkson, C., 2013. Measuring core reduction using 3D flake scar density: a test case of changing core reduction at Klasies River Mouth, South Africa. Journal of Archaeological Science 40, 4348–4357.
Conard, N.J., Will, M., 2015. Examining the causes and consequences of short-term behavioral change during the Middle Stone Age at Sibudu. South Africa. PLOS One 10 (6), e0130001.
Cybiktarov, A.D., 2002. Eastern Central Asia at the dawn of the Bronze Age: issues in ethno-cultural history of Mongolia and the southern Trans-Baikal region in the late third-early second millennium BC. Archaeology, Ethnology & Anthropology of Eurasia 3 (11), 107–123.
de la Peña, P., Wadley, L., 2017. Technological variability at Sibudu Cave: The end of Howiesons Poort and reduced mobility strategies after 62,000 years ago. PLoS ONE 12 (10), e0185845.
Derevianko, A.P. (Ed.), 2000. Paleolithic and Neolithic of the Northern Face of the Valley of the Lakes. Institute of Archaeology and Ethnography SB RAS Press, Novosibirsk in Russian, French and English.
Derevianko, A. P., Dorj, D., 1992. Neolithic tribes in northern parts of Central Asia. In: Dani, A. H., Masson, V. M. (Eds.), History of Civilization of Central Asia, Volume 1: The Dawn of Civilization, Earliest Times to 700 BC. UNESCO Publishing, Paris, pp. 169-189.
Derevianko, A.P., Olsen, J.W., Tseveendorj, D., (Eds.), 1996. A Preliminary Report on Archaeological Studies carried out by the Joint Russian-Mongolian-American Expedition in Mongolia in 1995. Institute of Archaeology and Ethnography SB RAS Press, Novosibirsk in Russian, Mongolian and English.
Derevianko, A.P., Olsen, J.W., Tseveendorj, D., (Eds., 1998. Archaeological Studies carried out by the Joint Russian-Mongolian-American Expedition in Mongolia in 1996. Institute of Archaeology and Ethnography SB RAS Press, Novosibirsk in Russian, Mongolian, and English.
Derevianko, A.P., Olsen, J.W., Tseveendorj, D., (Eds.), 2000. Archaeological Studies carried out by the Joint Russian-Mongolian-American Expedition in Mongolia in 1997–1998. Institute of Archaeology and Ethnography SB RAS Press, Novosibirsk in Russian, Mongolian and English.
Derevianko, A.P., Gladyshev, S.A., Nohrina, T.I., Olsen, J.W., 2003. The Mongolian Early Holocene excavations at Chikhen Agui Rockshelter in the Gobi Altai. The Review of Archaeology 24 (2), 50–56.
Dibble, H.L., Schurmans, U.A., Iovita, R.P., McLaughlin, M.V., 2005. The measurement and interpretation of cortex in lithic assemblages. American Antiquity 70 (3), 545–560.
Dodson, J., Li, X., Ji, M., Zhao, K., Zhou, X., Levchenko, V., 2009. Early bronze in two Holocene archaeological sites in Gansu. NW China. Quaternary Research 72 (3), 309–314. https://doi.org/10.1016/j.yqres.2009.07.004.
Dong, G., Yang, Y., Han, J., Wang, H., Chen, F., 2017. Exploring the history of cultural exchange in prehistoric Eurasia from the perspectives of crop diffusion and consumption. Science China Earth Sciences 60, 1110–1123. https://doi.org/10.1007/s11430-016-9037-x.
Dorj, D., 1971. Neolit vostochnoy Mongolii [Neolithic of eastern Mongolia]. Izvestiya Akademii Nauk Mongol'skoy Napodnoy Respubliki Institut Istorii, Ulaanbaatar in Russian.
Douglass, M.J., Lin, S.C., Braun, D.R., Plummer, T.W., 2018. Core use-life distributions in lithic assemblages as a means for reconstructing behavioral patterns. Journal of Archaeological Method and Theory 25 (1), 254–288.
Dubreuil, L., Evoy, A., Janz, L., 2022. The New Oasis: Potential of Use-Wear for Studying Plant exploitation in the Gobi Desert Neolithic. In: Pedersen, P.N., Jörgensen-Lindahl, A., Sørrensen, M., and Richter, T. (Eds.), Proceedings of the 3rd Meeting of the Association of Ground Stone Tools Research, Archaeopress, Oxford, pp. 116-138.
Dyakonov, V.M., Pestereva, K.A., Stepanov, A.D., Mason, O.K., 2019. The spread of metal and metal production technology in the Far Northeast and Alaska over the second millenium BC to the first millenium AD. World Archaeology 51 (3), 355–381. https://doi.org/10.1080/00438243.2019.1708785.
Elston, R.G., Chen, X., Madsen, D.B., Kan, Z., Bettinger, R.L., Jingzen, L., Brantingham, P. J., Huiming, W., Jun, Y., 1997. New dates for the North China Mesolithic. Antiquity 71, 985–993.
Elston, R.G., Dong, G., Zhang, D., 2011. Late Pleistocene intensification technologies in Northern China. Quaternary International 242 (2), 401–415.
