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The Changing Neolithic Landscape of Ulaan Nuur:
Modelling Hydro-Social Dynamics in the Mongolian Gobi Desert

by

Leah Ruth Holguín

Thesis for the degree of Doctor of Philosophy

February 2019
This dissertation examines human-environment interactions and human responses to changing landscapes, particularly Holocene aridification and evolving hydrological networks, in the Ulaan Nuur (Red Lake) palaeohydrological region in Omnogovi province in southern Mongolia. The field survey has identified several new archaeological areas of local Gobi Desert hunter-gatherer activity, dating between the Epipalaeolithic/Mesolithic to the Eneolithic/Early Bronze Age.

These archaeological areas are examined on local household and site scales, where new evidence for the geomorphological and taphonomic processes affecting the anthropogenic landscape are examined in detail. This creates a distribution of artefacts within the context of the geomorphological landscape.

These sites are all centred along key hydrological corridors of Ulaan Nuur, along specific ecosystems, including palaeowetlands, small palaeolakes, and the spring belt. The spatial patterns of these archaeological areas of activity highlight potential routes of both regional and local movement across this area of the Gobi. A model of movement of local Gobi Desert Holocene hunter-gatherers constructed around hydrological corridors is presented.

This creates a reconsideration of the spatial patterns in human movements across varying scales in desert landscapes, where landscape becomes accessible to spatial interpretation, including analysis of geospatial imagery and GIS based analysis, which identifies key hydrological and geomorphological processes. Combined with field survey, key areas of archaeological activity in relation to these environmental processes are identified.
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Academic Thesis: Declaration Of Authorship

I, Leah Ruth Holguín, declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

The Changing Neolithic Landscape of Ulaan Nuur: Modelling Hydro-Social Dynamics in the Mongolian Gobi Desert

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Parts of this work have been published as: Holguín, L.R. and Sternberg, T. 2016. A GIS based approach to Holocene hydrology and social connectivity in the Gobi Desert, Mongolia. Archaeological Research in Asia.
8. All figures were created by me unless otherwise explicitly stated in the text.

Signed:

Date: 11 February 2019
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Chapter 1: Introduction

1.1 Human Responses to Climate Change in Desert Landscapes

The human-water relationship is crucial, particularly in arid and semi-arid landscapes (Fig. 1.1) where concerns such as desertification, land degradation, and drought continue to increase the global scope of drylands and the marginality of landscapes. People living in currently arid and semi-arid landscapes have adapted in the past to increased aridification and environmental uncertainty by creating a deep and complex understanding of their local landscapes, including exploitation of resources adapted to marginal conditions, movement along hydrological corridors (Veth, 1989), management of risk and responses to tipping points (Dearing et al., 2006), and social mechanisms exchanging knowledge of these conditions (Hiscock, 2007).

Fig. 1.1: Distribution of global drylands, including major deserts, all of which experience variable interannual and interseasonal precipitation. Hyper-arid: <0.5 index of aridity, true deserts in the purest sense, like the Sahara; Arid: 0.05-0.20 index of aridity, annual grasslands; Semi-arid: 0.20-0.50 index of aridity, thorny savannahs, annual and perennial grass species; Dry sub-humid: 0.50-0.65 index of aridity, broad-leaved savannah woodland, dense tree canopies, perennial grass species (Thomas, 2011; United Nations, 2011). Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community. Aridity zones modified from the original shapefiles: UNEP-WCMC, 2007; www.unep-wcmc.org.
In the archaeology of movement and interaction in desert landscapes, it becomes necessary to examine the landscape at multi-scalar levels, from individual sites, to the spaces between the sites, as well as the overall broader region (Hritz, 2014). A landscape is defined as a repeating mix of locally diverse ecosystems (Forman, 1995a, 1995b; Forman and Moore, 1992), while a region is a broad coarse-grained geographical area composed of these locally diverse landscapes, while sharing a common macroclimate and an identifiable sphere of human activity, tied together by communication, transportation, and culture (Forman, 1995a, 1995b; Forman and Moore, 1992). A deep knowledge of the landscape allows people to move within it and inhabit areas that are less susceptible to variability during periods of environmental uncertainty and unpredictability. The presence or absence of fresh water is critical to mobility, and water becomes a conduit (Linton, 2008, 2010) that facilitates movement along hydrological corridors (Veth, 1989). These hydrological corridors are central to the ecological and anthropogenic landscape, and thus water may be used as a proxy variable across time (Kvamme and Jochim, 1989) in which to measure human-environment interactions across multi-scalar levels (Hritz, 2014; Linton, 2008, 2010).

Environment and society are closely interrelated, whether they recognise it or not. Currently, water security has become one of the most important global issues, particularly in currently semi-arid and marginal areas where an evolving global climate is substantially increasing the rate of aridification in these regions. For example, South Africa’s Cape Town is rapidly running out of water, with recent reports from several agencies including the local government (City of Cape Town, 2018) suggesting a dire situation reaching its peak in 2018. Similar scenarios are playing out in places like California in the United States (Pathak et al., 2018) and Omnogovi in Mongolia (JSL Consulting, 2017), where the impact of drought and decreasing local water supplies is felt even more acutely by unsustainable water use.

Local governments create strategies to manage these dwindling resources, and their relationship with their environment will determine the sort of strategies implemented. In these instances, archaeology provides an opportunity to help people understand how those in the past dealt with similar situations, particularly the relationship between finite resources and socio-economic development, energy and food production, or population growth and migration. This provides an opportunity to address cultural adaptation to change, including risk management, and the nature of this change, including uncertainty.

Many factors contribute to responses to changing environmental dynamics and no society is the same; however, water is at the heart of these adaptations. The adage that water is life represents a great truth because water is the crucial link between society and environment. Water is a
resource, but it also is a dynamic entity, an agent (Linton, 2008, 2010), and contributes to how people interact with their environment. Land use then becomes an issue of scale (Hritz, 2014), where successful adaptations to environmental degradation on local and household scales are not necessarily representative of adaptations, successful or unsuccessful, occurring at broader continental and global scales. Understanding the fine scale local ecosystems is imperative to understanding broader macro-processes (Forman, 1995a, 1995b; Forman and Moore, 1992). This is most important in marginal landscapes, because with increased aridity, water resources decrease and become unreliable, usually from salinisation or a lowered water table, leading to mass erosion, deflation, and desertification.

In desert landscapes, there is often a disjointed agreement between environmental and archaeological proxies, presenting difficulties in assessing human responses to long-term environmental change. To rectify this, human responses to these extensive environmental shifts must be examined over a vast temporal scale at household levels in terms of generations, and likewise, environmental changes must be evaluated at equally fine resolutions. However, this is often problematic because archaeological sites in these landscapes are distributed over broad spatio-temporal scales, while environmental records are often entirely lacking (Holdaway et al., 2010) or only available at coarse resolutions.

The Gobi Desert during the Early to Late Holocene presents similar issues. Environmental proxies, while abundant for neighbouring areas, are lacking at finer local resolutions, while archaeological proxies are similarly disjointed and come from various spatio-temporal scales. Recent work by Janz (2012) and Janz et al., (2015, 2017) has significantly added to the early archaeological chronology of the region, but there still remains a large data gap.

The Gobi has experienced diverse environmental changes and a lack of a hydrological surface network combined with patchy resources mark it as a region of high risk for Early to Late Holocene hunter-gatherer groups. In other global desert landscapes, evidence of hunter-gatherer land use is found in landscapes concentrating in specific ecosystems, particularly along hydrological corridors. These strategies often correlate with environmental shifts measured over a broad temporal scale, which may also provide indications of cultural shifts. The role of mobility in the minimisation of risk is potentially tied to cycles of aridity, with the responses to these cycles varied (Veth, 1996; Veth et al., 2005: 295).

Discussion of these micro-processes, both environmental and cultural, will contribute to broader issues concerning long-term cultural and environmental shifts including the relationship between
the marginality and patchiness of resources in desert landscapes, and minimisation of risk adopted by different groups, including residential and mobility patterns, as well as the significance of these responses to climate change and increased desertification in areas that were once less marginal than they are currently.

1.2 Research Question

Both fine scale local environmental and archaeological proxies are necessary for an archaeological evaluation of past human-environment responses to climate change. In the Gobi Desert, located within the Central Asian desert belt, this presents a challenge. Like other global desert settings, it represents a region of early human dispersal and a region of corridors (Veth et al., 2005). To understand the human responses to climate change, the social organisation and economy that allowed people to occupy and respond to increased aridity should be examined (Veth et al., 2005). This includes the extent of marginality and local ecosystems that would have hindered or encouraged occupation during arid conditions.

The research presented here examines the region of Ulaan Nuur located in the Gobi Desert of southern Mongolia (Fig. 1.2), where a different sort of landscape prevailed during the Holocene (Lee et al., 2011, 2013; Sternberg and Paillou, 2015) consisting of varied micro landscapes, centred around an extensive palaeohydrological system. This area provides an excellent case study in which to measure human interaction and occupation in a marginal dryland landscape, which today lacks a large identifiable surface water network. Hunter-gatherer groups functioned in this landscape between the Early to Late Holocene (Late Epipalaeolithic/Mesolithic- Late Neolithic/Eneolithic/Early Bronze Age) until herding and pastoralism were adopted as the major subsistence strategy sometime during the Bronze Age, coinciding with broad environmental changes, including aridification. Examination of this area provides a small window into shifting regional micro-dynamics taking place during this period.
The response of local Holocene hunter-gatherer groups in the Ulaan Nuur region to increased aridification, as well as the relationship between society, environment, and water, will be examined in light of new evidence, combined with the local archaeology, and the best available understanding of the local environment and local hydrology, through the following research question:

**What economic and adaptive strategies did local Holocene Gobi Desert groups utilise around the Ulaan Nuur region and what role did climate play in these adaptations, particularly the changing hydrological landscape, as aridification increased?**

To begin to answer this research question, it is first necessary to establish to what extent the environment was actually marginal, including how the past hydrological landscape may have appeared, and how this may be reconciled with the local archaeological data. To do this, three major sub-questions will also be examined:

1. **How, from a geomorphological perspective, may the micro hydrology of the Ulaan Nuur area be examined, including less accessible areas such as pools, wetlands, ephemerals lakes, and springs,**
as well as transitional and boundary areas, and how may this be integrated with archaeological survey?

2. How may the archaeological evidence be linked to the hydrological and geomorphological evidence, through: 1. the influence of the modern landscape morphology and surface artefact distribution, and 2. the relationship between the spatial distribution of artefacts and the contemporary landscape morphology (the past landscape)?

3. After examining the micro hydrological landscapes, how is it possible to create a deeper historical understanding in which to evaluate the long-term hydro-social dynamics occurring in this area, and how may this understanding help to reassess ideas about macro hydrological landscapes occurring across the Gobi Desert?

This research question and sub-questions will be examined within the hydro-social cycle (Linton, 2008, 2010), and two major models of desert occupation (Hiscock and Wallis, 2005; Veth, 1989, 1996). Here, the role of water is evaluated within social contexts, where it influences exploration, mobility, site placement, and resource exploitation.

1.3 Conceptual Frameworks

The hydro-social cycle, the Barriers, Corridors, Refuges Model, and the Desert Transformation Model are the main conceptual frameworks utilised here to examine and evaluate the movement of Holocene hunter-gatherers around the Ulaan Nuur region. The hydro-social cycle evaluates how people interact with water, not only as a resource, but also as a conduit and an agent. Water shapes how people interact with their landscapes, including mobility and site structure. The Barrier, Corridors, Refuges Model and the Desert Transformation Model, building on ecological concepts, seek to understand desert settlement and adaptation to environmental change.

1.3.1 The Hydro-Social Cycle

The hydro-social cycle views water as an active and dynamic participant in society, and has been a subject of much research in geography (Bakker, 2012; Linton, 2008, 2010; Linton and Budds, 2014; Mosse, 2008; Swyngedouw, 2004). LaTour (2005) introduces the concept of hybridity in his Actor Network Theory, where the water network is just one actor linked to many other networks such as culture, nature, and other species, all of which are tied together in a constant, fluctuating flow. Swyngedouw (2004) proposes that water and social power are internally related, differing from Wittfogel’s (1957) assertions that water and social power are externally related. He believes that
in this way, much like LaTour (2005), water and society may be considered hybrids, because they exist, co-evolve, and function within natural and societal realms.

However, it is the concept of the hydro-social cycle expressed by Linton (2008, 2010) which is the most compelling. In Linton’s (2008, 2010) interpretation, water becomes imbued with social values in such a way that water influences social processes, and social processes influence water. Therefore, water becomes an agent of social change and organisation (Linton and Budds, 2014). In this way, an alternative framework is presented in which to examine the entwining depths of socio-natural processes forged between water and society (Linton 2008, 2010; Linton and Budds, 2014). In Linton’s view, water plays the part of three main roles, so that both ontological and epistemological questions may be posed over the nature and identity of water (Linton, 2010; Linton and Budds, 2014).

First, water has the ability to change the organisation of a society as a society attempts to control its flow, so water and society make and remake each other (Linton and Budds, 2014). Second, water and society are connected internally. Different societal relations create different ways of viewing water (Linton and Buds, 2014). Third, the physical properties of water itself have the ability to structure and disrupt society (Linton and Budds, 2014). Mosse (2008) brings clarification to this when he discusses the flexibility of water. Water has the ability to create and destroy boundaries and categories that shape perceptions of landscapes and social classifications (Mosse, 2008).

In these contexts, the hydro-social cycle describes water within modern social frameworks, such as public policy, water management, and infrastructure. However, viewing water in such terms also makes it possible to view it in other anthropological contexts of social organisation (Mosse, 2008), including those societies in the archaeological record, such as hunter-gatherers.

In deserts, the role of water as agent, as defined by Linton (2010), is applicable to both agriculturalist and hunter-gatherer societies. In these contexts, deserts lack not only water, but also consistent resources over space and time (Veth et al., 2005). The absence or presence of water influences movement, communication, and land use. Hunter-gatherer groups may overcome this by utilising micro landscapes, such as springs and ground water sources (Kvamme and Jochim, 1989; Veth et al., 2005). The flows of water, therefore, play a significant role in how...
 hunter-gatherer societies organise and structure their interactions with the landscape, especially in disruption or stabilisation of these social systems (Linton and Budds, 2014).

1.3.2 Models of Desert Occupation and Mobility

Much hunter-gatherer research comes from American research-based ethnographies of desert societies, such as the !Kung of the Kalahari Desert in Africa (Lee, 1969; Lee and Devore, 1976), and the Great Basin Shoshone and Paiute (Steward, 1933, 1938), and are used as a basis for various mobility models. In the general forager model, hunter-gatherers are defined as highly mobile groups who exploit naturally occurring resources in the environment, utilising a base camp (Lee and Devore, 1968). This base camp moves throughout the year in response to seasonally available resources (Lee and Devore, 1968). The society itself is egalitarian, flux in band composition, with low population density, lack of territoriality, and minimal food storage (Lee and Devore, 1968; Kelly, 1995; Smith et al., 2005). Complex hunter-gatherers (Price and Brown, 1985), on the contrary, are essentially sedentary rather than highly mobile, and exhibit more complex organisation and structure, which do not conform to the traditional hunter-gatherer model (Bettinger, 2001). Examples of these groups are found on the northwest coast of North America (Maschner and Fagan, 1991) and along the Scandinavian seafront (Bonsall, 1989). Binford (1980) explains this with the collector forager continuum, where low resource variability favours a foraging strategy (represented by fine-grained evidence), and high variability favours a collecting strategy (represented by coarse-grained evidence). Two similar American approaches include Kelly’s (1995) human behavioural ecology approach and Dyson-Hudson and Smith’s 1978 model of economic defendability, both examining the effects of environment and available resources on land use and mobility.

Smith et al. (2005) criticise ethnographic approaches to desert hunter-gatherer dynamics because the unique dynamics of the desert setting itself are often ignored, particularly the effect of long-term environmental changes in deserts on human adaptations and how this influences the management of risk, which are not readily accessible to modern ethnography. Whittle (1996) though, believes there are some useful analogies that may be taken away from ethnographies of current hunter-gatherers. Among these traits are flexibility and diversification, while the secondary major traits are egalitarian hunting and gathering societies based on an ethic of sharing. However, Whittle (1996) points out that while egalitarianism is an idealised model, in real life people may be motivated by more individualistic tendencies.
Instead, using the case of European postglacial foragers and hunter-gatherers, Whittle (1996, 1997) offers alternative scenarios to those derived from contemporary ethnographic case studies. Residential (circulating) mobility varies over annual and lifetime ranges where short stay camps are produced. Logistical (radiating) mobility also varies annually and over lifetime ranges, involves camps, bases or settlements that are occupied on a seasonal basis with additional, outlying camps, for hunting, gathering, raw material acquisition, and cultivation (Whittle, 1996, 1997). These European postglacial groups differ from contemporary hunter-gatherers because they are not characterised in terms of immediate return economic systems because they show long-term investment strategies, such as fixed fish traps, food storage, and canoes, indicating greater stability in settlement and greater control over resources (Whittle, 1985).

Another major criticism of using current contemporary ethnographic studies applied to the archaeological record comes from Smith et al. (2005), who criticise the use of landscape as a general frame of reference across all hunter-gatherer societies, rather than evaluating landscapes as unique and individual entities. Landscapes exist within a constant state of change along several spatio-temporal scales, creating unique characteristics and dynamics (Darvill, 1997). Societies existing within these landscapes must be examined within the landscape they operate taken as a frame of reference (Darvill, 1997; Smith et al., 2005). In this case then, the desert landscape must be used as a unique frame of reference.

To use the desert landscape as a frame of reference, it is first necessary to examine to what degree the landscape was actually marginal or semi-arid/arid when it was occupied (Smith et al., 2005; Veth et al., 2005). This may be addressed by first building a spatio-temporal environmental framework of an appropriate resolution, through a variety of proxies. The second step is the examination of the types of long-term adaptive and economic strategies that would have allowed people to settle in deserts (Smith et al., 2005). Veth (1987, 1989) and Hiscock and Wallis (2005) argue that current hunting and gathering strategies found in modern contexts are recent, rather than representing adaptations of continuous desert occupation.

First introduced by Veth (1989) as the Refuge, Barriers, and Corridors Model, Hiscock and Wallis (2005) build on this with a biogeographic approach, dubbed the Desert Transformation Model. This model is a two-phase process entailing desert colonisation and adaptation (Veth, 1989; Hiscock and Wallis, 2005; Smith et al., 2005), utilising the biogeographic landscape concepts of refuges, barriers, and corridors (Veth, 1989). Both of these theoretical frameworks offer better
models for desert adaptation and land use over many others because they take into account palaeoenvironmental and geomorphological processes in addition to social processes. In this way, mobility and risk reducing behaviours are considered as a series of economic and social strategies tied to cycles of varying degrees of aridity. Within each cycle, the societal response is different, including fluctuations in long-term economic practices and the development of new behaviours and practices (Veth, 1996).

Major deserts were resource poor without identifiable surface drainage networks, and thus extremely challenging to occupy. They posed significant barriers to human movement and settlement. Refuges, such as uplands and piedmonts, had reliable water resources and were less sensitive to climatic changes and thus easier to settle, even in times of low precipitation. Corridors, depending on climatic conditions, may have been passageways for settlement in some periods and barriers during other periods. This is in strong contrast to Gould's (1971) ethnographic approach of a conservative desert culture, represented by stable and consistent occupation.

The first step in the Desert Transformation Model represents initial colonisation, or an exploratory or pioneer phase (Smith et al., 2005), beginning with foragers employing a broad spectrum approach (see Bettinger, 2001; Bettinger et al., 2015). In the second phase, following changes in local resources due to increased aridification, these foragers modify their behaviours to create new economic adaptations consistent with hunter-gatherers (Hiscock and Wallis, 2005). The exploratory phase occurred when the desert was more resource rich, and by the time aridification increases, local groups already had a deep understanding of their local landscapes. Thus, these economic adaptations would have been made in situ, based on this local environmental knowledge (Hiscock and Wallis, 2005).

In the western Australian Great Sandy Desert, the first initial colonisation occurred during the Pleistocene, with foragers concentrating on abundant hydrological resources, with desert adaptations appearing only at the onset of dry conditions. Groups settled permanently during the Mid Holocene when the availability and predictability of water encouraged exploration and exploitation of desert landscapes, and were most likely important economic bases (Hiscock and Wallis, 2005; Veth, 1989). In the Atacama Desert in South America, similar patterns are observed (Santoro et al., 2005). These case studies demonstrate the flexibility and adaptability of hunter-gatherer groups to variable environmental conditions.
These conceptual frameworks are applicable to evaluations of human-environment relationships in marginal environments across the Central Asian desert belt, including the Gobi Desert. The next section introduces the Central Asian desert belt, its major features, and the theoretical archaeological frameworks relating to water that have been used in evaluating regional desert occupation. This is then followed by an overview of the current environmental conditions present in the Gobi Desert today. These sections are included because they provide a current environmental framework in which to evaluate the archaeological evidence introduced in Chapter 2, as well as to contrast the past environmental context, discussed in Chapter 3.