Elston, R.G., Zeanah, D.W., 2002. Thinking outside the box: a new perspective on diet breadth and sexual division of labor in the Prearchaic Great Basin. World Archaeology 4 (1), 103–130.
Elston, R.G., Zeanah, D.W., Codding, B.F., 2014. Living outside the box: an updated perspective on diet breadth and sexual division of labor in the Prearchaic Great Basin. Quaternary International 352 (1), 200–211.
Evoy, A., 2019. Neolithic Resource Use and Adaptation in the Eastern Gobi Desert: Functional Analysis of Axes and Adzes. Trent University. Unpublished MA thesis.
Fairservis, W.A., 1993. The Archaeology of the Southern Gobi. Carolina Academic Press, Durham, Mongolia.
Farquhar, J.M., 2022. Human-Environment Interactions: The Role of Foragers in the Development of Mobile Pastoralism in Mongolia's Desert-Steppe. University of Pittsburgh. Unpublished PhD thesis.
Felauer, T., Schlütz, F., Murad, W., Mischke, S., Lehmkuhl, F., 2012. Late Quaternary climate and landscape evolution in arid Central Asia: A multiproxy study of lake archive Bayan Tohomin Nuur, Gobi Desert, southern Mongolia. Journal of Asian Earth Sciences 48, 125–135.
Fernandez-Gimez, M.E., 1999. Sustaining the steppes: a geographical history of pastoral land-use in Mongolia. Geographical Review 89 (3), 315–342.
Fijn, N., 2011. Living together with herds: Human-animal coexistence in Mongolia. Cambridge University Press, Cambridge.
Filipović, D., Meadows, J., Corso, M.D., Kirleis, W., Alsleben, A., Akeret, Ö., Bittmann, F., Bosi, G., Ciută, B., Dreslerová, D., Effenberger, H., Gyulai, F., Heiss, A.G., Hellmund, M., Jahns, S., Jakobitsch, T., Kapcia, M., Klooß, S., Kohler-Schneider, M., Zerl, T., 2020. New AMS C dates track the arrival and spread of broomcorn millet cultivation and agricultural change in prehistoric Europe. Scientific Reports 10 (1), 13698. https://doi.org/10.1038/s41598-020-70495-z.
Fontes, L.M., Straus, L.G., González Morales, M.R., 2016. Lithic raw material conveyance and hunter-gatherer mobility during the Lower Magdalenian in Cantabria, Spain. Quaternary International 412, 66–81.
Frachetti, M.D., Spengler, R.N., Fritz, G.J., Maryashev, A.N., 2010. Earliest direct evidence for broomcorn millet and wheat in the central Eurasian steppe region. Antiquity 84, 993–1010. https://doi.org/10.1017/S0003598X0006703X.
Frieman, C., Janz, L., 2018. A very remote storage box indeed… The perils and rewards of revisiting old collections. Journal of Field Archaeology 43 (3), 1–13.
Gamble, C., 1986. The Mesolithic sandwich: Ecological approaches and the archaeological record of the early post-glacial. In: Zvelebil, M. (Ed.), Hunters in Transition: Mesolithic Societies of Temperate Eurasia and Their Transition to Farming. Cambridge University Press, Cambridge, pp. 33–42.
Gladyshev, S.A., Olsen, J., Tabarev, A.V., Kuzmin, Y.V., 2010. Chronology and periodization of Upper Paleolithic sites in Mongolia. Archaeology, Ethnography & Anthropology of Eurasia 38, 33–40.
Gladyshev, S.A., Olsen, J.W., Tabarev, A.V., Jull, A.J.T., 2012. The Upper Paleolithic of Mongolia: Recent finds and new perspectives. Quaternary International 30, 1–11.
Goodyear, A.C., 1989. A hypothesis for the use of crypto-crystalline raw materials among Paleoindian groups of North America. In: Ellis, C.G., Lothrop, J.C. (Eds.), Eastern Paleoindian Lithic Resource Use. Westview Press, Boulder, CO, pp. 1–10.
Guthrie, R.D., 1984. Mosaics, allelochemics and nutrients: an ecological theory of Late Pleistocene megafaunal extinctions. In: Martin, P.S., Klein, R.G. (Eds.), Quaternary Extinctions. University of Arizona Press, Tucson, pp. 259–298.
Han, F., Peng, F., Guo, J., Wang, H., Gao, X., 2024. Adaptions of Hunter-Gatherers before Younger Dryas in Gobi Desert, Northwest China: Flexible Technological Strategies in Pigeon Mountain Locality 10. Journal of Archaeological Science, Reports 56, 104531. https://doi.org/10.1016/j.jasrep.2024.104531.
Hayden, B., 1981. Research and development in the Stone Age: Technological transitions among hunter-gatherers. Current Anthropology 22 (5), 519–548.
Hayden, B., 1990. Nimrods, piscators, pluckers and planters: the emergence of food production. Journal of Anthropological Archaeology 9, 31–69.
Hedin, S., 1943. History of the expedition in Asia 1927–1935, Part I. Reports from the Scientific Expedition to the North-Western Provinces of China under the Leadership of Dr. Sven Hedin, Publication 23. Statens Etnografiska Museum, Stockholm.