1.4 The Central Asian Desert Belt

Central Asia encompasses the former Soviet Union Central Asian countries, northern China, and the Mongolian Plateau, which comprises the various Gobi deserts (Fig. 1.3). Additionally, the Mongolian Plateau and northern China also belong to Middle Asia, Inner Asia, East Asia, Northeast Asia, Central Eurasia, and Eurasia. These labels are reflective of broader historical, political, and cultural perceptions (and limitations) of geography and identity (see Akiner, 1998; Cowan, 2007; Di Cosmo, 2002; Frank, 1992; Honeychurch, 2014; Lioubimtseva and Henebry, 2009; Sinor, 1997).
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Fig. 1.3: In the Russian literature, “Middle Asia” consists of the former Soviet States: Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan (Lioubimtseva and Henebry, 2009). “Central Asia” includes these four states plus Kazakhstan, western and northern China, and Mongolia (Cowan, 2007; Lioubimtseva and Henebry, 2009). “Inner Asia” consists of Inner Mongolia, Manchuria, and Xinjiang (all in China), Mongolia, southern Siberia, and eastern Kazakhstan (Honeychurch, 2014). Additionally, there are variations within these categories depending upon the viewpoint of the researcher. Base Map/Inset Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

The term Inner Asia connotes an essentialist cultural phenomena rather than a geographical one. Often the “steppe and the sown dichotomy”¹ (Sinor, 1997) is used to describe the region characterised by four distinct vegetation zones: the steppe, the arctic tundra, the forest or taiga, and the desert. The dryland zone containing the desert belt (Fig. 1.4) represents one of the largest arid regions in the world (Chen et al., 2003; Chen et al., 2010). Additionally, it also represents an arid and semi-arid zone of limited water resource availability, which is extremely sensitive to changes in the hydrological cycle (Chen et al., 2003; Hartmann and Wunnemann, 2009). Over the last century, several lakes have dried or are in the final stages of desiccation, oases have turned to desert, and several important lakes, such as the Aral Sea, have experienced dramatic declines in water levels (Chen et al., 2010; Lioubimtseva and Cole, 2006).

¹ The steppe and the sown dichotomy refers to nomadic pastoralist societies vs. sedentary agricultural societies. The term originates from the 1928 book of the same name by British archaeologist Harold Peake and British geographer Herbert Fleure (Peake and Fleure, 1928).
Fig. 1.4: The Central Asian desert belt, with dryland zones ranging from hyper-arid to dry sub-humid. The Gobi covers most of southern Mongolia and northern China. Hyper-arid: <0.5 index of aridity, true deserts in the purest sense, like the Sahara; Arid: 0.05-0.20 index of aridity, annual grasslands; Semi-arid: 0.20-0.50 index of aridity, thorny savannahs, annual and perennial grass species; Dry sub-humid: 0.50-0.65 index of aridity, broad-leaved savannah woodland, dense tree canopies, perennial grass species (Thomas, 2011; United Nations, 2011). Base Map/Inset Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community. Aridity zones modified from the original shapefiles. Shapefiles: UNEP-WCMC, 2007; www.unep-wcmc.org.

Across Central and Inner Asia, essentialist conceptions of macro hydrological landscapes within this desert belt have received considerable attention for their perceived influence over societal phenomena. In these interpretations, the hydrologic cycle is regarded as an abstract and static entity, a resource burdened with strict parameters, separate from the societies utilising it. Examples of this are found in strict distinctions and categorisations of landscapes and societal phenomenon such as the steppe versus the sown, or desert versus steppe.

In archaeological investigations of these regions, the dominant focus has been on large regional surveys centred on macro hydrology. These include river systems, alluvial fans, inland seas, and lakes. Several scholars have investigated the relationship between societies and hydrology, many of them leading to environmentally deterministic interpretations of the past, which tie the development of complex societies to adverse changes in the environment and hydrological resources.
During his travels across Turkmenistan, American geologist R. Pumpelly first observed connections between oases and settlements (Pumpelly, 1908). V. Gordon Childe (1928) later developed this concept into what became popularly referred to as the Oasis Theory. This idea explains the presence of oases in the middle of the desert, as representing fertile landscapes suitable for human occupation, while surrounding regions with adverse conditions discouraged human activity. These oasis landscapes directly influenced the development of agriculture.

Similar Orientalist narratives have been developed by Wittfogel (1957), who, echoing Marxist dialectics, tied the evolution of despotic states in Central Asia directly to diminishing water resources in a concept called hydraulic despotism. He believed irrigation was the cause behind the emergence of authoritative political states. Likewise, S.P. Tolstov (1948), through his examination of Khorezm in Uzbekistan, connected changes in water supply due to climate change as the major reason behind the decline of settlements.

In the Gobi Desert of Outer Mongolia, geologist Berkey and archaeologist Nelson (1926) noted the presence of sites along eroded valley bottoms, hypothesising this site placement was due to encroaching desertification. Supported by these observations, as well as those made during the Sino-Swedish expedition around Lake Sogho in Inner Mongolia, Maringer (1950, 1963) ties the presence of artefacts around areas of modern springs, pools, and river beds, as evidence of past interconnected oases, and richly vegetated areas around rivers and lakes.

Current research between hydrology and societies in Central Asia recognises societal relationships with hydrology as a more complex process. Particularly excellent examples of this come from recent research in transitional marginal areas of Turkmenistan (Markosky et al., 2017; Rouse and Cerasetti, 2017), where water has been viewed as an active participant in the way societies organise and structure land use. The Gobi Desert, along the southwest of the desert belt (Fig. 1.4) remains relatively unstudied compared to other areas across Central Asia, and a brief overview of this region is next.
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1.5 The Gobi Desert

The Gobi Desert, the largest behind the Saharan and Arabian deserts, is over 1.3 million km² in size (Dennell, 2013; Sternberg et al., 2015; Yu et al., 2004). At one time, to the Western world, it represented the mysterious unknown. Early adventurers like Marco Polo (Fig. 1.5) noted that the desert seemed to be filled with music and strange noises, where malevolent spirits beckon to the tired and weary traveler, leading him to “destruction with extraordinary illusions” (Polo, in translation of Marsden, 1854: 103).

Fig 1.5: On the left, a statue of Marco Polo in Ulaan Baatar, Mongolia. He, like many other Western travellers, have viewed the Gobi Desert as a strange and mysterious entity. Marco Polo wrote that if any traveller lagged behind his companions, the desert spirits would call to them in familiar disguised tones or form, misleading them to danger and death (Polo in translation of Marsden, 1854). On the right is Artist Pietr Dirkx’s interpretation of the Mongolian Death Worm. The Mongolian Death Worm has inspired popular culture references, like J.R.R. Tolkien’s wild were-worms in The Hobbit: Battle of the Five Armies, and the sandworms in Frank Herbert’s Dune series. It has also inspired a terrible 2010 sci-fi B movie of the same name, a sensational 2011 National Geographic Beast Hunter documentary, and Tremors starring young Kevin Bacon in one of his finest roles (D. Wheatley, personal communication). Used with permission under the Creative Commons Attribution-ShareAlike 1.0 Generic (CC BY-SA 1.0) license: https://creativecommons.org/licenses/by-sa/1.0/

The Olgoi Khorkhoi, much like the Almas of the Altai Mountains, is still today rumored to creep through the sand, shooting a deadly acid at all those who are unfortunate to cross its path (Fig.

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2 Говь
3 Олгои Хорхой, Death Worm
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1.5). Roy Chapman Andrews (1926: 103-104) even noted the rumors surrounding its existence during the Central Asiatic Expedition.

Myths and fancy aside, the Gobi is indeed a shifting landscape of life and sand, which inspires the imagination; however, its spatial extent remains poorly defined, due in part to dynamic natural cycles of contraction and expansion, as well as conflicting geopolitically defined perceptions of its boundaries (Cressey, 1960; Sternberg, 2014; Sternberg et al., 2015; Yu et al., 2004).

The Gobi as it is known today is a rocky rain shadow desert where rain clouds from the Indian Ocean are blocked by the Himalayas and the Tibetan Plateau (Dennell, 2013; Yang et al., 2011), with the majority of rain falling between July and August (Natsagdorj et al., 2003). Aridification is an ongoing issue as the desert expands into the grasslands of China and the Mongolian steppe, with over 3600 km² of grassland and steppe overtaken every year (Sternberg et al., 2015). This is due in part to the low precipitation and extreme climate fluctuations where high summer temperatures and low winter temperatures create seasonal dust storms and icy sand storms, with temperatures ranging throughout the year (Natsagdorj et al., 2003; Sternberg et al., 2015). This is caused by several intercontinental climate systems, including monsoons from the southeast and the Siberian-Mongolian High Pressure System from the north, but also influenced by human activities in the present and past, like overgrazing and depletion of water resources (Dennell, 2013; Sternberg et al., 2015).

The Gobi actually is comprised of several desert zones in Mongolia and northern China classified as hyper-arid, arid, and semi-arid (Fig. 1.6). However, some researchers consider these various deserts zones as separate entities, and apply the term Gobi to only a specific area (Dennell, 2013; Sternberg et al., 2015). The term Gobi (Говь) literally translated as Gov or Govi, refers to a flat gravel sand expanse (Sternberg, 2014; Xuan et al., 2004; Yang et al., 2004), and the name itself does not completely reflect the ecosystems the desert encompasses.

4 Алмас, Wild Man, similar to the Yeti or Bigfoot
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Fig. 1.6: There are many deserts in northern China and Mongolia. Often all of the deserts in northern China are lumped into the category of the Gobi Desert (inside the light brown polygon). In reality, there are several with distinct ecosystems, ranging from semi-arid to hyper-arid. Deserts have active dune fields and sandy lands have fields of stabilised dunes (after Yang et al., 2011). The inset map depicts the world position of the Gobi, outlined in brown.

Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Generally, the desert is divided into five distinct ecosystems (Fig. 1.6): the Eastern Gobi, the Alashan Plateau, the Junggar\(^5\) Basin, the Tian Shan Mountain Range, and the Valley of the Gobi Lakes desert steppe. The majority of these are rocky rather than sandy. In contrast to the Sahara, sand dunes make up only 5% (Cressey, 1960; Sternberg et al., 2015). The Gobi also includes several sub deserts in northern China: the Badain Jaran, the Tengger, the Muu Us and the Hobq/Qubqi on the Ordos Plateau, the Gurbantunggut in the Junggar, and the Otindag/Hunshandake (Dennell, 2013; Sternberg et al., 2015). All have their own characteristics, which contribute to the unique and diverse landscape.

\(^5\) also Zhungar, Zunggar, or Dzungar
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Fig. 1.7: The extent of the Gobi Desert (inside the light brown polygon) defined in this dissertation. Deserts have active dune fields and sandy lands have fields of stabilised dunes (after Yang et al., 2011). There are several deserts and sandy lands within the Gobi, all of which have their own unique characteristics and ecosystems. The inset map depicts the world position of the Gobi, outlined in brown. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

In this dissertation, however, the term Gobi will apply to the entire area of dryland in Mongolia and northern China, as defined by Sternberg et al. (2015), but excluding the Taklamakan Desert, the Tarim Basin, the Desert of Lop, and all other areas separated from the main Gobi Desert area by the Kuruktag Uplift (Fig. 1.7). Local regions are unique and classified by ecosystem, but as complementary pieces to the whole.

The Gobi region is connected by alluvial fans, which run along the discontinuous mountain ranges across southern Mongolia, which are evidence that the Gobi Altai was once a centre of neotectonic activity and palaeoclimate change (Hulle et al., 2010; Owen et al., 1997). These palaeoclimate changes are recorded in the Chinese Loess Plateau, where loessic silt has been deposited by Gobi dust storms carried by the Siberian-Mongolian High Pressure System western winds (Feng et al., 1998; Owen et al., 1997) and provides a chronological record of climate change of the region. Many alluvial fans in this region were formed during the Late Pleistocene and Holocene and were strongly influenced by climate, and are still active today, with most being
ephemeral and dependent on rainstorms and snowmelt conditions (Berkey and Nelson, 1926; Hulle et al., 2010; Owen et al., 1997). Some of these active fans end in ephemeral lakes located in the Valley of the Gobi Lakes desert steppe region, including Ulaan Nuur, the easternmost lake of this region, which is the major study area examined here.

1.6 Ulaan Nuur⁶/ Улаан Нуур

This section describes the current environmental conditions occurring in the Ulaan Nuur region, part of the Valley of the Gobi Lakes. This sets the scene for the current geomorphological contexts in which the archaeological data is interpreted and modelled (Chapters 4-9). It also provides an understanding of current conditions in which to compare past environmental conditions, demonstrating how the environment has changed over time (Chapter 3).

The Valley of the Gobi Lakes (Fig. 1.8), situated between the Gobi Altai Mountains and Khangai Mountains, consists of a chain of 20 endhoreic, seasonal, shallow, and saline lakes including Ulaan, Adagiin Tsagaan, Boon Tsagaan, and Orog (Dulma, 1979; Lehmkuhl and Lang, 2001; Owen et al., 1998; Sternberg and Paillou, 2015). This valley lies in the larger Central Asian drainage basin, which is equal in size to both the Pacific and Arctic drainage basins, but without outlets (Dulma, 1979). They are fed by freshwater rivers originating from the Khangai Mountains with no major rivers coming from the Gobi Altai (Davies, 1989; Dulma, 1979; Lehmkuhl and Lang, 2001). These rivers, similar to others across the Central Asian desert belt, are generally wide and shallow, depositing salts and minerals before evaporation.

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⁶ translates in English as Red (Ulaan) Lake (Nuur)
Ulaan Nuur is the easternmost of the Gobi lakes in Omnogovi\(^7\) province (Fig. 1.8). Omnogovi province is one of the three provinces that form the Southern Gobi Region in Mongolia (the others are Dundgovi\(^8\) and Dornogovi\(^9\)). The Ulaan Nuur region represents a transitional semi-arid belt between the more arid southern desert zone and the northern steppe grasslands. This area is composed of several intermediate ecozones including semi-desert, dry steppe, and desert steppe. Summers here are dry and hot while winters are long and cold. Precipitation is low, seasonal, and unpredictable, with the majority falling during the summer months (June, July, August), on average 125mm/year. There are no perennial surface streams, and evaporation rates are high at 150mm/year, with groundwater recharge at 1mm/year (Tuinhof and Buyankhishig, 2010).

During drier years, lack of rain contributes to prolonged droughts and increased desertification. The desiccated Ulaan Nuur area is one of the largest dust storm spots in the Gobi region (Kang et al., 2015; Mijiddorj and Bayasgalan, 2006; Natsagdorj et al., 2003), coinciding with the distribution of the Westerlies and local winds. Extreme cold periods can occur in winter leading to zuds\(^{10}\).

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\(^{7}\) Ṯөмөнгөвь
\(^{8}\) Дундговь
\(^{9}\) Дорноговь
\(^{10}\) зүд, also written as dzud
caused by heavy snows, prolonged ice or snow cover, low forage production from the summer (caused by droughts), and flash floods. These are disastrous to livestock populations.

In recent years, the Gobi lakes have all suffered from water depletion and temporary disappearances. Temperatures in the region have been increasing since the 1980s, while precipitation has been decreasing since the 1990s (Kang et al., 2015). In Omnogovi, the most dramatic lake decreases were observed between 1991 and 2000, with an 80% reduction in lake sizes from 47.1 km² to 5.9 km², with the majority of larger lakes disappearing by 2000. By 2002, all lakes, including Ulaan Nuur had disappeared from the region; however, in 2006, 9 of these lakes were detected again (Kang et al., 2015).

Currently, there is some water in Ulaan Nuur (Fig. 1.9). It is brackish with a salt crust but only animals drink from it. There is no human habitation around the current lake as the soil is extremely saturated and soft due to seasonal fluctuations of the shoreline, which is surrounded by dune fields. Instead, herders build their homes farther away, around areas of natural springs and wells. At one time (pre 1990s), Ulaan Nuur was the largest permanent lake in the Gobi (Dulma, 1979; Kang et al., 2015) and was fed by the Ongi River, originating in the Khangai Mountains.

Fig. 1.9: The southern shore of Ulaan Nuur. The water here is shallow and surrounded by marshy vegetation and sand. Large dune fields border the periphery (in the upper left of the image). There is no human habitation around this lake as herders live more inland, closer to wells. The shore here mimics a micro seashore, and evidence suggests the lake has undergone significant movement and change.

11 ОНГИ
The Ongi (Fig. 1.10) is the only river that flows south into the Gobi and is one of the main sources of drinking water in the region. At one time, the Ongi flowed over 437 km, creating one of the largest riversheds in Mongolia; however, it is now less than 100 km (Renchin et al., 2009; Suzuki, 2013). In more recent years (post 1990s), the river often vanishes before it reaches the lake. This has been attributed to both climate change (leading to acceleration of pasture degradation and desertification) and mining activities upstream in Ovorkhangai\textsuperscript{12} province.

These mining activities disrupted the Ongi’s flow in the 1990s and at the same time Ulaan Nuur, 200 km\textsuperscript{2} in size, dried completely (Beck et al., 2007; Mijiddorj and Bayasgalan, 2006, Renchin et al., 2009; Suzuki, 2013). This spurred the political grassroots movement, the Ongi River Movement, which successfully stop local mining activities (Byambajav, 2015). Unfortunately, the Ongi and Ulaan Nuur have not recovered, demonstrating the importance of rivers as influencing factors in lake dynamics, including area change (Kang et al., 2015).

During the 1970s, the wetlands around Ulaan Nuur as well as the lake itself hosted several types of freshwater fish (e.g. Grayling: *Thymallus brevirostris*, Amur Carp: *Cyprinus carpio haematopterus*) and migratory birds (e.g. ducks, shorebirds, terns like *Chlidonias leucoptera*), but

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\textsuperscript{12}Өвөрхангай
was not important as a platform for breeding waterfowl, possibly because of its ephemeral and fluctuating water levels (Davies, 1989; Dulma, 1979).

Agriculture was practiced during the 1960-1980s to the northeast of the lake. Water was diverted from northern channels for foxtail millet farms situated along the Ongi and close to Mandal Ovoo (Konagaya, 2013). Currently, most agriculture occurs at household levels farther south, close to Bulgan and Dalanzadgad, around wells and springs, in oases like Dal, where crops include vegetables like potatoes, fodder, and cereals (Konagaya, 2013; Tuinhof and Buyankhishig, 2010). Lack of precipitation requires farming through sprinkler and drip practices, developed by government sponsored schemes. Additionally, a small-scale reed cutting industry operated around the lake during the 1980s (Davies, 1989).

1.6.1 Current Environment

The modern Ulaan Nuur is shallow and the lakebed sits exposed. Large reserves of fossil groundwater have been identified and assessed and is treated as a non-renewable, non-rechargeable resource (Tuinhof and Buyankhishig, 2010). Several mining companies hold exploration licenses for the area, but water availability constrains exploitation of mineral deposits (particularly gold and fluorite). The nearest mining operation lies to the east at the Oloon Ovoot gold mine, close to Mandal Ovoo, using Bayan Khoshuu as a groundwater source. The major mining operations lie in the southeast of the province; the largest is Oyu Tolgoi.

Current water supply in this area is provided by groundwater wells. Many of the mechanical wells in the study area are no longer operating; however, hand operated wells (Fig. 1.11) remain in use, as do solar powered mechanical wells. These wells were mostly built during the Socialist period, along with 30,000 others across the desert and desert steppe regions (Tuinhof and Buyankhishig, 2010; Upton, 2009), but today many of these are in disrepair or dry. Larger towns in Omnogovi treat water from well fields for domestic and livestock use, but areas that are more rural use individual water points, such as herders’ wells and deep wells with pipelines (Tuinhof and Buyankhishig, 2010). Some wells provide adequate drinking water, but the majority have high sulphur levels, and heavy salt and mineral content.
Chapter 1: Introduction

Fig. 1.11: A hand operated groundwater well for animals, located in the study area in Omnogovi province. The water is high in salts and heavy minerals and unfit for human consumption.