Herzschuh, U., 2006. Palaeo-moisture evolution in monsoonal Central Asia during the last 50,000 years. Quaternary Science Reviews 25, 163–178.
Hill, K., Hawkes, K., Hurtado, M., Kaplan, H., 1984. Seasonal variance in the diet of Ache hunter-gatherers in eastern Paraguay. Human Ecology 12 (2), 101–135.
Hill, W. P. T., N.d. "Inner Mongolia" [map]. 1:200,000. American Museum of Natural History, Central Asiatic Expeditions Route Maps, Sheet Nos. 20, 21, 22, 28, 29.
Hill, W. P. T., Roberts, L. B., N.d. "Inner Mongolia" [map]. 1:200,000. American Museum of Natural History, Central Asiatic Expeditions Route Maps, Sheet Nos. 24, 26.
Hill, W. P. T., Roberts, L. B., Butler, F. B., Robinson, H. G., N.d. "Inner Mongolia" [map]. 1:200,000. American Museum of Natural History, Central Asiatic Expeditions Route Maps, Sheet No. 27.
Holguin, L.R., 2019. The Changing Neolithic Landscape of Ulaan Nuur : Modelling Hydro-Social Dynamics in the Mongolian Gobi Desert. University of Southampton. Unpublished PhD thesis.
Holguín, L.R., Sternberg, T., 2018. A GIS based approach to Holocene hydrology and social connectivity in the Gobi Desert, Mongolia. Archaeological Research in Asia 15, 137–145. https://doi.org/10.1016/j.ara.2016.12.001.
Holliday, T., 1998. The ecological context of trapping among recent hunter-gatherers: Implications for subsistence in terminal Pleistocene Europe. Current Anthropology 39, 711–720.
Honeychurch, W., 2013. The Nomad as State Builder: Historical Theory and Material Evidence from Mongolia. Journal of World Prehistory 26 (4), 283–321. https://doi.org/10.1007/s10963-013-9069-2.

Honeychurch, W., 2015. Inner Asia and the Spatial Politics of Empire: Archaeology, Mobility, and Culture Contact. Springer, New York. https://doi.org/10.1007/978-1-4939-1815-7.
Honeychurch, W., Makarewicz, C.A., 2016. The Archaeology of Pastoral Nomadism. Annual Review of Anthropology 45 (1), 341–359. https://doi.org/10.1146/annurev-anthro-102215-095827.
Honeychurch, W., Rogers, L., Amartuvshin, C., Diimaajav, E., Erdene-Ochir, N.-O., Hall, M.E., Hrivnyak, M., 2021. The earliest herders of East Asia: Examining Afanasievo entry to Central Mongolia. Archaeological Research in Asia 26, 100264-. https://doi.org/10.1016/j.ara.2021.100264.
Jaang, L., 2015. The Landscape of China's Participation in the Bronze Age Eurasian Network. Journal of World Prehistory 28 (3), 179–213. https://doi.org/10.1007/s10963-015-9088-2.
Janz, L., 2012. Chronology of Post-Glacial Settlement in the Gobi Desert and the Neolithization of Arid Mongolia and China. School of Anthropology, University of Arizona. PhD Thesis.
Janz, L., 2016. Fragmented landscapes and economies of abundance: the Broad Spectrum Revolution in arid East Asia. Current Anthropology 57 (5), 537–564.
Janz, L., Feathers, J., Burr, G.S., 2015. Dating surface assemblages using pottery and eggshell: assessing radiocarbon and luminescence techniques in Northeast Asia. Journal of Archaeological Science 57, 119–129.
Janz, L., Odsuren, D., Bukhchuluun, D., 2017. Transitions in palaeoecology and technology, hunter-gatherers and early herders in the Gobi Desert. Journal of World Prehistory 30 (1), 1–81.
Janz, L., Cameron, A., Bukhchuluun, D., Odsuren, D., Dubreuil, L., 2020. Expanding frontier and building the sphere in arid East Asia. Quaternary International 559, 150–164. https://doi.org/10.1016/j.quaint.2020.04.041.
Janz, L., Rosen, A.M., Bukhchuluun, D., Odsuren, D., 2021. Zaraa Uul; an archaeological record of Pleistocene-Holocene palaeoecology in the Gobi Desert. PloS One 16 (4), e0249848–e. https://doi.org/10.1371/journal.pone.0249848.
Jerozolimski, A., Peres, C.A., 2003. Bringing home the biggest bacon: a cross-site analysis of the structure of hunter-kill profiles in neotropical forests. Biological Conservation 111, 415–425.
Jezkova, T., Olah-Hemmings, V., Riddle, B.R., 2011. Niche shifting in response to warming climate after the last glacial maximum: Inference from genetic data and niche assessments in the chisel-toothed kangaroo rat (Dipodomys microps). Global Change Biology 17 (11), 3486–3502.
Jia, W.M., 2007. Transition from foraging to farming in northeast China. BAR International Series 1692. Archaeopress, Oxford.
Jiang, W., Guo, Z., Sun, X., Wu, H., Chu, G., Yuan, B., et al., 2006. Reconstruction of climate and vegetation changes of Lake Bayanchagan (Inner Mongolia): Holocene variability of the East Asian monsoon. Quaternary Research 65, 411–420.
Jones, M.K., Liu, X., 2009. Origins of agriculture in east Asia. Science 324, 730–731.
Keally, C.T., Taniguchi, Y., Kuzmin, Y.V., 2003. Understanding the beginnings of pottery technology in Japan and neighboring East Asia. The Review of Archaeology 24 (2), 3–14.
Keates, S.G., 2007. Microblade technology in Siberia and neighbouring regions: An overview. In: Kuzmin, Y.V., Keates, S.G., Shen, C. (Eds.), Origin and Spread of Microblade Technology in Northern Asia and North America. Archaeology Press, Simon Fraser University, Burnaby, pp. 125–146.
Keddy, P.A., 2000. Wetland ecology: Principles and conservation. Cambridge University Press, Cambridge, U.K.
Kelly, R., 1988. The three sides of a biface. American Antiquity 51, 737–747.
Kelly, R.L., 1995. The foraging spectrum: diversity in hunter-gatherer lifeways. Smithsonian Institution, Washington, DC.
Knutsson, H., Knutsson, K., Molin, F., Zetterlund, P., 2016. From flint to quartz: Organization of lithic technology in relation to raw material availability during the pioneer process of Scandinavia. Quaternary International 424, 32–57.
Kuhn, S.L., 1992. On planning and curated technologies in the Middle Paleolithic. Journal of Anthropological Research 48, 185–214.
Kuhn, S.L., 1994. A formal approach to the design and assembly of mobile toolkits. American Antiquity 59 (3), 426–442.
Kuhn, S.L., 2004. Upper Paleolithic raw material economies at Üçağızlı cave, Turkey. Journal of Anthropological Archaeology 23, 431–448.
Kuhn, S.L., 2013. Roots of the Middle Paleolithic in Eurasia. Current Anthropology 54 (S8), S255–S268.
Kuhn, S.L., Stiner, M.C., 2006. What's a mother to do? The division of labor among Neandertals and modern humans in Eurasia. Current Anthropology 47 (6), 953–980.
Kuhn, S. L., 1995. Chapter 2. Technology, foraging, and land use: a strategic approach. In: Kuhn, S. L., Mousterian Lithic Technology: An Ecological Approach. Princeton University Press, Princeton, New Jersey, pp. 18-37.
Kuzmin, Y.V., 2007. Geoarchaeological aspects of the origin and spread of microblade technology in northern and central Asia. In: Kuzmin, Y.V., Keates, S.G., Shen, C. (Eds.), Origin and Spread of Microblade Technology in Northern Asia and North America. Archaeology Press, Simon Fraser University, Burnaby, pp. 115–124.
Kuzmin, Y.V., Orlova, L.A., 2000. The neolithization of Siberia and the Russian Far East: Radiocarbon evidence. Antiquity 74, 356–364.
Kuzmin, Y.V., Shewkomud, I.Y., 2003. The Palaeolithic-Neolithic transition in the Russian Far East. The Review of Archaeology 24 (2), 37–45.
Laland, K.N., Odling-Smee, J., Feldman, M.W., 2000. Niche constructions, biological evolution, and cultural change. Behavioral and Brain Sciences 23, 131–175.
Lee, M.K., Lee, Y.I., Lim, H.S., Lee, J.I., Yoon, H.I., 2013. Late Pleistocene-Holocene records from Lake Ulaan, southern Mongolia: Implications for East Asian palaeomonsoonal climate changes. Journal of Quaternary Science 28 (4), 370–378.
Li, S., 2008. Early cereal crop remains known archaeologically from within China. In: Huang, S. (Ed.), Asian Civilization, Vol. IV. Sanqin chubanshe, Xi'an, pp. 50–72 in Chinese.
Li, H., Kuman, K., Li, C., 2015. Quantifying the reduction intensity of handaxes with 3D technology: A pilot study on handaxes in the Danjiangkou Reservoir region. Central China. Plos One 10 (9), e0135613.
Liu, X., Zhao, Z., Liu, G., 2015. Xinglonggou, China. In: Barker, G., Goucher, C. (Eds.), A World with Agriculture, 12,000 BCE-500 BCE. The Cambridge World History, Vol. II. Cambridge University Press, Cambridge, pp. 335-352.
Lu, L.D., 1998. The microblade tradition in China: Regional chronologies and significance in the transition to Neolithic. Asian Perspectives 37 (1), 84–112.
Lupo, K.D., Schmitt, D.N., 2002. Upper Paleolithic net-hunting, small prey exploitation, and women's work effort: a view from the ethnographic and ethnoarchaeological record of the Congo Basin. Journal of Archaeological Method and Theory 9, 147–179.
Manninen, M.A., 2016. The effect of raw material properties on flake and flake-tool dimensions: A comparison between quartz and chert. Quaternary International 424, 24–31.
Marean, C.W., 2016. The transition to foraging for dense and predictable resources and its impact on the evolution of modern humans. Philosophical Transactions of the Royal Society B 371 (1698), 20150239.
Maringer, J., 1963. Mongolia before the Mongols. Arctic Anthropology 1 (2), 75–85.
Maringer, J., 1950. Contribution to the Prehistory of Mongolia. Reports from the Scientific Expedition to the North-western Provinces of China under the Leadership of Sven Hedin, Sino-Swedish Expedition Publication, Publication 34. Statens Etnografiska Museum, Stockholm.