During wet years, Ulaan Nuur is surrounded by wetlands and marshes, resembling the marshy environments of the other Gobi lakes. Heavy rains occurring during the summer months may also lead to the temporary filling of the lake and overbank flooding. Marshes and saltpans form from the water as it becomes stagnant in the shallow lake basin. Generally, lakes tend to pass through a phase of wetland in their early development, and pass it again when they lose water (Scheffers and Kelletat, 2016).
Fig. 1.12: At the southern shoreline of Ulaan Nuur, clumps of hydrophilic plants grow loosely from the shallow bottom creating a lacustrine marshy environment. Coppice dunes cluster inside the exposed lakebed making it impossible to cross by car. During heavy rains, the area quickly turns to mud.

The wetlands around Ulaan Nuur are both lacustrine (associated with the current small lake, Fig. 1.12) and palustrine (isolated or closed). These differ from a lake environment because of the presence of hydrophilic plants, like sedges, which either cluster around the shoreline, grow loosely from the shallow bottom, or grow in floating islands that have broken from the periphery (Pigati et al., 2014; Scheffers and Kelletat; 2016).

In maps made by the Mongolian government during the 1960s/1970s, Ulaan Nuur had more extensive wetlands, particularly along the former south-east channel. This area is now entirely covered by large dune fields.

There is significant dune and sand coverage in the area, though these dunes are not as large as the Khongoriin Els dune field in southern Omnogovi, and unlike those in popular imagination, as in the Sahara or Badain Jaran. Chief among these are sand sheets and dune fields. Dune fields are low and rolling without slip faces. These dune fields are primarily smaller coppice dunes13 (Fig. 1.13), where sand is trapped by vegetation clumps, and are common across semi-arid areas (Lancaster, 2005).

Sand sheets14 are areas of flat sand surfaces, which develop in conditions where dunes cannot (Lancaster, 2005). This includes higher water tables, episodic flooding, coarse-grained sands, and vegetation limiting sand supply and acting as a stabilising force (Babaev, 1973; Lancaster, 2005; Maman et al., 2013).

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13 also shrub coppice or nebkha
14 also ergs
Linear dunes (Fig. 1.13) are straight and partially vegetated (Tsoar, 2013); while topographically climbing or creeping dunes are easily observed where sand accumulates adjacent to topographic obstacles (Lancaster, 2005). In this area, these are often around yardangs, where dunes occur on the windward side (Lancaster, 2005).

These are accompanied by wind ripples (Fig. 1.13), which indicate local wind dynamics. The ripples in much of the local area indicate the local winds are not consistent with the Westerlies regional wind dynamics. This variation is possibly caused by the corridor created by the Gobi Altai Arts Bogd Khan Mountains and Gurvan Saikhan Mountains, as well from local barriers within the study area itself.

There are many interdune areas, which become wet during the rainy season in which they are flooded by surface water or alternatively where the water table intersects the surface (Lancaster, 2005).

While rarer, at least one major barchan occurs in the Ulaan Nuur area, close to large linear dunes fields. Barchans occur in margins of sand seas and in sand transport corridors linking sand source zones and depositional areas (Fryberger and Gouldie, 1981; Lancaster, 2005).

Fig. 1.13: Some common dune types around the Ulaan Nuur area. Clockwise from upper left: a) A dune field in the south-east channel. Dune fields here are smaller than those found in deserts like the Sahara. b) Ripples indicate a local south-west wind direction. c) Vegetated coppice dunes form when sand becomes trapped by vegetation. d) Linear dunes have wet interdune areas, flooded by recent heavy rains.
1.6.2 Flora & Fauna

The primary vegetation types are desert, desert steppe, semi-desert, and mountain semi-desert. Soil here is consistent with these types with thin A horizons and limited humus and clay content (Tuinhof and Buyankhishig, 2010). Vegetation here acts as stabilisers for active dunes and sandy areas. The primary stabilisers are *Nitraria siberica* and saxaul (*Haloxylon ammodendron*, Fig. 1.14). Saxaul sends its roots as far as 10m below the surface to reach the water table, forming forests and scrubs, common across Central Asia (Gunin et al., 1999; Von Wehrden and Wesche, 2006).

**Fig. 1.14:** Saxaul has a primary growing season between mid-May to mid-August. Saxaul is among the most common vegetation type in the Gobi, and is found abundantly in the study region.

Other vegetation is drought resistant. This includes succulents, shrubs, graminoids, and perennial forbs (Fig. 1.15). These forbs are often suitable for grazing. The largest patches of vegetation, dominated by graminoids, occur along areas with groundwater.
Fig. 1.15: Gobi flora is resistant to droughts. The most common vegetation types include succulents and perennials.

There are diverse species of animals around the Ulaan Nuur area, which contribute to the rich ecosystem (Fig. 1.16). Around the lakebed, wetlands support diverse bird species, and small fish in ephemeral pools. These marshy areas have large populations of insects including mosquitos, flies, and dragonflies.

Fig. 1.16: The Gobi has diverse fauna including butterflies. The caterpillar on the left is feasting on the desert flora, while the lizard on the right enjoys a sunny day.
Brandt’s voles (steppe vole, *Microtus brandti*) are commonly found around archaeological sites. These little voles incessantly chirp and call to each other in high pitched squeaky voices. They dig their burrows (Fig. 1.17) deep into sites along with another common mammal, hedgehogs.

![Image](image1.png)

**Fig. 1.17:** In archaeological sites, burrowing animals such as hedgehogs and Brandt’s voles make their homes deep into the stratigraphy, often disturbing the archaeological material underneath and throwing it to the surface. The holes seen here at the top of the picture at this archaeological site are many in a series of vole burrows.

Around the Ulaan Nuur area, herders predominately keep goats (Fig. 1.18). However, camels and horses are also common (Fig. 1.18). Further south around Bulgan, cows and yaks are also raised. Further north around Mandal Ovoo, sheep, goats, and camels are kept.

![Image](image2.png)

**Fig. 1.18:** In the left image, goats at this archaeological site graze on plants, destroying the topsoil, leading to increased deflation and erosion of the archaeological landscape. On the right, Bactrian camels at Bayanzag drink the water at this small ephemeral lake. Camels like these were once used in treks across the Silk Road and the Gobi Desert. An old caravan trail is not far from here.
Grazing animals, particularly goats, pose a great threat to degradation of archaeological sites here. Erosion and preservation of sites can be directly linked to overgrazing compacted with desertification. This includes shrinking of water resources causing coarsening of topsoil, leading to increased drifting and expansion of mobile sand dunes (which are no longer stabilised by vegetation) and further deflation by seasonal flash flooding. Overgrazed areas are also most likely to be the preferred habitat of Brandt’s voles (Zahler et al., 2004), which contributes to site destruction.

The way these animal and plant populations potentially differed during the Early to Late Holocene are explored further in Chapter 3 and extensively discussed in Chapter 9, which take into account the relevance of environmental change in reconstructing isoscapes.

1.7 Dissertation Structure

This dissertation aims to explore how people operated within the local Ulaan Nuur area through a reinterpretation of regional and local macro hydrological landscapes, including availability and exploitability of resources, and facilitation or hindrance of regional movement through hydrological corridors. In this way, this work lays the foundation for continued research that seeks to better understand Holocene human-environment dynamics in the Gobi Desert.

The structure of the dissertation is formatted into ten chapters. The next chapter, 2, will review the archaeological background of Mongolia and Omnogovi province, the home of Ulaan Nuur. The goal of this chapter is to establish the current archaeological context in which to compare the environmental proxies.

Following the archaeological chronology, Chapter 3 will review the environmental proxies of the Gobi Desert, and compare these to global, regional, and local indicators. A new and up to date synthesis of Holocene Gobi Desert environmental change is presented. Additionally, a new interpretation of the lifecycle of Ulaan Nuur is offered via a new Palaeoenvironmental Age-Depth Model (PADM chart), attempting to better examine the local environmental conditions present during the Holocene. This provides an environmental framework in which to structure the regional archaeology.

Chapter 4 will introduce the major methodologies, satellite imagery and GIS modelling, used for analysis and introduces the core theoretical concepts of geomorphology and hydrology that are
used to interpret this data, including the concept of hydrological corridors. Chapter 5 presents the results of the satellite imagery, including the identification of the spring belt corridor and river channel corridors. Chapter 6 presents the results of the GIS based hydrology model and introduces a hypothesised model of how the hydrological network may have appeared when it was active. Additionally, identification of the lakeshore corridor and the spatio-temporal evolution of Ulaan Nuur is examined. Based on this, a hypothesis for the Holocene coastline is presented.

Chapter 7 details the formation of the field survey strategy. This integrates the results of Chapters 5 and 6 and takes into account theoretical concepts of survey, particularly in desert landscapes. Chapter 8 presents the major archaeological findings of the field survey. This includes detailed geomorphological and hydrological contexts for each identified archaeological area of activity.

Chapter 9 discusses the results of Chapter 8 and implications of these findings. A model of movement along hydrological corridors of Gobi Desert hunter-gatherers is presented. Chapter 10, the concluding chapter, reviews the major points of the dissertation and how well the research question and sub-questions have been addressed throughout, particularly within the chosen theoretical frameworks. Suggestions for future research and concluding thoughts end the chapter.

This chapter has introduced the major themes, the research question and sub-questions, the theoretical frameworks, and the Ulaan Nuur study area, including an introduction to the current environmental conditions. This provides a current environmental context in which to place the known archaeological proxies, and demonstrates how local sites are situated within the current landscape. The known archaeological proxies are reviewed next.
Chapter 2: Archaeological Background

2.1 Introduction

This chapter introduces the known archaeological proxies of the Gobi Desert and reviews the history of archaeological research in the region. This will set the scene for the results of archaeological fieldwork described in Chapter 8, and allows for the placement of the regional archaeology within the environmental context established in Chapter 3.

To understand how archaeology as a discipline developed in Mongolia, it is necessary to explore the key events that have shaped Mongolia as a political entity. This chapter will first explore the development of archaeology in Mongolia in the early 20th century, moving on to Mongolia’s period as a Soviet satellite, where the theoretical platforms and key events also occurring in Russia is also explored, because to some extent, these ideas are also reflected in the history of Mongolian research. Following this, is a discussion about the post-Soviet period and the current state of archaeology in Mongolia.

Next, the development of exploration in the Gobi Desert will be reviewed, beginning with early exploration of the 20th century to present exploration in the region. Finally, the last section will detail a brief chronological survey discussing major sites and events, beginning with the Mesolithic and ending with the Bronze Age.

2.2 Archaeological Investigation in Mongolia

Before it became an independent republic in 1921, explorers and adventurers alike flocked to Mongolia in the early 20th century to discover new territories, carrying on in the same spirit as the monk William of Rubruck, who visited the Mongol court of Kharkhorin in 1254 (Rubruck, 1990). Most notable among these early explorers were Russian Petr Kuzmich Kozlov and his discovery of Khara Khot in the Inner Mongolian Gobi and his Noyon Uul excavations (Kozloff, 1910; Kozlov, 1925); Russian V.V. Radloff and his expedition through the Orkhon and Tuul River Valleys (Radloff, 1899); American Roy Chapman Andrews and the Central Asiatic Expedition (Andrews, 1926); and Swede Sven Hedin and the Sino-Swedish expedition through Inner Mongolia (Hedin, 1933). These expeditions were some of the first of serious scientific investigation in Mongolia, and their findings have contributed greatly to knowledge of the archaeological record.
After Mongolia officially became a satellite state of the Soviet Union in 1924, archaeological scholarship was conducted in conjunction with Soviet Bloc countries. Most notable among these were Russia, the Czech Republic, and Hungary (Amartuvshin and Batzorig, 2014; Bazarsad, 2012; Gunchinsuren, 2017). Mongolia was subsequently closed to Western archaeologists, leaving large gaps in Western knowledge of the archaeological record, since findings and reports by Soviet scholars were not published outside of the Soviet Union (Frank, 1992).

The partnership between Mongolia and the Soviet Union influenced the way in which the archaeological record was interpreted, mainly through a Marxist cultural historical theoretical approach. In this approach, history, archaeology, and ethnography reconstruct stages of social structure by using material remains as evidence of social change (Dolitsky et al., 1985; Klejn, 2012; Kradin, 2011). The changes and developments in the social sciences of Mongolia reflected those changes occurring simultaneously in Russia, also corresponding to the political climate, beginning with this theoretical approach.

This approach views the development of society in stages. The stages in which past societies have undergone are representative of an evolving social process. Past societies can be grouped into specific cultural typologies based on their material culture, placing the source of development as dependent on social production (Klejn, 2012; Kradin, 2011).

Archaeology was considered an extension of history, viewing a cultural group as a specific stage of social development in the population (Klejn, 2012). This meant that research was focused on specific sites and areas seen as historically important. Kradin (2011) says questions of rank and inequality in the nomadic societies of the Eurasian steppes were especially of interest since there were large discrepancies between sizes and types of graves and grave goods, which allowed studies of social structure through archaeological data.

An analogy in the West can be made for comparison with this archaeological school of thought occurring in the Soviet Union with the archaeological theory advanced by V. Gordon Childe, who also promoted a cultural historical approach similar to Soviet archaeologists. However, it must be mentioned that not all archaeologists in the Soviet Union agreed with this political ideology and cultural historical approach being forced upon a scientific framework. Several notable archaeologists publicly dissented and were subsequently punished by the government (Dolitsky et al., 1985; Klejn, 2012).

The early collaborations between Soviet and Mongolian archaeologists contributed greatly to knowledge of the archaeological record. Frachetti (2006) notes that in the former Soviet satellite
of Kazakhstan, archaeology in the 1930s was conducted by large-scale survey expeditions. This trend is similar in Mongolia, as several famous Russian archaeologists became front-runners in Mongolian archaeological research, including V.V. Volkov (1967, 1981) and his studies of deer stones. However, Formozov (1995) criticises Volkov’s analyses as being rife with party phrases though his typologies of deer stones remain the most cited and in use today.

Sergei Rudenko (1970) and his studies of the Pazyryk and Altai tombs, and G.I. Borovka (1928) and his studies of Scythian art in the Altai, were both influential and prominent archaeologists in Central Asian and Mongolian studies. Both Rudenko and Borovka made connections between geography and archaeological features, and both advocated the use of a natural science methodology, such as radiocarbon dating, to be applied to archaeological methodology. This went against Soviet ideology at the time, and consequently Rudenko was arrested and exiled, while Borovka, on return from exile, was arrested and executed (Formozov, 1995; Klejn et al., 2012).

During the 1940s and 1950s, professional Mongolian archaeologists were trained in Moscow and Leningrad, supported by an agreement between the Institute of Scripture in Mongolia and the Science Academy of the Soviet Union, and began to conduct archaeological surveys on their own (Amartuvshin and Batzorig, 2014; Bessac, 1964; Gladyshev et al., 2010; Gunchinsuren, 2017; Gunchinsuren et al., 2011). Kh. Perlee, Ts. Dorjsuren, and N. Ser-Odjav were the most prominent Mongolian archaeologists conducting full-scale surveys during this period and are today considered the founding figures of Mongolian archaeology.

The period of the 1960s, dubbed “The Thaw”, showed a slight reduction of state control over science. During this period, the cultural historical approach underwent several transformations and modifications in response to the political climate (Klejn et al., 2012). In Kazakhstan, expeditions continued throughout the 1960s, but transitioned to a period of synthesis and material studies, a trend seen across the U.S.S.R. (Dolukhanov, 1993; Frachetti, 2006).

By the 1970s and 1980s, Soviet archaeology developed a distinct theoretical approach (Dolitsky, 1985; Frachetti, 2006; Kradin, 2011). This new theoretical platform marked a decidedly different approach to archaeological interpretation from its strict Marxist predecessor. A growing focus on the reconstruction of social structures with descriptive approaches to study inequalities using methods such as mathematics, statistics, dendrochronology, and pollen analysis, coincided with a period in Soviet history called perestroika. This period witnessed the overall restructuring of Soviet ideology on both political and economic levels, and allowed for more contact and exchange
of ideas between Western and Soviet archaeologists (Chard, 1969; Klejn et al., 2012; Kradin, 2011). In 1980s Mongolia, these changes coincided with the reforms of party and state leader J. Batmonkh who followed those begun by Gorbachev, and consequently, the nature of historical studies was more widely and freely debated (Kaplonski, 2004).

After M.P. Griaznov (1980) excavated the Iron Age site of Arzhan I in Siberia, and discovered a rich array of artefacts, archaeologists explored Mongolian Bronze Age and early Iron Age sites attempting to find a duplicate of treasures like those found in Arzhan I. Most sites yielded little to no artefacts in addition to poorly preserved remains, and archaeologists quickly lost interest (Fitzhugh 2009a; Rolle 1989). Other monuments such as Bronze Age deer stones produced interest for their decorations only, and have been studied by Russian archaeologists for over 100 years (Fitzhugh 2009a).

After the collapse of the Soviet Union in 1991, collaboration between Mongolia and the West has steadily risen. Earlier publications about sites and findings were published in Russian and Mongolian, making it difficult to access outside of these two countries. In recent years, new collaborations between Mongolian, Western, and Russian archaeologists are making efforts to fully explore and document the country’s history, allowing findings to become internationally accessible.

2.3 Exploration in the Gobi Desert

Major archaeological exploration in the Mongolian Gobi took place in the early 20th century, most notably with the Roy Chapman Andrew’s (1926) led Central Asiatic Expeditions to Outer Mongolia, sponsored by the American Natural History Museum between 1922 and 1930. Knowledge in the West about Gobi archaeology comes primarily from these expeditions, which identified over 180 sites in the Gobi and other parts of Mongolia, and sent over 50,000 artefacts, mostly Palaeolithic flint tools, back to the United States (Maringer, 1963).

After the Central Asiatic Expedition, several joint Soviet-Mongolian expeditions led by Okladnikov (1951, 1978) and Gabori and Merbs (1963) in the 1940s through the 1960s explored the Gobi region, which primarily reinvestigated the sites found by the Central Asiatic Expeditions. Several Palaeolithic sites were discovered in the 1950s (Gladyshev et al., 2010). In the 1970s, D. Navaan discovered evidence of metal processing in Omnogovi province (Ser-Odjav, 1977; Gunchinsuren et al., 2011).
Expeditions including the Joint Mongolian-Russian-American Archaeological Expedition (JMRAAE; Olsen, 1998), the Joint Mongolian-Italian Expedition (Marcolongo, 2004, 2005, 2007), and the Joint Russian-Mongolian Expedition (Kovalev and Erdenebaatar, 2009) have all carried out small-scale surface surveys in Omnogovi province. These expeditions have located sites from many archaeological periods.

JMRAAE has investigated several regions around the Gobi and Gobi Altai regions, locating many areas of activity (Olsen, 1998, 2000). Though their primary focus is the Palaeolithic, they have also located several Mesolithic and Neolithic period sites. In 1997 and 1998, Holcomb (2001) surveyed Bayankhongor and southern Gobi Altai provinces using an enhanced image map from a mosaic of RADAR-SAT imagery coupled with a ScanSAR Narrow Scene of 50 m resolution, attempting to locate Palaeolithic surface sites by identifying areas where human activity was most likely to have occurred. After locating strandlines associated with Boon Tsagaan Nuur and Orog Nuur in the Valley of the Gobi Lakes region (Holcomb 2001; Komatsu et al., 2001), a low level survey was conducted, identifying several sites from Palaeolithic to historic periods. Major discoveries and research of the expedition include Flint Valley2 and the cave sites of Chikhen and Tsagaan (Derevianko et al., 2000, 2003, 2008).

The creation of the Oyu Tolgoi mine in southern Omnogovi province has led to archaeological exploration around the mining site and within an 80 km radius. These surveys have uncovered several archaeological finds, ranging from Palaeolithic to Bronze Age periods (Gunchinsuren et al., 2011). Over 149 sites have been documented including two potential Neolithic settlements; however, these remain unexcavated (Gunchinsuren et al., 2011).

Additionally documentation for over 600 sites in Omnogovi province alone was identified in historical records. However, Gunchinsuren et al. (2011) note there is no central database and these sites are unevenly distributed in the eastern area of the province as a result of selected surveys conducted due to planned mining activities, and therefore, do not represent the true extent of site distribution in Omnogovi. Gunchinsuren et al. (2011) hypothesise, based on meetings with local residents, more sites are located in the poorly explored western region of Omnogovi and the number documented during the Oyu Tolgoi cultural management archaeological survey (500) in the east is actually less than 1% of the province’s total number of sites. There also many more known sites around Omnogovi and along the Ongi River that have never been published (B. Gunchinsuren, Ts. Odbaatar, personal communication).