Martínez, G., Valero, F.S., Flensborg, G., Carden, N., Stoessel, L., Alcaraz, A.P., Vaz, E.B., 2017. Was there a process of regionalization in northeastern Patagonia during the late Holocene? Journal of Island and Coastal Archaeology 12, 95–114.
Miehe, G., Schlütz, F., Miehe, S., Opgenoorth, L., Cermak, J., Samiya, R., et al., 2007. Mountain forest islands and Holocene environmental changes in Central Asia: A case study from the southern Gobi Altay, Mongolia. Palaeogeography, Palaeoclimatology, Palaeoecology 250, 150–166.
Morales, J.I., 2016. Distribution patterns of stone-tool reduction: Establishing frames of reference to approximate occupational features and formation processes in Palaeolithic societies. Journal of Anthropological Archaeology 41, 231–245.
Morales, J.I., Soto, M., Lorenzo, C., Vergès, J.M., 2015. The evolution and stability of stone tools: The effects of different mobility scenarios in tool reduction and shape features. Journal of Archaeological Science: Reports 3, 295–305.
Morgan, C., Barton, L., Bettinger, R., Chen, F., Dongju, Z., 2011. Glacial cycles and Palaeolithic adaptive variability on China's western Loess Plateau. Antiquity 85 (328), 365–379.
Morgan, C., Jamsranjav, B., Tumurbaatar, T., Barton, L., 2022. Paleolakes, archaeology, and late Quaternary paleoenvironments in northwestern Mongolia. Quaternary Research 109, 1–15. https://doi.org/10.1017/qua.2022.9.
Nash, D.J., Coulson, S., Staurset, S., Ullyott, J.S., Babutsi, M., Smith, M.P., 2016. Going the distance: Mapping mobility in the Kalahari Desert during the Middle Stone Age through multi-site geochemical provenancing of silcrete artefacts. Journal of Human Evolution 96, 113–133.
Nelson, N.C., 1925. Diary of the Central Asiatic Expedition into Mongolia, Saturday, April 18 to Wednesday, September 16. Department of Anthropology Archives, American Museum of Natural History, New York City.
Nelson, N.C., 1926. The dune dwellers of the Gobi. Natural History 26, 246–251.
Nelson, M.C., 1991. The study of technological organization. Archaeological Method and Theory 3, 57–100.
Nicholas, G.P., 1998. Wetlands and hunter-gatherers: A global perspective. Current Anthropology 39 (5), 720–731.
Norin, E., Montell, G. (Eds.), 1969. Sven Hedin Central Asia Atlas. Reports from the Scientific Expedition to the North-western Provinces of China under the Leadership of Sven Hedin, Sino-Swedish Expedition Publication, Publication 47. Statens Etnografiska Museum, Stockholm.
Norin, E., 1978. "The Edsengol-Gurnai Basin" [map]. 1:500,000. In: Norin, E., Montell, G. (Eds.), 1969, Sven Hedin Central Asia Atlas. Reports from the Scientific Expedition to the North-western Provinces of China under the Leadership of Sven Hedin, Sino-Swedish Expedition Publication, Publication 47. Statens Etnografiska Museum, Stockholm, NK 47: VII-XII, d-h.
Odling-Smee, F.J., 1988. Niche constructing phenotypes. In: Plotkin, H.C. (Ed.), The Role of Behavior in Evolution. MIT Press, Cambridge, pp. 73–132.
Odsuren, D., Bukchuluun, D., Janz, L., 2015. Preliminary results of Neolithic research conducted in eastern Mongolia. Studia Archaeologica 35 (6), 72–96.
Odsuren, D., Janz, L., Fox, W., Bukhchuluun, D., 2023. Otson Tsokhio and Zuun Shovkh: the Initial Upper Palaeolithic in Eastern Mongolia. Journal of Paleolithic Archaeology 6 (1), 10. https://doi.org/10.1007/s41982-023-00139-x.
Okladnikov, A.P., 1962. Новое в изучении древнейших культур Монголии (по работаМ 1960 г.) [New in studies on the ancient cultures of Mongolia—work to 1960]. Советская Этнография [sovetskaya Etnografiya] 1, 83–90 in Russian.
Pankova, E.I., 2008. Environmental conditions and soils of natural oases in the Alashan Gobi Desert. Mongolia. Eurasian Soil Science 41 (8), 827–836.
Parry, W.J., Kelly, R.L., 1987. Expedient core technology and sedentism. In: Johnson, J. K., Morrow, C.A. (Eds.), The Organization of Core Technology. Westview Press, Boulder, pp. 285–304.
Peng, L., Brunson, K., Jing, Y., Zhipeng, L., 2017. Zoo archaeological and genetic evidence for the origins of domestic cattle in ancient China. Asian Perspectives 56 (1), 92–120.

Phillipps, R.S., Holdaway, S.J., 2016. Estimating core number in assemblages: Core movement and mobility during the Holocene of the Fayum. Egypt. Journal of Archaeological Method and Theory 23 (2), 520–540.
Phillipps, R.S., McAlistar, A.J., Allen, M.S., 2016. Occupation duration and mobility in New Zealand prehistory: Insights from geochemical and technological analyses of an early Māori stone artefact assemblage. Journal of Anthropological Archaeology 42, 105–121.
Pike-Tay, A., 1993. Hunting in the Upper Perigordian: A matter of strategy or experience? In: Knecht, H., Pike-Tay, A., White, R. (Eds.), Before Lascaux: the Complete Record of the Early Upper Paleolithic. Press, Boca Raton, FL, C.R.C, pp. 85–100.
Pleuger, S., Breitenfeld, B., Zoljargal, A., Nelson, A.R., Honeychurch, W., Amartuvshin, Ch., 2023. What's in a Hearth? Preliminary Findings from the Margal Hunter-Gatherer Habitation in the Eastern Mongolian Gobi Desert. Asian Perspectives 62 (2), 131–158.
Pond, A. W., 1928. Gobi Diary. Micro 1178, Reel 2. Wisconsin Historical Society, Madison.
Pond, A. W., N.d. Unpublished Manuscript summarizing archaeological sites from 1928 Central Asiatic Expedition. 47 pages. Division of Anthropology, American Museum of Natural History, New York. Note: original copy is missing, only remaining copy is contained in W. A. Fairservis' archival material, which is housed at the Peabody Museum, Harvard University.
Pope, M., Roberts, M., 2005. Observations on the relationship between Palaeolithic individuals and artefact scatters at the Middle Pleistocene site of Boxgrove, UK. In Gamble, C., Porr, M., The Hominid Individual in Context : Archaeological Investigations of Lower and Middle Palaeolithic Landscapes, Locales and Artefacts. Routledge, London, pp. 81-97. Doi: 10.4324/9780203007693.
Popov, A.N., Tabarev, A.V., 2008. Neolithic cultures of the Russian Far East: Technological evolution and cultural sequence. TÜBA-AR XI 41–62.
Popov, A.N., Tabarev, A.V., 2017. The preagricultural human occupation of Primorye (Russian Far East). In: Habu, J., Lape, P.V., Olsen, J.W. (Eds.), Handbook of East and Southeast Asian Archaeology. Springer, New York, pp. 379–396.
Qu, T., Bar-Yosef, O., Wang, Y., Wu, X., 2013. The Chinese Upper Paleolithic: Geography, chronology, and techno-typology. Journal of Archaeological Research 21 (1), 1–73.
Ramsey, M.N., Rosen, A.M., 2016. Wedded to wetlands: Exploring late Pleistocene plant-use in the eastern Levant. Quaternary International 396, 5–19.
Reis Cordeiro, J. 2024. Set in Stone: Ground Stone Tools and Wild Plant Processing in the Middle Holocene Gobi Desert. Unpublished MSc thesis. Trent University.
Revedin, A., Longo, L., Mariotti Lippi, M., Marconi, E., Ronchitelli, A., Svoboda, J., et al., 2015. New technologies for plant food processing in the Gravettian. Quaternary International 359, 77–88.
Rhee, S. N., Aikens, C. Melvin., Barnes, G. L., 2021. Archaeology and History of Toraijin: Human, Technological, and Cultural Flow from the Korean Peninsula to the Japanese Archipelago C. 800 BC-AD 600. Archaeopress.
Roberts, L. B., Butler, F. B., Robinson, H. G., N.d. Mongolia Route Maps: Covering Traverse of the Expedition from Kalgan Westward, 1925. American Museum of Natural History, New York.
Rosen, A.M., Hart, T.C., Farquhar, J., Schneider, J.S., Yadmaa, T.s., 2019. Holocene vegetation cycles, land-use, and human adaptations to desertification in the Gobi Desert of Mongolia. Vegetation History and Archaeobotany 28 (3), 295–309. https://doi.org/10.1007/s00334-018-0710-y.
Rosen, A.M., Janz, L., Dashzeveg, B., Odsuren, D., 2022. Holocene desertification, traditional ecological knowledge, and human resilience in the eastern Gobi Desert. Mongolia. Holocene 32 (12), 1462–1476. https://doi.org/10.1177/09596836221121777.
Schiffer, M.B., 1975. An alternative to Morse's Dalton settlement pattern hypothesis. Plains Anthropologist 20 (70), 253–266.
Schiffer, M.B., 1987. Formation Processes of the Archaeological Record. University of Utah Press, Salt Lake City.
Schneider, J. S., Yadmaa, Ts., Farquhar, J. M., Hadel, P., 2021. Entering new territory: the results of a random-sample archaeological inventory at Ikh Nartiin Chuluu Nature Reserve, Dornogovi Aimag, Mongolia. Archaeological Research in Asia 25, 100251-. Doi: 10.1016/j.ara.2020.100251.
Schollmeyer, K.G., Driver, J.C., 2013. Settlement patterns, source-sink dynamics, and artiodactyl hunting in the prehistoric U.S. Southwest. Journal of Archaeological Method and Theory 20, 448–478.