2 In literature, also referred to by the Mongolian name, Tsakhiuriin Khondii (Цахиуртын Хондий)
Chapter 2: Archaeological Background

Expeditions in the early 20th century also focused on the Gobi in Inner Mongolia and northern China. Maringer (1963) mentions several of these surveys including the Sino-Swedish Expedition led by explorer Sven Hedin and archaeologist Folke Bergman (Hedin, 1933), which discovered Palaeolithic tools and lithic materials from over 61 sites in the Alashan Desert of Inner Mongolia, and exported several of these artefacts to Stockholm. Janz (2012) and Janz et al. (2015) have extensively studied these collections.

Other notable surveys in Inner Mongolia revealing Neolithic and Palaeolithic sites were conducted by Namio Egammi and Selichi Mizuno in 1930 of the eastern border area (Mizuno, 1935; Maringer, 1963; Minns, 1935). A survey of the sand dune region of Khunsha organised by the Koai Institute of Japan in 1940 (in Maringer, 1963), and the Haardt-Citroen Expedition of Inner Mongolia by P. Teilhard de Chardin (Maringer, 1963; Teilhard de Chardin and Young, 1933) also revealed several Palaeolithic through Neolithic period sites.

The overwhelming trend in the Gobi continuing from the early 20th century to the present is a focus on large-scale survey, dependent on surface finds, and an absence of excavation. This is due, in part, to the difficult terrain, large areas of land, and high costs required for surveys and excavation, including bringing all supplies, like gas and water, with expeditions. However, it is also problematic, as there is a lack of stratigraphy and poor chronological controls, especially since the majority of artefacts found together on the surface are from several archaeological periods. Additionally, many field reports remain unpublished, and form a large body of grey data (B. Gunchinsuren, personal communication), making it difficult to catalogue the true extent of known Gobi sites.

It is also important to note that most Gobi sites have been surface finds, with the notable exception of Bayanzag, which was originally detected on the surface of deflated sand dunes and subsequently excavated (Berkey and Nelson, 1926; Nelson, 1926). Bayanzag is arguably one of the most important Gobi sites, and is discussed in more detail in Section 2.4.2.2, and was investigated during the field survey (Chapter 8).

Records from the Central Asiatic Expedition showed the team followed broad survey tracts along the landscape rather than a complete systematic survey; this was most likely due to the broader scientific focus of the expedition, as well as constraints on time and accessibility.

Berkey and Nelson (1926) observe specific spatial patterns between topography and artefact placement. They note that at the majority of sites, artefacts are mixed; the most prolific sites represented by several horizons, exposed to repeated erosion. Where there are irregularities on
the surface, there are most likely to be surface artefacts, especially in areas where there is repeated mountain uplift and local deposition. Artefacts are commonly found in eroded and deflated areas substantially influenced through fluvial and aeolian processes. Every artefact located by the Central Asiatic Expedition was either in the open or in deposits of regular sedimentary formation, especially because the region lacks caves and shelters (Berkey and Nelson, 1926).

The Gobi Desert represents not only a geographic, but also a cultural and technological barrier between northern people who eventually adopted a nomadic pastoralist subsistence strategy, and those further south who adopted a sedentary agriculturalist subsistence strategy. Pottery found in the Gobi has stylistic features of both Siberia and Northwest China, fuelling hypotheses that the Gobi was an area of migration rather than an area of prolonged occupation, strongly influenced by broad archaeological changes occurring in surrounding regions, instead of those unique changes occurring locally (Chard, 1974). Further exploration of this area could reveal important new datasets to answer questions of migration and interregional movement.

The Gobi itself presents considerable challenges to those who wish to explore it. Dunes often cover archaeological sites, and artefacts that are present one day in the dunes, are gone the next. Ground visibility presents challenges, as it is extremely difficult to see artefacts on the surface. Adding to the difficulty, the Gobi is a huge area, making it almost impossible to survey everything in a systematic fashion, which would take years and require substantial funding.

As a result, much of the area of the Gobi remains unexplored or only superficially explored, opening the potential for extensive investigation to be conducted, especially with the advances in technology as well as regional infrastructure that has improved accessibility to the region.

2.4 Archaeological Chronology

The Gobi has been a place of prolonged human occupation for thousands of years and possibly a centre of dispersal, and people during this time were the explorers and the colonisers of the desert. Thus, the past environment of the Gobi represented very different environmental conditions and land use patterns. Here, the major periods of interest range between the Late Epipalaeolithic/Mesolithic and the Eneolithic/Early Bronze Age (Fig 2.1).

It is important to note, during several surface surveys, Palaeolithic artefacts are often found in association with artefacts from later periods (Fig. 2.1). In North Asia, the Upper Palaeolithic is characterised by a small blade component produced through a burin-core technology (Zwyns et
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al., 2014b). The Mongolian Upper Palaeolithic is mainly characterised by stone tool and microlith assemblages (Zwyns et al., 2014b) and there are many sites across Mongolia that have been found dating to this period. Often, field reports fail to identify the difference between artefacts from the Palaeolithic, or artefacts from later periods, which are simply crude and unfinished, and therefore placed into the Palaeolithic typology for lack of better identification. Berkey and Nelson (1926) and Bergman (in Bettinger et al., 1994) both discuss the perils of this classification, which make chronological controls on sites difficult to impose, especially with the lack of excavation and direct observations of stratigraphy.

In Inner Mongolia, the Sino-Swedish Expedition discovered Palaeolithic tools in the Alashan region of the Gobi and noted that wherever sites were found, lithic materials were especially abundant; however, found it difficult to distinguish between Palaeolithic period implements and those from the Neolithic (Maringer, 1963). Maringer says most of the finds were Neolithic and the rest Mesolithic (Fig. 2.1), and any resemblances to Palaeolithic technology was a result of these previous technological traditions continuing into the Neolithic (Bettinger et al., 1994).

Janz (2012) offers an alternative chronological framework in which to reference Gobi sites to avoid confusion between fuzzy notions of chronological concepts. Janz (2012) notes that in the Gobi, the term Neolithic is often used to distinguish between those sites with pottery, and those without. To avoid confusion, Mesolithic should be referred to as Epipalaeolithic, followed by the Neolithic, and finally the Eneolithic (synonymous with the Late Neolithic/Early Bronze Age). In the Gobi, she introduces a local chronological terminology, where Epipalaeolithic corresponds to Oasis 1, Neolithic to Oasis 2, and Eneolithic to Oasis 3. The current model to the end of the Neolithic has a form of hunting as the major subsistence strategy, which is gradually replaced sometime during the Bronze Age by 3.4 ka cal B.P. with pastoralism, the major subsistence strategy shift (Fig. 2.1), which also corresponds to a tipping point for economic and social change.
Fig. 2.1: A more precise view of the archaeological chronology used and referenced here. Sources of Dates:
Derevyanko & Dorj, 1992; Gladyshev et al., 2010; Honeychurch, 2010; Houle 2010; Janz 2012; Janz et al., 2015; Zwyns et al., 2014a. All dates have been converted to cal. B.P.
The plain located between Ulaan Nuur and the local Gobi Altai Mountains (the Arts Bogd), is referred to by the Central Asiatic Expedition as the Ulaan Nuur-Arts Bogd plain (Fairservis, 1993; Fig. 2.2). This region is rich in raw resources, particularly red jasper and chalcedony. The Central Asiatic Expedition found many archaeological areas of activity ranging between the Palaeolithic and more recent historical periods. Nelson also noted problems distinguishing between Palaeolithic tools and those from later periods, which he says may have simply been crude and unfinished, resembling Palaeolithic technology (Maringer, 1963; Nelson, 1926).

Fig. 2.2: The Ulaan Nuur-Arts Bogd plain. Sites within this area are especially known for red jasper assemblages. The inset map shows the location of the Ulaan Nuur-Arts Bogd plain (in red) in Southern Mongolia. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: SRTM 90m resolution DEM. Jarvis et al. (2008); http://srtm.csi.cgiar.org.

The Ulaan Nuur assemblage, produced with red jasper, is recorded as being more advanced compared to other sites of the same period (Fairservis 1993; Zwyns et al, 2014; Gabori and Merbs, 1963). The Central Asiatic Expedition identified this site by a creek bank, 59 kilometres northwest of Bayanzag (Fairservis, 1993). Artefacts were mixed from several periods, but included rough cores, polyhedral cores, end scrapers, side scrapers, choppers, flakes, and projectiles points (Berkey and Nelson, 1926; Fairservis, 1993).
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However, Nelson (Berkey and Nelson, 1926: 12) writes identification of artefacts in this area is difficult because of the amount of readily available raw materials, which makes distinguishing between crude but finished implements from an early period, and unfinished implements from a later period impossible. Bergman records similar data in the Alashan Plateau in Inner Mongolia and believes some objects might be earlier than the Neolithic (in Bettinger et al., 1994; Gabori and Merbs, 1963), but with the lack of stratigraphic observations, he could not distinguish between implements from early and later periods.

More recent expeditions have located other less well known areas of high archaeological importance within the Ulaan Nuur-Arts Bogd plain. Eregiin Kholooi, a Neolithic habitation site close to Flint Valley in the west, was first discovered in 1972 and was revisited during a general reconnaissance survey by JMRAEE as part of the Oyu Tolgoi gold mine project (Gunchinsuren, 2017; Gunchinsuren et al., 2011; Janz et al., 2017). Flint Valley, on the border of Omnogovi and Ovorkhangai shows use from the Palaeolithic through the Neolithic (Derevianko et al., 1996). Another important but lesser known site, Khoyor Khairkhan was located by a Russian and Mongolian expedition in 1971 led by Okladnikov and Dorj (Okladnikov, 1976, 1978) and revisited by Odsuren (2014). This site will be discussed in more detail in the field survey results in Chapter 8.

2.4.1 Late Epipalaeolithic/Mesolithic (13.5-8.0 ka cal B.P.)

Elements of a Mesolithic technological lithic industry are mainly characterised by an advanced microblade technology, cores, scrapers, and flake tools, occurring without the presence of pottery (Derevianko and Dorj, 1992; Fairservis, 1993; Janz et al., 2015). Additionally, the Gobi core continues to develop during the Mesolithic and is found among Early Neolithic assemblages (Derevianko and Dorj, 1992).
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Fig. 2.3: Mesolithic sites discussed in Section 2.4.1 only (does not represent the total number of Mesolithic sites distributed across Mongolia). For an extensive overview of sites from this period, refer to Janz et al., 2017. Base Map: SRTM 90m resolution DEM. Jarvis et al. (2008); http://srtm.csi.cgiar.org.

The Mesolithic phase at Kere-Uula (Kheree Mountain), between the Khereul and Khalkhin rivers (Fig. 2.3), exhibits a departure from previous technologies through manufactured early blade techniques (Derevyanko, 1994). Identical artefacts were also found at the Rashaan Khad and Moiltiin Am settlements (Fig. 2.3) in northern Mongolia (Derevyanko and Dorj, 1992; Gunchinsuren, 2013). Nelson, at Bayanzag (Fig. 2.3), reports the same technology, where he discovered an undisturbed stratigraphy of this context under a Neolithic occupation, centred around hearth clusters (Derevyanko and Dorj, 1992; Chard, 1974; Fairservis, 1993). Gabori and Merbs (1963) supports this idea of a purely Mesolithic culture at Bayanzag, although Chard (1974) reports that Soviet expeditions visited the site several times and found pottery to occur on all levels, where there is no evidence of an aceramic Mesolithic occupation.

Near Mandal Gobi (Fig. 2.3), Gabori and Merbs (1963) describes the area as predominantly Mesolithic, although Palaeolithic sites have been located, and are often found alongside Mesolithic microlith tools (Gabori and Merbs, 1963). He further compares the similarities between tools found in the Gobi Altai to those in the Gobi, suggesting Mesolithic people at Bayanzag originated before those in the Gobi Altai. Nelson and Berkey (1926) emphasise that
because of erosional processes, the surface stratigraphy is an unreliable indicator of distinct cultural horizons because artefacts from several periods are mixed together.

Derevianko et al. (2003, 2008) report dates from Mesolithic assemblages at Chikhen Agui (Fig. 2.3) to be between 11,500-7000 B.C (13500-9000 cal. B.P.), obtained from charcoal and rodent burrow fill. The cave was a centre of activity for Early Holocene people who used it as a long-term shelter, beginning in the Pleistocene. Other artefacts include remains of several animal bones, hearths, ostrich eggshells, blades, lithic tools, handles of composite tools, and the potential remains of an ostrich eggshell bowl filled with grass seeds, adjacent to a wooden pole (Derevianko et al., 2008). Geometric lithics are unlike those found in surrounding regions, especially those at Bayanzag, but similar to those found to the northwest and Inner Mongolia (Derevianko et al., 2008). Derevianko et al. (2008) hypothesise the cave was used as a hunting shelter rather than as a site of prolonged habitation, arguing that evidence from the cave indicates groups in the area were foragers. They further suggest that because of the variety of flora and fauna discovered in each layer, in addition to blades and tools, which bear resemblance to blades and tools found in other distant areas, the Palaeolithic to Neolithic transition occurred at a time of significant environmental and climatic change. They hypothesise that this forced people to change the implementation of hunting and gathering strategies, travelling long distances to find available resources (Derevianko et al., 2008).

Amartuvshin and Batzorig (2014) cite archery as a major technological development evidenced through arrowheads found at Dulaan Gobi in Dornogovi province, Chikhen Agui in Bayankhongor province, and Kheree Mountain in Dornod province. In the Kerulen area, close to Kheree Mountain, a continuous occupation between Mesolithic and Neolithic strata was identified, including a large cache of arrowheads. These arrowheads were also similar to those found at Gurmiin Nuur and Bat Khan in Khentei province (Derevyanko and Dorj, 1994). The presence of arrowheads indicates a Neolithic transition.

2.4.2 Neolithic (8.0-5.0 ka cal B.P.)

The Mongolian Neolithic is characterised by micro blades and associated small tools as well as pottery (Chard, 1974). This includes arrowheads, grinding stones, blades, and adzes and axes (Derevyanko, 1994; Derevyanko and Dorj, 1992; Dorj, 1971; Janz 2012; Janz et al., 2015; Tsogtbaatar et al., 2010). Derevyanko (1994) describes the Early Neolithic as depending heavily on the preceding Mesolithic. Early Neolithic sites across Mongolia have related features but systematic excavations and published field reports are few.
Amartuvshin and Batzorig (2014) place the Neolithic from 8000 to 4000 and 3000 B.C. (10-6 ka cal. B.P. and 5 ka cal. B.P.), while Seferiades (2004) places it as beginning in the fifth millennium B.C. (7000 cal. B.P.) on par with the earliest indications of occupation at Tamsagbulag, corresponding to the general spread of agricultural technologies in Western Europe. Derevyanko and Dorj (1994) believe the Mesolithic to Neolithic transition began during the early fifth millennium B.C. (7000 cal. B.P.), while Gunchinsuren (2000) places it from the 6th millennium (8000 cal. B.P.). Janz et al. (2015) show the earliest dates from pottery yield 5500 cal BP., extending the Neolithic in the Gobi to between 7733-7549 B.C. (9683-9499 cal. B.P.), but conservatively place it as beginning to 5720-5561 B.C. (7670-7511 cal. B.P.), due to the lack of the pottery’s stratigraphic context. However, they believe it is plausible to push this date to 6000 B.C. (8000 cal B.P.) (Janz et al., 2015).

Early Neolithic pottery is generally characterised as red, red and black, or grey coarse ware. Decorations may be incised, corded or netted. In contrast, late Neolithic pottery is finer, high-fired, and usually string paddled or geometrically incised (Chard, 1974; Derevyanko, 1994; Derevyanko and Dorj, 1992; Fairservis, 1993; Janz, 2012; Janz et al., 2009; Janz et al., 2015).

Fig. 2.4: Neolithic sites discussed in the Section 2.4.2 (does not represent the total number of Neolithic sites distributed across Mongolia). For an extensive overview of sites from this period, refer to Janz et al., 2017. Base Map: SRTM 90m resolution DEM. Jarvis et al. (2008); http://srtm.csi.cgiar.org.
Neolithic surface finds usually consist of a small tool lithic industry including blades, arrowheads, and fishhooks, along with pottery associated with present and former watercourses (Amartuvshin and Batzorig, 2014; Chard, 1974). These assemblages are also similar to Neolithic artefacts found in the Alashan Plateau, which also consist of ceramics, blades, cores, hammer stones, grinding stones and beads (Bettinger et al., 1994).

Neolithic sites in both eastern and southern Mongolia have yielded pottery. In the case of Tamsagbulag in the east (Fig. 2.4), animal domestication makes an appearance, which is described as undergoing three distinct stages of development (Allard and Erdenebaatar, 2005; Derevyanko and Dorj, 1992; Derevyanko, 1994), though this is the exception rather than the norm.

Most Mongolian Neolithic sites with associated permanent settlements have been found in the central and eastern parts of the country. These include Dulaan Govi (Fig. 2.4) in Dornogovi province in the east, which contains unifacial and bifacial points associated with buried soils (Derevyanko, 1994; Derevyanko and Dorj, 1992; Seferiades, 2004). Ostrich eggshell, hearths, and pottery, and cattle bones were also found (Dorj, 1971; Perlee and Ser Odjav, 1957). Other sites include Khuiten Bulag and Ovoot mountain settlements (Fig. 2.4) containing corded ornamental pottery, bone weapons, and composite hafts, indicating hunting, fishing, and possibly early animal domestication and farming (Dorj, 1971; Seferiades, 2004; Tsybiktarov, 2006). Major eastern sites are Tamsagbulag and the Lake Yamat Nuur complex (Fig. 2.4), which include micro and macro blades, burins, and end scrapers, and are similar to the Mesolithic Khereul sites (Derevyanko, 1994; Seferiades, 2004).

Another series of settlement complexes was identified in the western Gobi, adjacent to the area of Dariganga (Fig. 2.4). Derevyanko (1994) says remains of dwellings were found along with mortars, pestles, grinding stones, blades, painted pottery, hoe like tools, and blades, and bifacially worked tools, similar to those from the south Gobi. However, the nature of the sediment makes it difficult to distinguish between each cultural stratum, a reoccurring situation at many Neolithic sites, including the Ulaan Nuur plain where Neolithic blades were found alongside Palaeolithic artefacts (Derevyanko, 1994; Derevyanko and Dorj, 1992; Seferiades, 2004). This is also true for Flint Valley and Eregiin Khooloi settlements found in Omnogovi province (Gunchinsuren et al., 2011).

At Chikhen Agui in the Gobi Altai and in the vicinity, dwelling foundations and materials were found among playa remnants identified by JMRAAE (Olsen, 1996). Artefacts identified include microblade technology, retouched flakes, and projectile points (Derevianko et al., 2003).
In the central Gobi, sites include the Ulziit settlement, discovered with associated petroglyphs. Another notable complex are the Chandman mountain petroglyphs further north (Derevyanko, 1994; Derevyanko and Dorj, 1992; Seferiades, 2004).

Finally, in the north, notable complexes are the Rashaan Khad settlement and petroglyphs in the Khurkh basin (Fig. 2.4), a Mesolithic continuation, as well as several campsites along the Kerulen River (Ovoot) basin, where bones of wild animals and horses, and rock carvings indicate Neolithic use (Gunchinsuren, 2013). Minor sites include Baruun Ulziit and Zuukh (Derevyanko, 1994; Derevyanko and Dorj, 1992).

Neolithic sites with settlements are often found in close proximity with palaeowater sources and an observed spatial pattern between site location and palaeowater sources is evident, often with sites moving closer to shorelines as water disappears. An example of this is the complex of sites near the almost dry Yamat Nuur, where the water line is now 300 to 400 meters away from the palaeolakeshore (Derevyanko and Dorj, 1992).

This spatial pattern is especially true at Tamsagbulag in eastern Mongolia (Dorj, 1971; Seferiades, 2004), which shows strong similarities to the palaeoenvironmental setting of Bayanzag. Due to similarities in palaeoenvironmental conditions between Bayanzag and Tamsagbulag, it is beneficial to examine the conditions occurring at Tamsagbulag in more detail. This will aid in understanding the potentiality of local dynamics occurring at Bayanzag.

**Tamsagbulag**

Tamsagbulag sat on the periphery of a large palaeohydrological system, where residents adopted a very different land use strategy compared to other sites located in equally optimal palaeoenvironmental conditions. Like Bayanzag, the environment around Tamsagbulag underwent several important changes coinciding with the general degradation of Holocene palaeohydrological environments across Mongolia. Increased desertification and shrinking water resources saw a marked change in the spatial organisation of the landscape. Evidence suggests people moved closer to the lake as it shrank, until final lake desiccation, corresponding to a total disappearance of sites.