Sériadès, M. L., 2006. Ancient hunter-gatherers, first sedentary farmers and nomad stock herders of Mongolia (8000–3000 BC): New researches at Tamsagbulag (Dornod aimak). In: Le Secrétariat du Congrès (Ed.), Préhistoire de l'Asie et de l'Océanie (Asian and Oceanic prehistory). Actes du XIVe'me Congre's UISPP, Université de Liège, Belgium, 2–8 September 2001, Section 16. BAR International Series 1523. Oxford: Archaeopress, Oxford, pp. 25-39.
Shott, M.J., 1986. Technological organization and settlement mobility: an ethnographic examination. Journal of Anthropological Research 42 (1), 15–51.
Shott, M.J., 1996. An exegesis of the curation concept. Journal of Anthropological Research 52 (3), 259–280.
Stephens, L., Fuller, D., Rick, T., Gauthier, N., Kay, A., Marwick, B., Armstrong, C.G.D., Barton, C.M., Denham, T., Douglass, K., Driver, J., Janz, L., Roberts, P., Rogers, J.D., Thakar, H., Altaweel, M., Johnson, A.L., Sampietro Vattuone, M.M., Aldenderfer, M., Ellis, E., 2019. Archaeological assessment reveals Earth's early transformation through land use. Science 365 (6456), 897–902. https://doi.org/10.1126/science.aax1192.
Stiner, M.C., Munro, N.D., Surovell, T.A., 2000. The tortoise and the hare: small game use, the Broad Spectrum Revolution, and Paleolithic demography. Current Anthropology 41 (1), 39–73.
Surovell, T.A., 2009. Toward a Behavioral Ecology of Lithic Technology: Cases from Paleoindian Archaeology. The University of Arizona Press, Tucson.
Takashi, T., 2012. MIS3 edge-ground axes and the arrival of the first *Homo sapiens* in the Japanese archipelago. Quaternary International 248, 70–78.
Taylor, W., Wilkin, S., Wright, J., Michael, D., Erdene, M., Clark, J., Tuvshinjargal, T., Bayarsaikhan, J., Fitzhugh, W., Boivin, N., 2019. Radiocarbon dating and cultural dynamics across Mongolia's early pastoral transition. PloS One 14 (11), e0224241–e. https://doi.org/10.1371/journal.pone.0224241.
Testart, A., 1982. The significance of food storage among hunter-gatherers: residence patterns, population densities, and social inequalities. Current Anthropology 23 (5), 523–537.
Torrence, R., 1983. Time budgeting and hunter-gatherer technology. In: Bailey, G. (Ed.), Hunter-Gatherer Economy in Prehistory. Cambridge University Press, Cambridge, pp. 11–22.
Torrence, R., 1989. Retooling: towards a behavioral theory of stone tools. In: Torrence, R. (Ed.), Time, Energy and Stone Tools. Cambridge University Press, Cambridge, New Directions in Archaeology, pp. 57–66.
Tseveendorj, D., Khosbayar, P., 1978. Дулааны говийг археологи, геологийн талаар дахин судалсан нь (Archaeological and geoarchaeological reanalysis of the Dulaany Gobi site). Studia Archaeologica 10 (3), 22–47 in Mongolian.
Tsydenova, N.V., Tumen, D., Erdene, M., 2012. Dornod Mongol dakhi "Barga Els" ertniy suuringiyn tukhay [The ancient settlement Barga Els in eastern Mongolia]. In: Tumen, D., Erdene, M., Mijiddorj, M. (Eds.), Ancient Cultures of Mongolia and Baikal Siberia. The Materials of the 3rd International Scientific Conference (Ulaanbaatar, September 05–09, 2012). Ulaanbaatar, pp. 121-133. (in Mongolian).
Tsydenova, N. V., Tumen, D., Erdene, M., Piezonka, H., Khenzikhenova, F. I., Lorenz, S., Zekh, W., Andreeva, D. B., Bazarova, V.B., and Namzalova, O.D., 2015. New Holocene site Togootyn Gol-V in eastern Mongolia. In: Ancient Cultures of Mongolia, Baikalian of Siberia and the Northern Area of China. Proceedings of VI International Conference, Vol. 1. Beijing: Kexue Chubanshe, pp. 88-105.
Tumen, D., Khatanbaatar, D., Erdene, M., 2014. Bronze Age graves in the Delgerkhaan Mountain area of eastern Mongolia. Asian Archaeology 2, 40–49.
Wadley, L., 2010. Were snares and traps used in the Middle Stone Age and does it matter? a review and case study from Sibudu, South Africa. Journal of Human Evolution 58, 179–192.
Wallace, I.J., Shea, J.J., 2006. Mobility patterns and core technologies in the Middle Palaeolithic of the Levant. Journal of Archaeological Science 33, 1293–1309.
Wang, H., Liu, H., Cui, H., Abrahamsen, N., 2001. Terminal Pleistocene/Holocene palaeoenvironmental changes revealed by mineral-magnetism measurements of lake sediments for Dali Nor area, southeastern Inner Mongolia Plateau, China. Palaeogeography, Palaeoclimatology, Palaeoecology 170, 115–132.
Wang, H., Liu, H., Zhu, J., Yin, Y., 2010. Holocene environmental changes as recorded by mineral magnetism of sediments from Anguli-nuur Lake, southeastern Inner Mongolia Plateau, China. Palaeogeography, Palaeoclimatology, Palaeoecology 285, 30–49.
Wilkin, S., Ventresca Miller, A., Taylor, W.T.T., Miller, B.K., Hagan, R.W., Bleasdale, M., Scott, A., Gankhuyg, S., Ramsøe, A., Uliziibayar, S., Trachsel, C., Nanni, P., Grossmann, J., Orlando, L., Horton, M., Stockhammer, P.W., Myagmar, E., Boivin, N., Warinner, C., Hendy, J., 2020. Dairy pastoralism sustained eastern Eurasian steppe populations for 5,000 years. Nature Ecology & Evolution 4 (3), 346–355. https://doi.org/10.1038/s41559-020-1120-y.
Winkler, M.G., Wang, P.K., 1993. The late–Quaternary vegetation and climate change of China. In: Wright Jr., H.E., Kutzbach, J.E., Webb III, T., Ruddiman, W.F., Street-Perrott, F.A., Bartlein, P.J. (Eds.), Global Climates since the Last Glacial Maximum. Minnesota Press, Minneapolis, pp. 221–261.
Wright, J., 2007. Organizational Principles of Khirigsuur Monuments in the Lower Egiin Gol Valley. Mongolia. Journal of Anthropological Archaeology 26 (3), 350–365. https://doi.org/10.1016/j.jaa.2007.04.001.
Wright, J., 2017. The honest labour of stone mounds: monuments of Bronze and Iron Age Mongolia as costly signals. World Archaeology 49 (4), 547–567.
Wright, J., Honeychurch, W., Amartuvshin, Ch. 2023. Continuity and Authority on the Mongolian Steppe: The Egiin Gol Survey 1997–2002. Yale University Publications in Anthropology 98. New Haven: Yale Anthropological Press.
Wright, J., Ganbaatar, G., Honeychurch, W., Byambatseren, B., Rosen, A., 2019. The earliest Bronze Age culture of the south-eastern Gobi Desert. Mongolia. Antiquity 93 (368), 393–411. https://doi.org/10.15184/aqy.2018.174.
Wu, X., Zhang, C., Goldberg, P., Cohen, D., Pan, Y., Arpin, T., Bar-Yosef, O., 2012. Early pottery at 20,000 years ago in Xianrendong Cave. China. Science 336 (6089), 1696–1700.
Yang, Y., Shevchenko, A., Knaust, A., Abuduresule, I., Li, W., Hu, X., Wang, C., Shevchenko, A., 2014. Proteomics evidence for kefir dairy in Early Bronze Age China. Journal of Archaeological Science 45 (1), 178–186. https://doi.org/10.1016/j.jas.2014.02.005.
Zeanah, D.W., 2002. Central place foraging and prehistoric pinyon utilization in the Great Basin. In: Fitzhugh, B., Habu, J. (Eds.), Beyond Foraging and Collecting: Evolutionary Change in Hunter-Gatherer Settlement Systems. Kluwer Academic/Plenum Publishers, New York, pp. 231–256.
Zeder, M.A., 2012. The Broad Spectrum Revolution at 40: Resource diversity, intensification, and an alternative to optimal foraging explanations. Journal of Anthropological Archaeology 31 (3), 241–264.
Zhao, C., Janz, L., Bukhchuluun, D., Odsuren, D., 2021. Neolithic pathways in East Asia: early sedentism on the Mongolian Plateau. Antiquity 95 (379), 45–64. https://doi.org/10.15184/aqy.2020.236.
Zhao, K., Wei, H., Zhao, Z., Zhang, Y., Liu, W., Wang, J., Chen, G., Shen, H., Du, H., Cheng, P., Chen, S., Jia, P.W., Zhou, X., Li, X., 2023. Synchronous change in the intensified millet cultivation and ecological environment from the early to middle

Holocene on the Inner Mongolia Plateau, northern China. Holocene 33 (3), 347–354. https://doi.org/10.1177/09596836221138336.

Zhao, C., Wu, X., Wang, T., Yuan, X., 2004. Early polished stone tools in South China: Evidence of the transition from Palaeolithic to Neolithic. Documenta Praehistorica 31, 131–137.

Zwyns, N., Gladyshev, S.A., Gunchinsuren, B., Bolorbat, T., Flas, D., Tabarev, A., Dogandžic, T., Gillam, J.C., Khatsenovich, A., McPherron, S.H., Odsuren, D., Paine, C., Purevjal, K.E., Stewart, J., 2014. The open-air site of Tolbor-16 (Northern Mongolia): Preliminary results and perspectives. Quaternary International 347, 53–65.

Zwyns, N., Paine, C.H., Tsedendorj, B., Talamo, S., Fitzsimmons, K.E., Gantumur, A., Guunii, L., Davakhuu, O., Flas, D., Dogandžić, T., Doerschner, N., Welker, F., Gillam, J.C., Noyer, J.B., Bakhtiary, R.S., Allshouse, A.F., Smith, K.N., Khatsenovich, A.M., Rybin, E.P., Hublin, J.-J., 2019. The Northern Route for Human dispersal in Central and Northeast Asia: New evidence from the site of Tolbor-16. Mongolia. Scientific Reports 9 (1), 11759–11810. https://doi.org/10.1038/s41598-019-47972-1.