The Tamsagbulag complex (Fig. 2.5) in Dornod province in eastern Mongolia is a series of sites occupied between the Mesolithic and the Bronze Age, centred around the Lake Buir palaeohydrological complex. Buir and a series of small lakes located to the south are all almost now completely dry and surrounded by small sand dunes. They presently occupy the site of what was once a large Holocene palaeolake (Li and Sun, 2006; Seferiades, 2004; Xiao et al., 2009)
where evidence shows people practiced animal domestication, hunting and gathering, fishing, and potentially agriculture (Derevyanko and Dorj, 1992).

One site, 7 km from the main Tamsagbulag complex, located next to the palaeolake, is situated on a high fluvial terrace at the foot of a spring above the floodplain (Derevyanko, 1994; Seferiades, 2004). Extensive excavations by Soviet-Mongolian and French-Mongolian expeditions have revealed large subterranean dwellings, 40 m² in size and larger.

There is only one published date from one of the Tamsagbulag complexes, dubbed Tamsagbulag 3, located on the eastern side of the palaeolake. A radiocarbon analysis of a gazelle bone dates the site to the third millennium B.C. (5000 cal. B.P.) (Seferiades, 2004). However, Seferiades (2004) believes the site was heavily occupied around the fifth millennium B.C. (7000 cal. B.P.), and points to similarities between other regional artefacts and sites as evidence of this.

Fig. 2.5: The main site of Tamsagbulag in relation to the maximum palaeoshoreline of Lake Buir. The palaeoshoreline was first identified by Seferiades, 2004, but is evident in modern satellite imagery. As the palaeoshoreline disappeared, sites follow the shoreline until evidence of habitation disappears during the Bronze Age. The inset map shows the location of Tamsagbulag (in yellow) in Eastern Mongolia. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: SRTM 90m resolution DEM. Jarvis et al. (2008); http://srtm.csi.cgiar.org.
Grinding stones, mortars and pestles, weights for digging sticks, pottery (ranging between the Neolithic and Early Bronze Age), millet, and stone tools such as blades and burins were found next to these dwellings (Derevyanko and Dorj, 1992; Seferiades, 2004). The presence of millet suggests agriculture may have been practiced. Artefacts found at southern Gobi sites, such as grinding stones are similar in typology to those found at Tamsagbulag (Berkey and Nelson, 1926; Derevyanko and Dorj, 1992); however, Derevyanko (1994) places these Gobi sites as belonging to a separate and distinct culture.

Bones and bone tool assemblages of pigs, horses, cattle, and fish suggest animal domestication and fishing (Seferiades, 2004). A woman, found under one of the floors, was buried with ornaments made of mother of pearl, bone daggers, and a necklace of deer canines (Derevyanko and Dorj, 1992; Seferiades, 2004).

A spatial pattern at Tamsagbulag is evident showing sites moving closer to the areas with water as palaeoshorelines decrease, then cease to exist beyond the Bronze Age. Seferiades (2004) hypothesises that Mesolithic hunter-gatherers adopted a sedentary lifestyle at Tamsagbulag during the Neolithic, then adopted nomadic pastoralism during the Bronze Age, perhaps in part due to changes in the palaeohydrological system at the onset of the Late Holocene drying phase (see Xiao et al., 2009).

Derevyanko and Dorj (1992) see the development of Neolithic Gobi sites as evidence of adaptation to environmental change. They cite Bayanzag as evidence of this, through identification of three distinct developmental stages. These stages differ from the trends observed at Tamsagbulag. This first stage corresponds to the Late Mesolithic/Early Neolithic, characterised by advanced flake tool technology, and artefacts like knife-shaped flakes. Nelson and Maringer similarly characterise the development of the Gobi Mesolithic and Neolithic culture (Derevyanko and Dorj, 1992; Nelson 1926; Maringer 1963).

**Bayanzag**

Bayanzag is the largest Neolithic complex in the Gobi first discovered in 1925 by the Central Asiatic Expedition, and subsequently investigated by archaeologists Nelson and Pond. Located in Omnogovi province in Bulgan soum\(^3\), 65 km north of Dalanzadgad, Bayanzag is about 1.5 km north of the Flaming Cliffs (Fig. 2.6), an area more famous for its dinosaur fossils.

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\(^3\) In Mongolia, a soum (сум) is the administrative unit below a province or province (аймаг), similar to a district or county. Omnogovi province is divided into 15 districts/counties.
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Fig 2.6: The Flaming Cliffs are a popular tourist attraction in Omnogovi province, especially because of their unusual red colour, indicating soil rich in iron oxide content. Famous for its dinosaur bone deposits first discovered by the Central Asiatic Expedition, they also overlook the archaeological site of Bayanzag.

Microlith tools and other artefacts were discovered on deflated dunes. Evidence suggests the site experienced several occupations over time and the assemblage is an important window into the Mesolithic and Neolithic culture in the Gobi, but lack of published data from both the American and Soviet expeditions leaves the chronology of occupation unclear (Chard, 1974; Tsybiktarov 2002; Derevyanko and Dorj, 1992; Fairservis 1993).

The environmental conditions present at Bayanzag are similar to those found at Tamsagbulag. Centred within proximity of a large palaeochannel, the extremely irregular profiled channel was eroded to a depth of over 120 metres and extremely active under more humid conditions. Berkey, Nelson, and Andrews hypothesise there was a large palaeolake close to Bayanzag which would have fed into the palaeochannel and provided an optimum environment for extended occupation for people in the area (Andrews, 1926; Berkey and Nelson, 1926).

Increased aridity created dunes on the valley bottom where artefacts were deposited and subsequently exposed on the dune surfaces (Berkey and Nelson, 1926; Fairservis, 1993; Fig. 2.7). Two distinct cultural horizons were identified in these deflated areas, classified by Derevyanko (1994) as two distinct stages of development of the local Neolithic culture. In contrast, Nelson believes these differences are evidence of a distinct Mesolithic stratum and a distinct Neolithic
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stratum, with the latter borrowing upon the ideas of the preceding phase (Berkey and Nelson, 1926; Derevyanko and Dorj, 1992; Maringer 1963; Okladnikov, 1951).

Fig 2.7: Similar to when it was explored by Nelson, Pond, and Okladnikov, many artefacts remain on the surface at Bayanzag today. These are often on deflated and eroded surfaces, lacking stratigraphic context. Bayanzag is discussed in more detail in Chapter 8.

The lower horizon, described by Nelson (Berkey and Nelson, 1926), is Mesolithic with hammer stones, perforators, cores, flakes, end scrapers, chipped stones mostly of red jasper, and thousands of flints. Also discovered were Gobi cores, burins, knives and ostrich eggshell beads (Berkey and Nelson, 1926; Derevyanko, 1994). Larichev et al. (1962) contend tools found in Mongolia were manufactured the same way as tools found in the Lake Baikal region with some identical forms.

The upper horizon, described by Nelson (Berkey and Nelson, 1926), is the Neolithic stratum. Artefacts were found along with hearths containing ashes and broken stone, along with grinding stones, globular mortars, hammer stones, rubbing stones, axes, cores, flakes, perforators, end scrapers, side scrapers or choppers, spear points of knife blades, and arrow points (Berkey and Nelson, 1926; Derevyanko, 1994). Materials include agate, red jasper, yellow jasper, and white and translucent chalcedony. Similar grinding stones, mortars, and pestles were found at
Dariganga in Sukhbaatar province in the Eastern Gobi. At Dariganga, the cultural material was also found in buried soil with difficulties in distinguishing between cultural strata (Derevyanko, 1994).

The upper horizon at Bayanzag was found with pottery in situ as well as scattered on the surface, while the lower was found without pottery (Berkey and Nelson, 1926). Nelson describes the pottery as grey and brick red in colour, string marked, incised, stamped with geometric patterns, with decoration (Berkey and Nelson, 1926; Fairservis, 1993). Derevyanko (1994) expands the description to clay vessels with egg shapes, and twining textile imprints, which share similar characteristics with pottery found in the Lake Baikal region. The second type of pottery was red with some fragments painted with a black design on both a red and yellow background. Similar pottery fragments of this type were found at Dariganga (Derevyanko, 1994).

Pottery was identified as part of the Ulaan Nuur assemblage, and is similar in typology to those fragments found at Bayanzag. Ulaan Nuur fragments are reddish with an indication of burnishing by vertical strokes and paddle markings. Other fragments are brown grey or reddish with a herringbone design, stamped or rolled, or with a parallel dash decoration (Fairservis, 1993).

These are also similar in typology to pottery from Tamsagbulag and the Neolithic sites found at Ovoot Mountain. Cord wrapped pottery with paddle impressions as well as egg-shaped pottery covered with net or mat impressions was found in Siberia at Bel’kachi I (Chard, 1974). Seferiades (2004) believes Tamsagbulag pottery is similar to pottery of the Lake Baikal and the Amur region of Siberia. Nelson (1926), Derevyanko (1994), and Larichev et al., (1962) make similar observations between Lake Baikal and Bayanzag pottery. In Inner Mongolia, Egami and Mizuno also found ceramics with similar typological characteristics (in Larichev et al., 1962).

Okladnikov and the Soviet-Kiselev expedition revisited Bayanzag in 1947 and reported no evidence of a distinct aceramic layer, but rather two distinct layers both accompanied by pottery (Maringer, 1963; Okladnikov, 1978). In unpublished site data, Okladnikov classes both horizons as Neolithic, because the lower was found in association with small Early Neolithic tools, while the late Neolithic horizon was on top. He labels this culture similar to the Serovo culture ceramics found in the Lake Baikal region (in Chard, 1974).

Okladnikov also refined the stratigraphy and collected new material (Derevyanko and Dorj, 1992; Derevianko et al., 2003), although it is not recorded if these excavations took place in the same area of the dunes where Nelson had excavated. Nelson, however, insists there was a distinct aceramic layer (in Maringer, 1963). Chard (1959) sides with Okladinkov saying there is no evidence of a Mesolithic as pottery was found in all layers, while Maringer (1963) doubts these were the two same layers investigated by the Central Asiatic Expedition, saying that the presence
or absence of pottery is an element hard to overlook, and supports Nelson’s hypothesis of a distinct Mesolithic culture. Kozlowski (1972) confirms an aceramic layer in excavations carried out on the site.

Okladnikov reported all artefact assemblages as surface finds, and attempted to create a chronology based on typology, weathering, and patination (in Chard, 1974), inherently creating problematic interpretations. Spock and Nelson (1934) insist that Gobi artefacts are rarely coated with patina and few show signs of weathering.

Information on the spatial distribution of other artefacts at Bayanzag, such as grinding stones, bifaces, and axes was only recorded on a limited basis, so not enough information is available from the site excavation record to truly know the extent of artefact distribution (Tsybiktarov, 2002).

Janz et al. (2015) sampled pottery using AMS and thermoluminescence from Bayanzag, the Ulaan Nuur plain, and Barun Daban in Omnogovi province. They compared these results to pottery from Chikhen Agui and Orog Nuur, as well as pottery from sites collected by the Sino-Swedish Expedition in the Alashan Plateau. They found several sherds dated to earlier than was expected, placing the Gobi Neolithic firmly before 6200-6000 cal. B.P. The Ulaan Nuur plain pottery was placed between 5116 +/- 41- 5061 +/- 49 cal. B.P.

Since 1925, similar sites have been found across the Gobi Desert, but Bayanzag is the most extensive of these sites, especially since Nelson took the greatest care in recording details. Nelson, supported by Gunchinsuren et al. (2011), observes the later Gobi culture is distinctly different from the Gobi culture found at Bayanzag. He suggests these later people migrated to the region rather than originated from it (Berkey and Nelson, 1926).

For this dissertation, Bayanzag was visited during fieldwork to compare observations of the current palaeoenvironmental context to the observations of Berkey and Nelson (1926). There are still many artefacts, mostly lithics and pottery, exposed on the surface, from several chronological periods. The results of this field investigation will be discussed in more detail in the field survey results in Chapter 8.

2.4.3 Eneolithic (5.0-3.0 ka cal B.P.) & Bronze Age

Janz (2012) and Janz et al. (2015) dub the Neolithic to Bronze Age transition the Eneolithic (5000-3000 cal. B.P.). The Eneolithic was technologically distinct because several characteristics appear together, including milling stones, mortars, pestles, pottery, and copper slag. Many of the sites
across the Gobi region belong to the Eneolithic, with elements of both Early Bronze Age and Late Neolithic (Derevyanko and Dorj, 1992; Janz, 2012; Janz et al., 2017).

At some point during the Bronze Age, herding and later pastoralism were adopted as the dominant subsistence strategies. This marks a tipping point for regional economic and social change. One of the leading hypotheses is that herding animals were introduced from the West by the Afanasievo, eventually spreading across Mongolia, with clear evidence of herding reaching the Gobi by 3.4 cal B.P. (Kovalev and Erdenebaatar, 2009; Honeychurch, 2014; Janz et al., 2017). The Afanasievo are the earliest documented hunter-gatherer group to use metal in East Asia (Janz et al., 2017). However, Honeychurch (2014: 109) points out there were likely many points of introduction.

Associated with this shift, two major monuments appear during the Late Bronze Age: deer stones (Fig. 2.8) and khirigsuurs (Fig. 2.9). These are interpreted as a broader indicator of societal changes occurring in Bronze Age society (see Allard and Erdenebaatar, 2004; Fitzhugh 2009a; Fitzhugh 2009b; Honeychurch, 2014; Magail, 2008; Jackson and Wright, 2014; Wright, 2007). Another Late Bronze Age chronological marker is the slab burial. In Omnogovi, all of these archaeological features are predominantly found in the foothills and in intermontane meadows of the Gobi Altai, including the Arts Bogd and Gurvan Saikhan mountain ranges (Fairservis, 1993; Gunchinsuren et al., 2011; Honeychurch, 2015; Kovalev and Erdenebaatar, 2004; Janz et al., 2017). A brief description of deer stones, khirigsuurs, and slab burials is next.

**Deer Stones**

Deer stones are stelae with deer as the central theme of their iconography (Fig. 2.8). Their geographical extent encompasses Outer Mongolia and surrounding regions, including the Russian Altai, Tuva, China, Kazakhstan, and as far west as the Caucuses and the Black Sea Region (Askarov et al., 1992; Fitzhugh, 2009a; Jacobson, 1993). Deer stones occurring further west towards the Caucuses have been attributed to the later Scythian and Pazyryk cultural complexes, while those occurring in Mongolia and the immediate surrounding regions are attributed to the early nomadic pastoralism cultural complex (Askarov et al., 1992; Jacobson, 1993). The stones, ranging from 4 meters to less than one meter in height, are found in groups or singly, and often in conjunction with khirigsuurs (Allard and Erdenebaatar, 2005; Fitzhugh, 2009a; Magail, 2008). Deer stones are generally distributed across central and western Mongolia (Honeychurch, 2015; Houle, 2010).
Fig. 2.8: Examples of deer stones from northern Mongolia. Deer stones occur singly or in groups, as in the left hand image. The deer is the central theme, with other images such as geometric designs, moons, and animals. In the right image, the deer features prominently, where the elaborate hooves, almost bird-like face, and body wrap around the stone. Deer stone photos taken by A. Kessler and used here with permission.

Khirigsuurs

Khirigsuurs are also referred to as kurgans although they are not kurgans in the true sense of the term (Fig. 2.9). They consist of a large mound of stones, often surrounded by a circle or square stone perimeter or fence, as well as external associated features like stone circles, which often contain animal bones. Unlike kurgans, khirigsuurs were not a mortuary function, as the main mound often contains no artefacts or burials. The rare few that do are debated as to whether they are true khirigsuurs, or if instead, are another type of monument. Houle (2010) has proposed that these khirigsuur burials belong to another category, called slope burials.
Fig. 2.9: Urt Bulagyn (on the left), in Arkhangai province, is one of the largest khirigsuurs in Mongolia with over 1700 satellite mounds. On the right, also in Arkhangai province, excavated satellite mounds typically contain horse skulls. Sometimes these excavated mounds also contain skulls, hooves, and vertebrae.

The nature of khirigsuurs, particularly the larger ones, suggests that large groups of organised labour would have been necessary to construct them. For example, Urt Bulagyn, one of the largest khirigsuurs in Arkhangai province measures 390m x 390m, 5 m tall, and is accompanied by 100 stone circles, and 1,700 satellite mounds (Fig. 2.9). The excavated satellite mounds and circles often contain horse skulls and/or cervical vertebrae, and animal bones with indications of cremation (Allard and Erdenebaatar, 2004; Fig. 2.9). Like deer stones, khirigsuurs are generally distributed throughout central and western Mongolia (Honeychurch, 2015; Houle, 2010).

**Slab Burials**

Slab burials (Fig. 2.10) typically appear during the Late Bronze Age but are generally distributed throughout eastern Mongolia (Honeychurch, 2015; Houle, 2010; Janz et al., 2017). Slab burials are thus named because of distinctive stone slabs on their surface creating a rectangular enclosure around the burial (Honeychurch, 2015). Slab burials appear around the same time as deer stones and khirigsuurs, and continue after these monuments cease to be built (Honeychurch, 2015). One slab burial was identified during the field survey at Khoyor Khairkhan (Chapter 8).
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Fig. 2.10: A slab burial located in central Mongolia. The upright slabs, hence the name, are typical markers of these Late Bronze Age burials.

However, the Eneolithic/Early Bronze Age is most applicable to the research question posed in Chapter 1. These periods will be discussed in more detail in Chapter 9, within the context of the archaeological areas of activity identified during the field survey.

2.5 Movement within the Landscape

Some researchers have proposed routes of movement through the Gobi that are applicable to mobility studies around Ulaan Nuur. Rybin (2014) proposes the route between the western Gobi Altai and the Valley of the Lakes and Gobi Lakes as key to Upper Palaeolithic dispersal. Sites like Chikhen Agui would have been important stops along this route (Derevianko et al., 2008). Honeychurch (2014: 83) proposes a north-south route along rivers, like the Ongi, as key to movement across the Gobi, leading into Inner Mongolia and China. These routes would have promoted local interaction and regional exchange following distinct ecological corridors.

Based on the sites discussed in this chapter, it is apparent that hydrology played an important role in desert exploitation and mobility, possibly indicative of a more resource rich landscape. In a
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Refuges, Barriers, and Corridors Model (Chapter 1), water facilitates (corridors) and hinders (barriers) mobility, while areas of stable water resources are easier to occupy and exploit (refuges).

This would be particularly applicable during the Early and Mid Holocene when hunter-gatherers explored and settled the landscape, when corridors and refuges would have been at a maximum. Sites like Tamsagbulag, Bayanzag, Moiltiin Am, and Rashaad Khan are evidence that people clustered around areas of extensive palaeohydrological networks. A Late Holocene shift towards herding could be indicative that these corridors shifted to barriers, while refuges reduced. These economic changes are also consistent with a Desert Transformation Model (Chapter 1).

The permanence of hydrological resources played an important role for local Gobi groups. These hydrological resources will be tested during fieldwork (Chapters 7 & 8), including how these local groups may have reacted to changes in these hydrological resources, and will be discussed in more detail in Chapter 9. However, to investigate the hydrological landscape, it is important to identify potential networks of movement.

One way to identify potential networks of movement is through examination of the palaeoenvironment, including palaeohydrological networks, and relating these to the archaeological proxies introduced in this chapter. This will be discussed in more detail in Chapters 4-6. However, to do this, it is first necessary to establish the extent of landscape marginality. In the broader Gobi region, there is more environmental data than archaeological data. One way to advance the archaeological narrative is through identification of those areas around palaeolakes and along palaeohydrological corridors that would have been optimal for long-term human occupation and movement.

In the local Mongolian Gobi, the local environmental changes occurring between the Early and Late Holocene remain largely unstudied. However, the broader Holocene global and regional environmental and climatic changes have been investigated. This includes how these changes may have contributed to patterns of human activity and land use. To examine the archaeological patterns around Ulaan Nuur, it is first necessary to establish the palaeoenvironmental conditions occurring in this local area, by establishing a spatio-temporal environmental framework. The next chapter will review the global, regional, and local climatic literature regarding the Holocene. Additionally, the changes at Ulaan Nuur are reviewed, including new interpretations via a Palaeoenvironmental Age-Depth Model (PADM chart). These are then compared to broader environmental changes.
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3.1 Introduction

While Chapter 2 established the background of archaeological research in the Gobi Desert and the Ulaan Nuur region, the goal of this chapter is to establish the environmental context in which the archaeological data may be evaluated. First, a discussion of climate systems at play in the Gobi is discussed because they strongly influence environmental change. The next section provides an overview of Ulaan Nuur during the Holocene. This reviews past environmental work published about Ulaan Nuur, and introduces a new and alternative interpretation related to the lake’s evolution, via a PADM chart. Following this, is an overview of climate and environmental changes across global, regional, and local contexts, ranging between the Younger Dryas to the Late Holocene. The final section compares and explains the significance of Ulaan Nuur’s evolution in relation to all of the indicators presented in the previous section. Discussion of this climate and environmental change is achieved primarily through the discussion of multi proxy records from lakes.

Lake basins provide excellent multi proxy records of climate change in deserts (Chen et al., 2003a) because they record temporal and regional variations of the palaeoclimate and provide high-resolution records of these changes. This is essential in understanding long-term changes in climate variations (Chen et al., 2003a; Rach et al., 2014). The majority of this comes from multi proxy data derived from the analyses of palaeolakes and palaeohydrological life cycles using records such as lake levels, pollen, and diatom assemblages (An et al, 2006).

However, there is criticism of using lakes as records of climate change. The first criticism stems from conflicting radiocarbon dating chronologies and conflicting interpretations over Holocene moisture variations (Long et al., 2014; Mischke et al., 2005). Discontinuous lake sequences, lack of appropriate material for carbon dating, weak and inconsistent proxies (particularly pollens and diatoms, and those stemming from the reservoir/hard water effect), and local hydrological variations are major reasons behind this deficient understanding of Holocene Gobi climate change (Chen et al., 2003a; Mischke et al., 2005; Yang et al., 2011).

Chronologies from lake, swamp, and peat bog archives evaluated with radiocarbon with extreme hard water effects are often the reason behind unreliable interpretations. The miscalculation or
an absence of calculation of hard water leads to severe dating errors (Yang et al., 2011). Yang et al. (2011) demonstrate several current studies reviewing Gobi Holocene lake chronology ignore hard water effects, where miscalculations skewed dates by thousands of years. Additionally, the effect of local conditions are often overlooked, especially the role of aquifers acting as buffers from desiccation (Hartmann and Wunnemann, 2009; Yang et al., 2011). These errors all contribute to deficiencies in the temporal and environmental sequences in the Gobi (An et al., 2008).

Additionally, interpretations of pollen records in Central Asia and Mongolia are often criticised as unreliable due to poor pollen identification, as well as the absence of good indicator species, and the higher than average percentage of long-distance transported tree pollen (Herzschuh et al., 2004). Added to that, Holocene pollen records for the Gobi region are criticised as representing either too short of an interval or having poor resolution (Herzschuh et al., 2004).

Often the reviews of the Mongolian Gobi climate and environmental changes are inferred based on the studies conducted in the neighbouring desert areas of northern China (see An et al., 2008; Zhang et al., 2012 for examples) as well as multi proxy studies of palaeolakes in northern, central, and western Mongolia. This is problematic because the geographic differentiation of Holocene climate variations renders the application of climate history from other regions adjacent to the South Gobi Desert problematic (Chen et al., 2010; Feng et al., 2005; Hartmann and Wunnemann, 2009; Sternberg and Paillou, 2015).

Two major issues are highlighted. First, is the disagreement over synchronous versus asynchronous events. The Pleistocene-Holocene boundary, as well as those events occurring globally, were not synchronous and did not occur along the same spatio-temporal boundaries, and thus, cannot be treated as such. This is problematic because specific local spatio-temporal events cannot be compared to those occurring globally and regionally if they do not occur simultaneously. This demonstrates the need for a formal environmental framework of chronology to be set into place. Several researchers emphasise caution when superimposing regional climate events onto local climate events (see Hartmann and Wunnemann, 2009; Sternberg and Paillou, 2015, among others). One way to reconstruct these changes comes from multi proxy records like speleothems, ice cores, and ocean and lake sediments.

The second issue is conflicting chronological controls. Often, how dates are determined, if they are calibrated, and what period is being referenced, are not explicitly specified. Steinthorsdottir et al. (2014) cite dating approach methodology as a major reason behind these conflicts, as each record requires a unique and specific chronological construction, and each is dependent on the
radiocarbon calibration data and age-depth model used to reconstruct these sequences. In Central Asia, including Mongolia, these various influences on age depth models often lead to an age overestimation by over 2000 years (Felauer et al., 2012; Feng et al., 2005; Murad, 2012).

Fig. 3.1: The chronological framework referenced in this dissertation. The top represents the archaeological period, and the bottom represents the corresponding environmental period. The Holocene is defined as the most recent interval of Earth’s history, extending and including present day (Walker et al., 2009). There are variations on this date, as some literature places it beginning at 11600 cal. B.P. (see Wanner et al., 2008), while other literature places it beginning at 11500 cal. B.P. (see Mayewski et al., 2004). These dates reflect regional and local variations of landscape and climate dynamics. The terms “Early”, “Mid”, and “Late” describe the three sub phases or sub epochs after Walker et al. (2012, after Neustadt, 1959), as they are reflected in the Greenland Ice Core, which is consistent with the current literature written about the Holocene epoch occurring in Central Asia. There are, however, some limitations with subdividing the Holocene into these three sub phases, which is summed up perhaps best by Walker et al. (2012). The precise temporal limits of each of these subdivisions have never been formally agreed upon, although they are used with great frequency in both archaeological and climatic literature. Thus, there are considerable inconsistencies in the understanding of temporal limits for each sub phase.

In this dissertation, the Holocene (Fig. 3.1) is referenced in accordance with the formal definition set by Walker et al., (2009). The Greenland Ice Core\(^1\) shows the early Holocene began about 11700 years b2k with a maximum counting error of 99 years, where b2k refers to the ice core zero age of A.D. 2000, which is a 50 year difference between the zero year for radiocarbon at 1950 (Walker et al., 2009). This is in agreement with the radiocarbon date advanced by the 8\(^{th}\) International Union for Quaternary Research (INQUA) congress in Paris, 1969. This date represents the point at which the largest, uninterrupted phase of climatic improvement occurred since the Last Glacial Maximum, and in the case of northwest Europe, the Younger Dryas/Early Holocene boundary (Hafsten, 1970).

However, environment and climate are multi layered and complex systems, and while global and regional climate conditions play a role in evolving environmental conditions, they are not

\(^1\) The Greenland Ice Core record extends back over 100,000 years and registers early signals of climatic change through several proxies (Walker et al., 2009).
necessarily indicators of local conditions. Local conditions play a large role in the variability of lake life cycles, where small changes in precipitation might have drastic changes in the local environment (Hartmann and Wunnemann, 2009). This is because of the sensitivity between precipitation and evaporation and water availability, such as headwater areas or glacier movements (Chen et al., 2003a; Magny, 1992; Mayewski et al., 2004; Muschitello et al., 2013; Yang and Scuderi, 2010).

Conditions around the Gobi and particularly the development of its palaeolakes are influenced by these local factors. For example, regional drops in precipitation are recorded during the Holocene in many areas across the Gobi due to fluctuating climate systems. Yet despite these regional drops in precipitation, at many sites, local vegetation growth remained steady and lake levels remained constant.

These hydrological cycles are connected to rapid environmental changes, which can occur within one or two generations (Rach et al., 2014). Hydrological cycles create latent heat distribution in the atmosphere through water vapour transport, which creates variability in monsoon activity, regional humidity, and lake level fluctuations (Mayewski et al. 2004). Like human societies, changing local conditions cause hydrological resources to react in different and unpredictable ways, particularly to aridification (Cremaschi and Zerboni, 2009).

When combined with geomorphological and archaeological evidence, patterns concerning climate change become evident. For example, in the Sahara, sites located at the base of dunes coincide with former palaeolake shorelines, marsh deposits, and palaeosols. In this area, lakes acted as refuges along desert migratory routes (Cremaschi and Zerboni, 2009).

The South Gobi Desert is an extremely important region because it could provide information about global Holocene climatic events (Feng et al., 2005) due to the climate systems that interact over the area, which in turn influence local conditions, like lakes. Chief among these are the Siberian-Mongolian High Pressure System, the East Asian summer and winter monsoon, and the North Atlantic Oscillation. A brief overview of these climate systems is discussed next.
3.2 Gobi Climate Systems

Currently, Mongolia is influenced by the Westerlies\(^2\) from the North Atlantic Oscillation, the Siberian-Mongolian High Pressure System, and the East Asian monsoon, which is associated with El Niño South Oscillations and the Intertropical Convergence Zone (An et al., 2008; Sternberg and Paillou, 2015), which causes higher moisture in most of northern Asia (Felauer et al., 2012) (Fig. 3.2). These global climate systems create a complex and interrelated web influencing temperature, precipitation, and moisture (Chen et al., 2010) causing considerable spatial and temporal variability (Sternberg et al., 2015). This is especially apparent in rates of precipitation which are directly observable based on each climate system area of influence (von Wehrden et al., 2005), particularly in regards to ecosystems.

*Fig. 3.2: An overview of the major climate systems and the major areas of interest. The modern East Asian Monsoon Limit is marked with a dashed line (after Chen et al., 2008). Deserts have active dune fields and sandy lands have fields of stabilised dunes (after Yang et al., 2011). Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.*

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\(^2\) The Westerlies are winds in the Middle Latitudes between 30°N and 60° N, originating in the western hemisphere, moving towards the east.
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The North Atlantic Oscillation (NAO) consists of two pressure centres over Iceland and the Azores, which affect temperature and precipitation via the jet stream. NAO precipitation via the Westerlies reaches Central Asia and the Mongolian Plateau, and consequently, the Gobi.

The Tibetan Plateau (Fig. 3.2) blocks the Westerlies into north and south flows, creating an anticyclonic flow in the north, which is the reason the Gobi is colder than other adjacent regions occurring at the same latitudes (Yang et al., 2011). The Tibetan Plateau also enhances aridity of the region because it blocks oceanic moisture, and its uplift, although debated, is believed to be the cause behind the formation of the Siberian-Mongolian High Pressure System (Yang and Scuderi, 2010; Yang et al., 2011).

The Siberian-High Mongolian Pressure System\(^3\) is a mass of cold and dry air originating in Siberia, centred on Lake Baikal. It is at its coldest in the winter, and affects Mongolia, China, and other areas as far as Europe and Canada. The Siberian-Mongolian High Pressure System and the East Asian winter monsoon (originating in the Indian Ocean and the Pacific Ocean), associated with high latitude forcing, dominate the northern Gobi.

The East Asian Monsoon system is further divided into the winter monsoon and the summer monsoon. Additionally, there is a complex interplay between the Pacific, Indian\(^4\), and East African monsoon systems, which also influence the East Asian winter monsoon (An et al., 2008).

The Indian monsoon occasionally passes into the Gobi over the Himalayas and the Tibetan plateau, bringing cyclonic disturbances (von Wehrden et al., 2005). The south central and the southern Gobi both experience considerable monsoonal climate variability. Additionally, disturbances originating in the Mediterranean basin, and the East Asian Monsoon influence the west (Sternberg et al., 2015; von Wehrden, 2005), which gradually weaken towards the east (von Wehrden et al., 2005).

There are several reasons why the Gobi is important to palaeoclimatic reconstruction. First, the Mongolian Plateau is the meeting point of the NAO and North Pacific Oscillation, where both affect the strength of the Siberian-Mongolian High Pressure System. This, in turn, affects and modulates the strength of the East Asian winter monsoon (Feng et al., 2005). Therefore, the winter monsoon is controlled by the extent of the high latitude ice sheets (Feng et al., 1998).

Secondly, the strength of the East Asian summer monsoon influencing the southern Mongolian Plateau is directly related to the interactions between the El Niño South Oscillation and the

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\(^3\) also referred to as the Siberian High or Anticyclone

\(^4\) also South East Asian
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Intertropical Convergence Zone in the tropical Pacific (Feng et al., 2005). Therefore, the summer monsoon is controlled by the temperature of low latitude oceans (Feng et al., 1998).

The intensity of the winter monsoon is inversely correlated to the summer monsoon, and the intensity of the summer monsoon modulates the winter monsoon and controls Gobi dust storm events. These interactions are recorded in both the Loess Plateau and the southern Mongolian Plateau, both of which are also centred in the heart of the Siberian-Mongolian High Pressure System (Feng et al., 1998; Owen et al., 1997). However, this was not always the case, as there was not always an inverse relationship between the summer and winter monsoon intensities, and the weakest summer monsoon period was not necessarily the strongest winter monsoon period (Chen et al., 2008; Feng et al., 1998). It is unknown whether the two monsoons responded to the same global forcing factors at the same rates (Feng et al., 1998).

Finally, the NAO is modulated by the Westerlies in the Middle Latitudes. Additionally, the western Gobi is also occasionally influenced by disturbances occurring in the Mediterranean (Sternberg and Paillou, 2015; von Werhden et al., 2005). Therefore, the reconstruction of the palaeoclimate changes in the Mongolian Plateau should significantly improve understanding of the mechanisms and processes of large-scale global Holocene climate changes (Feng et al., 2005).

During the Holocene, the Gobi region and possibly even the entire Mongolian Plateau was influenced by the East Asian summer monsoon in response to low latitude forcing (Zhang et al., 2012). However, each system may have operated with different strengths within different time intervals during the Holocene, and their influence on specific regions remains poorly understood (Chen et al., 2010; Zhang et al., 2012). The East Asian summer monsoon may have reached Ulaan Nuur during the Holocene (Lee et al., 2011, 2013). The next section will review this in addition to the palaeoenvironmental conditions occurring at Ulaan Nuur.

3.3 Palaeo Ulaan Nuur

The introduction of this dissertation (Section 1.6) reviewed the current environmental conditions of Ulaan Nuur. Past Ulaan Nuur represented a different environmental landscape compared to the one at present. Only one core has been drilled in Ulaan Nuur (Core ULB; 44°30’50.1”N, 103°39’16.0”E; z = ar. 1027m) and published by Lee et al. (2011; 2013). A large set of palaeoenvironmental analyses and dates produced from this core presents an idea of the evolution of the lake between the Late Pleistocene and the Holocene.
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The 5.88m long core was drilled in 2007 by the Korean research team led by Min Kyung Lee. A first publication in 2011 presents radiocarbon dates, OSL dates, and grain size analysis (Lee et al., 2011). The main issue in this paper relates to the chronology established by both radiocarbon and OSL techniques. These radiocarbon dates do not match the OSL dates, especially in the first 3m below the surface. In contrast, the upper part of the core demonstrates older radiocarbon dates than the OSL dates. Most of the radiocarbon dates were obtained using bulk samples, which led to these older dates. This may have been caused by aeolian and glacio-fluvial processes, which brought the old reworked carbon present in the dated bulk deposits, leading to older dates (Lee et al., 2011). Methodologically, organic material like vegetal fragments, charcoal, and wood gives better dates compared to dates performed on bulk samples. Seeds, fragments of leaves, and twigs are generally ideal for performing radiocarbon dates in sediments. The published OSL dates provide a more reliable chronological framework for this Ulaan Nuur core sequence.

In 2013, a second paper was published which complemented the grain size analysis through geochemical analysis, which more precisely defined the palaeoenvironmental context (geochemical analyses: major elements composition, organic carbon, C/N ratio) (Lee et al., 2013). Three units were identified: Unit 1 (0 to 392 cm, covering the last 11200 years); Unit 2 (392–530 cm, 11200 - 15000); and Unit 3 (530–588 cm, 15000 –16700). The authors suggest Units 1 and 3 were deposited in a lake influenced by aeolian processes, and Unit 2 was deposited in a lake mostly influenced by fluvial deposits. Based on the decrease of total organic carbon and the C/N ratio, they also reconstruct a decrease in humidity of the palaeoclimate during the Holocene. They identify an influence of the East Asian summer monsoon in the Ulaan Nuur region, further north than previously thought.

However, these interpretations were published before the publication of Sternberg and Paillou in 2015, which suggests a larger Ulaan palaeolake potentially existing in the Early Holocene. This larger palaeolake is also confirmed by Lehmkuhl et al. (2017). Using Sternberg and Paillou (2015)’s publication and the PADM chart, it is possible to reconsider the hypothesis of aeolian deposits suggested by Lee et al. (2011): “Considering the small lake size and lake-level fluctuations in a closed lake, it is difficult to interpret that the thick, homogeneous, very fine sediments in units 1 and 3 were deposited in the lake under the influence of fluvial processes. Accordingly, units 1 and 3 sediments are interpreted to have been primarily transported to the lake by aeolian processes.”

Additionally, Lee et al. (2013) suggest that Ulaan Nuur “is known to have been fed only by the Ongi River which originates from the southern part of the Khangai Mountains.” However, although it is true that the Ongi River is now the main tributary, during the Holocene another
important tributary may have previously flowed into the lake coming from the south-east, along with secondary tributaries (Sternberg and Paillou, 2015). The lower part of this south-eastern channel was widely surveyed during this dissertation. Complementary palaeoenvironmental analysis would be necessary to date the phases of activity of each of these tributary channels.

In consideration of a larger lake during the Holocene, the core drilled recorded the sedimentation in the middle of a large water body, with sediments coming from the suspended load of the tributary rivers and deposited in the lake far from the river mouths (silts and clays). Together with the fluvial inputs, some aeolian sediments also contributed to the sedimentation in the lake (see Fig. 3.3).

Fig. 3.3 proposes an alternative interpretation of Core ULB using a Palaeoenvironmental Age-Depth Model, or PADM chart (Salomon et al., 2016). This new interpretation of the lake is suggested in the context of a larger lake and a wider watershed. Unit 1 is subdivided into three different subunits. The age-depth model proposed in Fig. 3.3 was also built using OSL dates from Lee et al. (2011). Sedimentation rates were calculated using the depth of the sediment sampled at the top and the base of each subunit, and the mean age of these dates.

On the right are the reported results of the analysis (mean grain size in μm, the description of the grain-size histogram), the location of the calcite concretions, and the suggested aeolian materials.

- Unit 1 (top to 392 cm) = Silt and clay, unimodal distribution, mostly mafic, igneous provenance
  - Subunit 1.A – top 100 cm
  - Subunit 1.B – 100 to 340 cm
  - Subunit 1.C – 340 to 392 cm = highest TOC (total organic carbon) and CaCO₃ > Humid palaeoclimate ? – 11000 to 9000 cal. B.P.

- Unit 2 (392 to 530 cm) = Sand and clay, bimodal distribution, mostly quartzose sedimentary provenance

- Unit 3 (530 to 588 cm) = Clay with small amount of sand, origins of sediments are between quartzose sedimentary provenance and mafic, igneous provenance.
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Fig. 3.3: An alternative interpretation of Core ULB, using a PADM chart, based on Lee et al., 2011. Each side represents different levels of interpretation. The indicators of palaeoclimate data by Lee et al. (2012, 2013) are not strictly related to their interpretation of processes. The lake records a certain amount of organic carbon, which relates to the humidity of the area. In terms of climate, the size of the lake and the size of the watershed affect the interpretation of the processes.
The authors suggest that Units 2 and 3 were mostly recording airborne dust deposited by decantation settling into the lake. However, in the case of a wider lake in the Late Pleistocene/Early Holocene, this suspension load deposited by decantation could also be considered from fluvial origin in a large lake. In this case, glacio-fluvial transport was stronger in Unit 2. The difference of grain size between the layers and the different composition of the deposits, taking into account a larger watershed with the existence of other potential tributaries of Ulaan added to the Ongi River, suggest more complexity, considering the lithologies drained across time. A closer examination of the local sediment sources should be conducted for a precise reconstruction proposed by Lee et al. (2013).

Using the Total Organic Carbon (TOC) and CaCO3 contents, C/N ratio, and a Chemical Index Alteration, the authors reconstruct palaeoclimatic changes during the last 17000 years:

1. During Period 1, a warm and humid period around 16500 - 15000 years ago is followed by a palaeoclimate deteriorating between 15 and 12000 years ago;

2. Period 2 (11300 – 8800 years ago) records a shift from a cold and arid climate to a warm humid climate. Indicators suggest abundant vegetation cover (forest steppe) especially between 11500 to 10500 years ago (all other periods seem to show steppe and desert steppe vegetation);

3. Periods 3 (8600 to 7600 cal. BP), 4 (7500 to 4700 cal. BP) and 5 (4600 to 3100 cal. BP), record aridification with slightly more humid conditions with more vegetation cover than today;

4. Since 3000 cal. BP, the TAC and CIA value decrease suggesting more arid and dry conditions.

The existing conditions may be summarised as between the Younger Dryas and Early Holocene an increasingly warmer and more humid climate, with a shift to forest steppe vegetation. The Mid Holocene shows increased aridification but with more humid conditions than at present, with steppe and desert steppe vegetation, which was thicker than it is presently today. The Late Holocene shows increased aridification and dry conditions almost on par with how it is presently (reviewed in Chapter 1, though conditions today are considerably more marginal).

To examine how the conditions at Ulaan Nuur compare to those in other areas across the Gobi Desert, environmental periods and their respective proxies will now be reviewed, with the goal of placing Ulaan Nuur within global, regional, and local contexts. Cumulative charts summarising all of these reviewed indicators, including global, regional, and local proxies, in relation to Ulaan Nuur may be found in Section 3.8, pp 103-105; Fig. 3.22-3.24.
3.4 The Younger Dryas (GISP2 Ice Core, Greenland; 11700 year cal B.P.)

The Younger Dryas was the last major period of note of the Pleistocene. Walker et al. (2009) say this period lasted between 12900 cal. B.P. and 11500 cal. B.P. based on Greenland Ice Core records as well as proxy records from northern mid and high latitude regions. It is also reported to correspond to 11000-10000 C14 years B.P. or 13000-11700 calendar years B.P. (Fairbanks, 1990), as well as 12800 calendar years B.P., and depending on the core analysed, lasted until 1150-1300 years later (Steinthorsdottir et al., 2014). Around 13500 cal. B.P., the Mongolian Mesolithic (Fig. 3.1) transitioned from the Late Palaeolithic, in a phase also referred to as the Epipalaeolithic (Janz, 2012), and is underway by the time the Younger Dryas ends at 11500 cal. B.P.

The Younger Dryas met a rapid end with a warming transition that took place between 40 and 50 years in three discrete steps (Steinthorsdottir et al., 2014). This transition is marked in the Greenland Ice Core by a shift to heavier oxygen isotope values, a decline in dust concentration, a significant change in ice chemistry, and an increase in annual ice thickness, suggesting changes in atmospheric circulation and rising temperatures (Walker et al., 2009).

3.4.1 Global Indicators

The Younger Dryas corresponds to a cooling episode that interrupted the previous postglacial warming (Walker et al., 2009), causing significant environmental changes across Europe (Steinthorsdottir et al., 2014). Temperatures declined by over 2°-6° Celsius in the Northern Hemisphere, glaciers advanced, and global aridification increased. These events may have been the result of an ocean flushing event, indicated by more dynamic CO₂ levels in Greenland Ice Core records (Steinthorsdottir et al., 2014). This is in strong contrast to the warming trend observed during the Last Glacial Maximum, and the following warming trend marking the Holocene (Walker et al., 2009).

In Europe, abrupt changes in vegetation, such as reversals in northward spreading forests, were affected by sudden decreases in temperatures and replaced with cold tolerant plants like steppe flora (Muschitiello and Wohlfarth, 2015). Regional glacier advances and lowering of snow lines occurred in Scandinavia, while Coleopteran beetle fossil evidence in the United Kingdom suggests the mean temperature dropped to -5° C, with prevailing periglacial conditions in lowland areas, and ice fields and glaciers in upland areas (Muschitiello and Wohlfarth, 2015).

Similarly, the Arabian deserts also experienced colder temperatures and higher rainfall (Dennell, 2013). Later, the dry and cold conditions during this period resulted in the spread of arid and
semi-arid conditions at both the northern and southern margins of the Sahara-Gobi desert belt (Lioubimtseva et al., 1998). In the Greenland Ice Core, these conditions correspond to changing moisture sources (Rasmussen et al., 2006).

Data suggests this climate amelioration was locally abrupt, but was not synchronous across Europe (Lane et al., 2013; Muschitiello and Wohlfarth, 2015). Diachronous latitude environmental changes may be due to a reduction in NAO circulation (Muschitiello and Wohlfarth, 2015). This circulation transports water from the equator to the North Pole, and was possibly overwhelmed by an influx of cold water from North America into the Atlantic (Muschitiello and Wohlfarth, 2015; Steinthorsdottir et al., 2014). A slight warming in the southern hemisphere and some northern areas, such as the southeastern United States, interrupted this cold phase (Muschitiello and Wohlfarth, 2015; Steinthorsdottir et al., 2014).

A delay between the onset and end of the Younger Dryas in Asia and the North Atlantic region by 200-300 years is observed in Japan at Lake Suigetsu and in multi proxy records from China (Walker et al., 2009). In Mongolia, the interruption of the cold phase could be due to the weakening of Atlantic and Pacific influences (Tarasov et al., 1999).

3.4.2 Regional Indicators

Across the Tibetan Plateau, late glaciation created large alluvial fans alternating with high lake levels, affecting local humidity and precipitation across the Quaidam Basin and the Gobi. By the Younger Dryas, lakes levels lowered, corresponding to a cold period of hyper aridity and increased development of desert regions (Lehmkuhl and Haselein, 2000).
In Mongolia, conditions changed from wet to dry. Many lake basins emptied during the Pleistocene, but filled again at the onset of the Holocene. The most studied lakes are Gun Nuur\(^5\) (Fig. 3.4, 3.5) and Khovsgol Nuur (Fig. 3.4, 3.6) in the North, and Telmen Nuur (Fig. 3.4, 3.9) in the western Valley of the Lakes (An et al., 2008; Wang et al. 2004; Zhang et al., 2012). Because of this, lake sediment records from northern Mongolia receive considerable attention, even though satellite imagery suggests the presence of many Pleistocene palaeolakes in the desert belt of Northern China and the Mongolian Plateau (Yang et al., 2011). However, Mischke et al. (2005) list the many problems with lake records during this time, especially at lakes like Eastern Juyanze (Fig. 3.4) on the northern edge of the Badrain Jaran, as plagued by discontinuous sequences, frequent lack of suitable material for radiocarbon dating, and weak proxies.

\(^5\) Nuur, translated from the Mongolian Cyrillic нуур, means lake. In the literature, some lakes are referred to as “lake”, while others are referred to as “nuur” (e.g. Lake Khovsgol, Khovsgol Nuur). Others are redundantly referred to as both “lake” and “nuur” (e.g. Lake Khovsgol Nuur). Here, Mongolian lakes are referred to as nuur.
Fig. 3.5: Gun (Гүн) Nuur, in Selenge province of northern Mongolia, is highlighted in orange. Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Fig. 3.6: Khovsgol (Хөвсгөл) Nuur, in the northern province of Khovsgol, Mongolia, approximately 200 km from Lake Baikal in Russia, is highlighted in orange. Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
3.4.3 Local Indicators

In the Valley of the Gobi Lakes (Fig. 3.4 & 3.7), Lehmkuhl and Lang (2001) note two main beach lines 25-30m above Adagiin Tsagaan Nuur and Boon Tsagaan Nuur indicate a large palaeolake during the Late Pleistocene and Early Holocene. This massive lake broke into the smaller Orog Nuur.

Fang (1991) says conditions in China indicate deep freshwater lakes, evidenced by diatoms and pollens, with a cold and dry climate. However, the conditions around Lake Yainhaizi (Fig. 3.8) on the Ordos Plateau are wet, contradicting reports that the cold climate was synonymous with a dry one (Chen et al., 2003a,b). There is evidence that deserts in the Central Asian desert belt, including Mongolia, were spreading south during this time (Lioubimtseva et al., 1998).

Fig. 3.7: Valley of the Gobi Lakes: from left to right- Boon Tsagaan (Бөөн Цагаан) Nuur, Adagiin Tsagaan (Адгийн Цагаан) Nuur, Orog (Орог) Nuur are highlighted in orange. Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
The large Mongolian dune fields, Mongol Els and Khongoriin Els\(^6\), and dune fields in the Badain Jaran may have been actively mobilised by strong seasonal west-northwest winds indicating a cold, dry, and windy climate. Minor dune fields around Uvs Nuur (Fig. 3.9) may also have been active at this time (Grunert and Lehmkuhl, 2004; Grunert et al., 2000).

Dune formation was accompanied by intense fluvial processes, including palaeowater and groundwater formed during past periods, but details about impact on this climate in dune fields remains speculative (Dong et al., 2013; Grunert and Lehmkuhl, 2004; Grunert et al., 2009; Yang et al., 2004; Yang and Scuderi, 2010). Other hypothesised scenarios behind dune formation include processes due to underlying topography (Dong et al., 2013), and a relationship between wind velocity strength during cold periods, rather than one correlated to fluctuations in precipitation (Yang et al., 2011).

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\(^6\) In Mongolian, “Els” (элс) means sand. This term is used to denote dune fields, e.g. Mongol Els (Mongolian Sands) and Khongoriin Els (Singing Sands).
Fig. 3.9: The Valley of the Lakes consists of several lakes, but the main ones discussed in the text are Uvs (Увс) Nuur, Bayan Nuur, and Telmen (Тэлмэн) Nuur, as well as the major dune field, Mongol (Монгол) Els, which are highlighted in orange. Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

OSL dating of sediments from Mongol Els (Fig. 3.9) and Khongoriin Els (Fig. 3.10) show evidence of an arid Late Glacial (Grunert et al., 2009), when dune activity was high. At Bayan Tokhomiin Nuur (Fig. 3.10), at the edge of Khongoriin Els in the transitional zone between desert and desert steppe, lake levels begin to rise closer to the Holocene boundary (Felauer et al., 2012). This is similar to rising lake levels in northwest Mongolia at Uvs Nuur and Bayan Nuur, when temperatures and humidity increased around 11 ka cal. B.P. (Felauer et al., 2012; Grunert et al., 2000, 2009). At the centre of Khongoriin Els lake deposits indicate evidence of the past existence of another pluvial lake similar to Bayan Tokhomiin Nuur (Grunert et al., 2009).
Fig. 3.10: The Khongorin (Хонгорийн) Els dune field and Bayan Tokhomiiin (Баян Төхөмиийн) Nuur, in southern Omnogovi province, Mongolia, which are highlighted in orange. Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Records from the Chinese Loess Plateau indicate more dust originated from Asian deserts during the Last Glaciation due to the enhanced Siberian-Mongolia High Pressure System, while the East Asian winter monsoon strengthened and the summer monsoon weakened (Chen et al., 2003a). However, using data from the Chinese Loess Plateau is controversial because of sources potentially coming from depositional settings other than desert. These include piedmont alluvial fans and other dryland sources that vary considerably between glacial and interglacial epochs (Yang and Scuderi, 2010; Yang et al., 2011). Early radiocarbon and thermoluminescence dates from the plateau are also in dispute due to questionable laboratory procedures (Pye and Zhou, 1989).

Zhang et al. (2012) find that significant moisture increase on the Mongolian Plateau occurred in many regions ca. 1 ka later than the epoch transition (Prokopenko et al., 2007; Rudaya et al., 2009; Schichi et al., 2009). This contrasts with lake and climate records from the Tibetan Plateau showing that wet and humid conditions were already established at the beginning of the
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Holocene (Chen et al., 2003a,b; Herzschuh, 2006; Herzschuh et al., 2009; Mischke et al., 2010; Wang et al., 2010; Zhang and Mischke, 2009). This potentially reflects the presence of monsoonal precipitation and convective rain over the Tibetan Plateau, as well as enhanced precipitation over Central Asia (Zhang et al., 2012), caused by an intensified summer monsoon (Chen et al., 2003a; Lehmkuhl, 1997).

3.5 The Early Holocene (11500 cal. B.P.)

The onset of the Early Holocene witnessed filling lake basins and prevailing warmer and more humid conditions. These climate changes seem to occur roughly every 2800-2000 and 1500 cal. years (Mayewski et al., 2004), and may have been linked to plate tectonics, when ice melt caused sea levels to rise about 35m. In many areas above the 40°N latitude, melting Pleistocene glaciers caused these levels to rise by as much as 180m (Schlutz and Lehmkuhl, 2007), and were further boosted by considerable fluctuations in the Siberian High (Muschitiello et al., 2013).

3.5.1 Global Indicators

Lake levels in Sweden (Muschitiello et al., 2013) and pollen records from the Russian Altai and Siberia (Schlutz and Lehmkuhl, 2007) correlate these trends. In Southern Siberia, the region was dry as aridity persisted between 11.7-7.6 ka cal. B.P., and moisture did not increase until 7.6 ka cal. B.P. (Dirksen et al., 2007). This may have been caused by the influence of moisture carried by the NAO. However, conflicting studies based on pollen analysis and sediments from three lakes show this area as wetter and warmer during the same time frame (Blyakharchuk et al., 2004). Lake levels in the Baikal region and the Siberian Altai reached a high as early as 12 ka cal. B.P. (Blyakharchuk et al., 2004; Shichi et al., 2009).

3.5.2 Regional Indicators

In Mongolia, some areas are dry, while others are wet and warm (Blyakharchuk et al., 2004; Dirksen et al., 2007), but overall the general trend points to higher lake levels. The Dunde Ice Core from the Qilan Mountains shows the Holocene Optimum occurred between the Early and Mid Holocene across the Tibetan Plateau. This may be the case for the entire area of northeastern Tibet and the Gobi (An et al., 2006; Mischke et al., 2005).
Fig. 3.11: Location of lakes mentioned in the discussion of the Early Holocene, highlighted in orange, Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

Lakes in northern Mongolia show high lake levels at 9 ka cal. B.P. suggesting the Early Holocene was humid in this region (An et al., 2008; Blyakharchuk et al., 2004; Dorofeyuk, 1992; Dorofeyuk and Tarasov, 1998; Sevastyanov et al., 1989; Sevastyanov and Dorofeyuk, 1992). In the north (An et al, 2008; Feng, 2001; Feng et al., 2005) and west (Grunert et al., 2000) aeolian deposits are widespread. Holocene palaeosols from Gun Nuur (Fig. 3.11) in the north were formed under warmer and drier climate conditions at 8672 cal. B.P., while younger palaeosols were formed under cooler and more humid conditions (Feng et al., 2005). Other multi proxy analyses show the lake reached its lowest levels during the Early Holocene with the driest period between 10800-10300 cal. B.P., but these levels increased under wetter conditions between 10300 and 7000 cal. B.P. (Zhang et al., 2012).
3.5.3 Local Indicators

The moisture increase seen during the Early Holocene on the Mongolian Plateau was most likely due to several factors and because of the differences seen between that and the Tibetan Plateau during the same period, local factors that recycled moisture were significant.

Adagiin Tsagaan Nuur in the Valley of the Gobi Lakes (Fig. 3.11) showed high shorelines at 8.5 ka cal. B.P. (Lehmkuhl and Lang, 2001), similar to Bayan Tokhomiin (Fig. 3.11) in southern Mongolia, which shows increased precipitation and humidity, and a rise in temperatures beginning at 11 ka
cal. B.P. (Felauer et al., 2012). Degradation of permafrost sediments is evident in alluvial fan sediments in the Gobi (Felauer et al., 2012; Owen et al., 1997; Vassallo et al., 2005).

Manas Lake (Fig. 3.13) in northern Xinjiang in the Gurbantunggut shows high effective moisture between 11-8 ka cal. B.P. (An et al., 2006), coinciding with Mid Holocene increased moisture. These moisture sources are possibly from the East Asian monsoon (Yang and Scuderi, 2010).

Fig. 3.13: Manas Lake in the Gurbantunggut Desert, of the Junggar Basin in western China, is highlighted in orange. Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

In the Alashan7 Plateau, lakes were 5-15 meters higher during this period compared to present day. Dated beaches indicate lake levels were high during the Early Holocene due to the humid climate (Chen et al., 2003b). This contrasts with modern desert lakes that are currently maintained by groundwater and surrounded by mobile sand dunes (Chen et al., 2003b). Similarly, Juyanze lake levels changed due to changes in the aquifer system beneath the lake (Hartmann and Wunnemann, 2009) rather than the climate.

Juyanze formed around 10.7 ka cal. B.P. under extreme runoff events during a wet climate, which may reflect monsoon pattern variability (Hartmann and Wunnemann, 2009). As aridity increased,

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7 The Alashan Plateau extends northward from the Tibetan Plateau into the Mongolian Gobi, bounded by the Altai Mountains, where it borders the Mongolian Plateau. In the literature, some researchers refer to the area within China as the Inner Mongolian Plateau, others consider the entire area as the Mongolian Plateau.
the larger Juyanze lake separated into three smaller terminal lakes: Gaxun Nuur, Sogo Nuur, and Eastern Juyanze Nuur (Fig. 3.14) (Hartmann and Wunnemann, 2009; Mischke et al., 2002).

Juyanze lake levels may have relied on local rainfall and the lake was most likely controlled by atmospheric precipitation and water supply from the Gobi Altai Mountains (Hartmann and Wunnemann, 2009; Herzschuh et al., 2004). Furthermore, the changes at Juyanze may have been connected to changes occurring with the NAO and climate variability on the northeastern Tibetan Plateau (Hartmann and Wunnemann, 2009; Herzschuh et al., 2004).

Pollen records from the larger Juyanze provide good resolution and dating controls for northern China and southern Mongolia. During the first half of the Holocene (10700-5400 cal. B.P.), dry conditions with desert vegetation and low lake levels prevailed. This is in broad agreement with Early Holocene records from northern Mongolia. However, palaeoenvironmental reconstructions from adjacent regions of northern China point towards wetter conditions during the Early Holocene. These contrasts further demonstrate that the length and occurrence of the humid phase varied from site to site and occurred on local scales, not necessarily corresponding to regional changes (Hartmann and Wunnemann, 2009; Herzschuh et al., 2004).

Baahar Nuur (Fig. 3.15) from the Ordos Plateau shows a prolonged interval of maximum humidity in the region during the Early and Mid Holocene (9000-4000 cal. B.P.). This is in contrast with the
northern Mongolian Plateau when the most humid conditions occurred between 4000-2500 (and possibly 1650) cal. B.P. (Feng et al., 2005). Feng et al., (2005) say this discrepancy demonstrates the limitations of a generalised broader regional Holocene Climatic Optimum.

The Badain Jaran was dry before 10 ka cal. B.P., and then became wetter after 8 ka cal. B.P. (Yang et al., 2011). These humid conditions created dune stabilisation (Chen et al., 2003a, b). Evidence of deforestation of woody vegetation points to human activity in the Badain Jaran during the Early and Mid Holocene around 6 ka cal. B.P. (Fan et al., 2015). Fan et al. (2015) believe the present day desert landscape formed around 2 ka cal. B.P.

Palaeosols indicate alternating fluvial activity correlate to intensive solifluction processes and seasonal thawing and freezing cycles (Grunert et al., 2000; Serebryanny and Gravis, 1993). These correspond to observations made during the same period in the Taklamakan, Tarim Basin, Eastern Tibet, and the Mongolian Khangai Mountains (Grunert et al., 2000).

Pollen records indicate peat growth was limited to sites close to rivers and active since the Early Holocene. These pollen records, along with palaeosols suggest the limit of the Mongolian forest steppe was further south than at present, and the desert itself was shrinking (An et al., 2008; Dorofeyuk and Tarasov, 1998; Feng, 2001; Feng et al., 2005; Gunin et al., 1999; Grunert et al.,}

**Fig. 3.15:** Baahar Lake, on the Ordos Plateau in northern China, is highlighted in orange. Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
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2000; Tarasov et al, 2000), indicating wetter conditions in low elevations (Grunert et al., 2000). Corresponding to this, dunes stabilised as the warm and wet climate created vegetated areas that trapped dust (Grunert and Lehmkuhl, 2004). Additionally, Blyakharchuk et al. (2004) say after 10 ka cal. B.P. the influence of the Siberian High weakened, and the orbitally induced Pacific monsoons penetrated farther inland to the Altai Mountains.

Currently, a strengthening of the summer monsoon and the Westerlies leads to higher effective moisture in most parts of northern Asia (Felauer et al., 2012). This may have been the case during the Holocene as the Westerlies and the East Asian monsoon may have operated with different strengths across spatio-temporal boundaries (Chen et al., 2010; Zhang et al., 2012). The extent of the Westerlies’ influence over climate change is highly disputed (Chen et al., 2008; Schwanghart et al., 2009), but it is hypothesised there was a possible monsoon maximum (Chen et al., 2003a).

This monsoon maximum corresponds to similar conditions occurring in countries encircling the Arabian Sea. Low latitude vegetation development based on the observation of high atmospheric methane concentration during the Early Holocene (Chen et al., 2003a; Chen et al., 2010) supports this hypothesis.

However, Zhang et al. (2012) dispute this interpretation by insisting that a significant Holocene moisture increase in Central Asia did not occur before 8 ka cal. B.P. in the north of the monsoon influenced region. Chen et al. (2003a, 2010) link coinciding moisture increase at 8 ka cal. B.P. with rising SSTs in the North Atlantic and Norwegian Sea between 9-8 ka cal. B.P., as the cause behind significant moisture transport to Central Asia via the Westerlies. However, Zhang et al. (2012) argue that dry conditions before 8 ka cal. B.P. cannot be viewed as a characteristic palaeoclimatic feature of this region.

Many studies fail to take into account water balance, especially concerning rates of evaporation. This provides problematic interpretations about the role of the hydrologic cycle in Central Asian deserts (Yang et al., 2011). For example, local rates of evaporation versus regional rates of evaporation in deserts play very different roles. Lake levels in deserts are maintained where the mean annual rainfall exceeds 100 mm as long as other conditions are met, such as additional ground water supplies (Yang et al., 2011). This is the argument made for the Badain Jaran Desert lakes (Yang et al., 2011).

Zhang et al. (2012) advance the hypothesis of the northward shift of the current summer monsoon boundary beyond the Gun Nuur region in the Early Holocene, as an alternative hypothesis to that of Chen et al. (2008) of higher North Atlantic SSTs causing Westerlies moisture
transported across Central Asia. Blyakharchuk et al. (2004), Tarasov et al. (2000), and Wanner et al. (2008) agree with Zhang et al. (2012)’s assessment, citing the strengthening and northward displacement of the Pacific and northern monsoon boundary as influencing climate events in Mongolia after 9.5 ka cal. B.P.

High lake levels in climates that are presently arid may be attributed to the high Northern Hemisphere summer insolation during the Early and Mid Holocene. This insolation created an enhanced thermal contrast between land and sea, which in turn, created strong summer monsoons (Wanner et al., 2008). Pollen data from the Dunde Ice Core supports the hypothesis of the summer monsoon extension beyond the present limit to reach Dunde and westernmost Tibet, where it reached its maximum and retreated during the Mid Holocene (Liu et al., 1998).

Another alternative hypothesis advanced by Zhang et al. (2012) argues that the widespread delivery of meltwater from snow, ice, and frozen ground to local basins combined with the summer monsoon maximum may have caused the rapid warming of the Tibetan and Mongolian Plateau, which triggered increased precipitation. Because the Mongolian Plateau lagged behind the Tibetan Plateau by over ca. 1 ka years in terms of early moisture increase, local conditions may have been more of a significant factor instead of the regional shift of the monsoon boundary or moisture transmitted via the Westerlies.

3.6 The Mid Holocene (8.2 ka cal. B.P.)

The Early/Mid Holocene boundary coincided with an abrupt short cooling global event reflected in the Greenland Ice Core (Walker et al., 2012) and was a period of widespread aridity (Mayewski et al., 2004). However, it may also be indicative of a longer background-cooling event (Walker et al., 2012).

Following that, the Mid Holocene Optimum is defined as an effective moisture maximum without reference to temperature (An et al., 2000). An overwhelmingly number of researchers (see An et al., 2008; Chen, 2003a,b; Chen et al., 2010; Zhang et al., 2010; Liu et al., 1998; Herzschuch et al., 2004; Mayewski et al., 2004, among others) conclude climate conditions varied from region to region, and were inconsistent along spatio-temporal scales. This demonstrates the idea of an asynchronous Optimum occurring in all regions at once, since periods of warm climate contrast with cold and dry climates during the same time in different places. Some areas exhibited humid conditions coupled with increased vegetation, precipitation, and water tables (Grunert et al.,
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2000), although many lakes may not be reliable indicators of regional changes because aquifers may have provided buffers from desiccation (Hartmann and Wunnemann, 2009; Yang et al., 2011).

3.6.1 Global Indicators: Cooling Event & Optimum

The boundary cooling event has been detected in many proxy records, not only around the North Atlantic Ocean, but also worldwide including the northwest Pacific, the South Atlantic, Oman, Yemen, Brazil, Africa, the Mediterranean, China, the Tibetan Plateau, and Siberia, (Gupta et al., 2005; Mayewski et al., 2004; Walker et al., 2012). In the French Jura and Sweden, lake level regressions are observed, indicating climate oscillations across regions of Western Europe were most likely synchronous (Magny, 1992).

The Optimum in deserts translates to increased aridity, drought, and lake contraction. Central Asian arid zones retreat north, similar to the Sahara (Hartmann et al., 2009; Lioubimtseva et al., 1998). Chen et al. (2008) and An et al. (2008) say the desert regions in China were dry, but Yang and Scuderi (2010) say they were humid in the east and west. Some lakes exhibit higher levels, while others are lower (Yang et al., 2004). In the Sahara, the Optimum showed a significant increase in precipitation and a contraction in the desert boundary (Lioubimtseva et al., 1998). There was increased rainfall in tropical Africa and Chile, and widespread drought in the Amazon basin and Pakistan (Mayewski et al., 2004).

Guo et al. (2000) demonstrate a drier interval during the Mid Holocene in both northern Africa and across the Central Asian desert belt, though Chen et al. (2003a) indicate a humid Optimum in areas of higher magnetic susceptibility. Guo et al. (2000) demonstrate mechanisms attributed to orbital forcing and changes in the NAO were involved in the weakening of the monsoon, with the drier climate extending from northern Africa to eastern China.

Tarasov et al. (1998) believe changes in the Earth’s orbital geometry were the cause, and Gupta et al. (2005) claim these mechanisms related to solar output and activity. Wanner et al. (2008) present several possibilities, including orbital forcing, solar forcing, volcanic forcing, forcing through land cover change, and greenhouse gases.

However, Chen et al. (2003a) are critical of these explanations. First, they believe monsoon dynamics played a large role. These dynamics would have required an increased atmospheric convergence and rising motion, leading to increased monsoon precipitation balanced by increased upper-level divergence and subsidence, leading to decreased precipitation. They argue that discrepancies between dry versus humid intervals are due to the enhanced rate of evaporation, rather than to the higher monsoon precipitation in Inner Mongolia. This would have reduced the
effective humidity in the warm and arid climate near the northern boundary of the summer monsoon, and would account for the wide range of temperatures across Asia, correlating with the dry phases in the Alashan.

Monsoon dynamics, combined with the strengthening of the Westerlies, may have caused the humid phase directly before the Optimum, while areas bordering the region in the north and south were dry (Murad, 2012), but the reasons behind this remains unknown. Chen et al. (2003a) and Yang et al. (2011) agree the strengthened summer monsoon would have led to a significant moisture increase across the entire Central Asian desert belt.

Wanner et al. (2008) cite monsoon dynamics spilling over from the tropics and sub tropics as linked to the wet conditions seen in areas beyond the monsoon influence. However, they suggest that local conditions played an equally important role in this. This contrasts with the hypothesis of An et al. (2000) that the summer monsoon experienced a weakened state during this time due to decreased radiation.

Wang et al. (2010) conclude moisture levels decreased in areas outside of the present monsoon boundary ca. 7.5 ka cal. B.P., and earlier than in the region of the South East Asian and East Asian summer monsoons. Decreased moisture availability in Central Asia is attributed to reduced insolation (Herzschuh, 2006; Wang et al., 2010); however, Zhang et al. (2012) argue that this cannot be explained through increased SSTs in the North Atlantic region and instead, could be connected to local precipitation changes in moisture. Hartmann and Wunnemann (2009) support this, and believe relative small changes in moisture might cause drastic changes in local environments. This includes the appearance and desiccation of lakes, and the spread and retreat of desert plant communities.

Hartmann and Wunnemann (2009) raise an interesting point for the strengthened East Asian monsoon and Westerlies debate. There is an assumption that local rainfall and surface runoff are linked to the East Asia monsoon and Westerlies in the same way as they are presently. This leads to the belief that a strong monsoon results in a seasonal shift of effective moisture with more frequent contact with the Westerlies. These produce heavy local rainfall in desert regions so there is significant variability at spatio-temporal scales (Hartmann and Wunnemann, 2009).
3.6.2 Regional Indicators: Cooling Event & Optimum

Lioubimtseva et al. (1998) set the Mongolian and northwest Chinese Optimum between 8.5 and 6 ka cal B.P., resulting in increased precipitation and higher annual temperatures. However, Li et al. (2002) set the Holocene Optimum between 12 and 6.6 ka cal. B.P. in northeast Chinese deserts. There are conflicting opinions about when the Optimum began and when it ended, but it is clear that it occurred at different times in different regions, while it seemingly passed over others.

The Central Asian deserts, such as the Kyzyl Kum, experienced increased precipitation (Lioubimtseva and Cole, 2006) and deserts retreated north, similar to the northwards shift of the Sahara (Lioubimtseva et al., 1998). Sand dunes in the Central Asian Kara Kum and Kyzyl Kum deserts stabilised (Maman et al., 2011). These changes coincide with the greening of the Sahara during the Early and Mid Holocene, corresponding to increased moisture from an enhanced North African monsoon. Yang et al. (2011) believe northwest Chinese deserts, including the Mongolian Gobi, may have developed like the Sahara, and were greener than currently, evidenced by the relationship between sand seas and loess sequences. Chen et al. (2008) and An et al. (2008) suggest that desert regions during the early Mid Holocene were generally wet, contrasting with the view that they were dry (Hartmann et al., 2009). Additionally Chen et al. (2003a,b) support the hypothesis that deserts expanded in Inner Mongolia, but Sun et al. (2006) believe deserts contracted. Yang and Scuderi (2010) believe deserts in China were humid in both the east and west, though this interpretation is controversial.
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Fig. 3.16: Location of lakes mentioned in the discussion of the Mid Holocene, highlighted in orange, Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

The Tibetan Plateau shows increased vegetation and expansion of steppe over desert, supported by pollen records from the Dunde Ice Core, lasting until 4.8 ka cal. B.P. (Li et al., 2002). Forest steppe in northeast China transformed to steppe as precipitation decreased, and was impacted by human influence (Schlutz et al., 2008; Tarasov et al., 2006).

Likewise, short grasses in the Hunshandake Sandy Land suggest this area experienced increased vegetation cover due to the warmer and wetter climate. There is also evidence of a large, active Holocene palaeolake here (Yang et al., 2011).

Generally, the Mongolian Holocene Optimum is characterised as humid, with increased vegetation cover, higher temperatures, precipitation, and water tables (An et al., 2008; Grunert et al., 2000); however, was not synchronous, due to variations in the intensity of the Siberian High.

In northern Mongolia, temperatures and humidity are high at 9 ka cal. B.P. (An et al., 2008). This is supported by lake data from central and western Mongolia, including the Valley of the Lakes (Fig. 3.16), indicating major lake expansion (An et al., 2008; Lehmkuhl and Lang, 2001; Grunert et al., 2000; Tarasov et al., 2000). However, moisture levels decreased in areas outside of the present
monsoon boundary by 7.5 ka cal. B.P., and earlier than this in the region of the Southeast Asian summer monsoon and East Asian summer monsoon (Wang et al., 2010).

Conditions at Telmen Nuur (Fig. 3.16) indicate a small saline lake shallower than the lake today. This reflects the decrease in moisture balance (Peck et al., 2002). Despite the increase in humidity, both Telmen and Khovsgol (Fig. 3.16) experienced lower levels (Fowell et al., 2003). These are not consistent with other lakes during this time, which recorded higher lake levels. For example, there are recorded increases in precipitation after 7 ka cal. B.P. at Lake Baikal in Russia (Prokopenko et al., 2007).

3.6.3 Local Indicators: Cooling Event & Optimum

In northern China, Lake Yainhaizi shows a short humid phase between 6.4-5.8 ka cal. B.P. (Chen et al., 2003a). However, radiocarbon dates from the lake are challenged because of the reservoir effect, due to the inaccuracy of the dating of saline lake environments (Chen et al., 2003a). Currently, there have been no studies re-examining the contested Yainhaizi dates.

Lake level shorelines in the Badaing Jaran were at their highest, and fluvial deposits from the southern Tengger Desert indicate high lake levels around 8.5 ka cal. B.P. (An et al., 2006; Yang and Scuderi, 2010). Manas Lake (Fig. 3.16) experienced high moisture between 11.8 ka cal. B.P. (An et al., 2006).

Felauer et al. (2012) note a cooling event begins at 10.5 ka cal. B.P. and lasts until 9.5 ka cal. B.P. in the Mongolian southern Gobi Desert based on multi proxy data from Bayan Tokhomiin Nuur (Fig. 3.15). Lake levels were 8.8 m above the modern lake (Grunert et al., 2009). It follows a similar pattern as other local lake basins in Mongolia at Uvs Nuur (Fig. 3.16), Bayan Nuur (Fig. 3.15), Khoton Nuur (Fig. 3.15), and lakes in northwest China at Gaxun Nuur (Fig. 3.17) and Bosten Hu (Fig. 3.16) (Grunert et al., 2009).

OSL dating of dunes at Mongol Els and Khongoriin Els indicate a humid Mid Holocene (Grunert et al., 2009). On the northern edge of Khongoriin Els an endorheic depression suggests a 15m freshwater lake existed (Grunert et al., 2009) and soil development in mountains and basins prohibited movement of dunes (Grunert and Lehmkuhl, 2004).
Vegetation increased in other areas such as Lake Yainhaizi (Fig. 3.15) (Chen et al., 2003a). In this area, the Optimum occurred at 8 ka cal. B.P., while it was still arid in other areas such as the Tengger (Chen et al., 2003a; Guo et al., 2000). Yainhaizi shows evidence of high temperatures corresponding to sites in the Okinawa Trough and the South China Sea, but contrasts with other sites in China and Taiwan (Chen et al., 2003a).

An et al. (2006) say the climate was generally wet up to 6000 cal. B.P. in Xinjiang, the Alashan Plateau, and the Loess Plateau, but local records at some sites, such as in the Taklamakan Desert, show the climate to be dry. These records are not necessarily reflective of regional climate changes.

It is unclear whether some lakes experienced periods of complete desiccation during the Holocene (Yang et al., 2011). Yang et al. (2011) believe that most dunes were vegetated and active sand dunes were rare during this time, especially at Khulun Lake (Fig. 3.18) in Inner Mongolia. There was most likely a moisture increased in the eastern Badain Jaran Desert, the
Tengger Desert, and the Gurbantunggut Sandy Land, but moisture levels are unknown (Yang et al., 2011).

In the Badain Jaran, which was generally wetter (Yang et al., 2011), the Eastern Juyanze Lake (Fig. 3.17) formed between 5400-4000 cal. B.P. Hartmann and Wunnemann (2009) say this was due to lithological settings like aquifers, catchment characteristics, and a stabilised water table rather than from wet climate conditions. Because of these local conditions, Hartmann and Wunnemann (2009), in agreement with Yang et al. (2011), believe that many lakes may not necessarily be reliable indicators of regional Holocene changes, especially where aquifers provided buffers from desiccation.

Herzschuh, et al. (2004) show the Optimum occurred at different times in the northern part of China. Chen et al. (2003a,b) agree with this assessment because the Optimum in the Alashan Plateau occurred separately from other areas of China, such as the Ordos Plateau. The Alashan was drier in varying degrees. The Guliya Ice Core from the Tibetan Plateau shows this region experienced cooling (Chen et al., 2003b).
3.6.4 End of the Optimum

A drought contiguous with changes in NAO circulation interrupted the Optimum. This signalled an abrupt end to the African Humid Period, including increased desiccation of the Sahara, as well as the temporary advancement of North American prairies (Fedotov et al., 2004). The Mediterranean region and Central America also experienced increased aridity (Wanner et al., 2008).

In Asia, a humid beginning turned dry but this dry period varies from place to place in an asynchronous pattern (An et al., 2008), lending credence to the debate that the Optimum was not a global synchronous event. The drought intensity increased from north to south, particularly in arid and semi-arid zones, increasing desert aridity (An et al., 2006; An et al., 2008). The evidence for this is seen in falling lake levels, pollen, and diatom records (An et al., 2008). Additionally, increased aridity in Asia corresponds to higher dust flux of aeolian dust deposition in the northwest Pacific Ocean (Pye and Zhou, 1989).

Fig 3.19: Khoton (Хотон) Nuur, the westernmost lake of Mongolia, in Bayan Olgii province, is highlighted in orange. Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

From 5 ka cal. B.P. onwards, high lake levels are followed by falling lake levels, which indicate lower temperatures and decreased precipitation (Grunert et al., 2000). During this phase, dunes were remobilised and soil formations were covered (Grunert et al., 2000). Records suggest the
Mid Holocene experienced a drought at Khoton Nuur (Fig. 3.19) and Uvs Nuur (Fig. 3.16), when the climate turned cool and dry after 5 ka cal. B.P., though the beginning of this dry interval varies from place to place, as the intensity of this drought increased from north to south (An et al., 2008). This is supported by records from Telmen (Fig. 3.16), which was at a standstill between 6100-4600 B.P. (Komatsu et al., 2001).

Telmen showed a higher aridity index at 6100 cal. B.P., despite the increased summer monsoon (Fowell et al., 2003). Uvs Nuur shows strandlines stood at 10-4 m above the present lake level, indicating a short-term rise during a period of generally falling water levels (Grunert et al., 2000). Khovsgol and Gun (Fig. 3.16) also record this short-term rise of higher lake levels as well as increased vegetation cover, which point to enhanced precipitation and higher temperatures as well as a pattern of unstable climate conditions between 7000-2500 cal. B.P. (Fedotov et al., 2004; Grunert et al., 2000; Zhang et al., 2012). Drier conditions are not reflected in lake records from western Mongolia and Xinjiang (Zhang et al., 2012).

Archives from Bayan Tokhomiin (Fig. 3.16) show aridity in southern Mongolia increased after 3.8 ka cal. B.P. (Murad, 2012). These drought conditions further led to the desiccation of the entire southern Mongolian Plateau (Chen et al., 2003a).

Fig. 3.20: Bosten Lake, in western China, is highlighted in orange. Ulaan Nuur is highlighted in blue. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community; Inset Map: ArcGIS 10.5.1; Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.
There are conflicting interpretations for Bosten Lake (Fig. 3.20), which indicates dry and humid conditions (Yang and Scuderi, 2010). Bosten Lake was warm and wet between 7-4 ka cal. B.P., consistent with records from the Tibetan Plateau, which was wet until 5000 cal. B.P., and the Loess and Alashan Plateaus, which were wet until 4000 cal. B.P. (An et al., 2006). A regression is recorded at 5.5 ka cal. B.P. (Felauer et al., 2012). Other lakes in the northern Gobi also appear to thrive in humid conditions until 4000 cal. B.P. (Felauer et al., 2012).

Desiccation occurred across the Alashan Plateau, the Mongolian Plateau, and the Tengger Desert (Chen et al., 2003 a,b; Herzschuh et al., 2004). Lakes in the eastern Tengger either dried or hit low levels around 7-9 ka cal. B.P. and the drought interval is evident at the present summer monsoon boundary (Chen et al., 2003a).

Eastern Juyanze (Fig. 3.16) exhibited high lake levels at 5100 cal. B.P., evidenced by increased long distance transported pollens and mountain taxa, which thrive under increased moisture conditions (Mischke et al., 2005). High lake levels at Eastern Juyanze and other sites may have been due to charging of local aquifers and groundwater, rather than increased available precipitation (Mischke et al., 2002; Mischke et al., 2005). Afterwards, the lake shrank and became shallower, which may indicate drought conditions (An et al., 2008).

Records show inconsistencies between northwest China and Mongolia in timing and moisture supply, as well as changes in temperatures. Felauer et al. (2012) attribute these variations to several factors, which create mixed signals, such as river and glacier activities. An et al. (2006) say these discrepancies may be due to rapid dry climate changes, which occurred in a generally wet background where the timespan was shorter than wet periods. Additionally, deserts including the various ones of the Gobi have different aridity indices, in which the rates of evaporation exceed precipitation (An et al., 2006). However, opinions vary and are contradictory over the severity of desertification (Yang et al., 2011).

3.7 The Late Holocene (4.2 ka cal. B.P.)

The Late Holocene coincides with widespread mid and low latitude aridification (Walker et al., 2012). Most Mongolian records show this as beginning as humid, evidenced by high lake levels, aeolian sediments, pollen records, and palaeosols. Dunes were reactivated across Mongolia (Felauer et al., 2012; Grunert et al., 2000). However, the time at which this occurs varies from place to place, but overall, there appears to be smaller oscillations, possibly triggered by summer monsoons (Yang et al., 2004). The deserts show more variations possibly due to changes in, and
influences of the Westerlies (Yang et al., 2004), as well as the southward shift of the Intertropical Convergence Zone and the weakening of monsoon systems in both Africa and Asia (Gupta et al., 2003, 2005; Wanner et al., 2008).

3.7.1 Global Indicators

This aridification event is reflected in worldwide proxy records in North America, the Middle East, China, Africa, South America, and Antarctica (Walker et al., 2012). This event was possibly caused by the southward migration of the Intertropical Convergence Zone (Mayewski et al., 2004; Walker et al., 2012), and is consistent with increased strength of the Westerlies over the North Atlantic, as well as increased precipitation and increased glacial readvances in North America (Walker et al., 2012). Additionally, the Pacific may have cooled, creating the modern El Niño Southern Oscillation, which became pronounced after 4 ka cal. B.P., which would have weakened the Asian monsoon, resulting in widespread drought (Walker et al., 2012).

At 4.2 ka cal. B.P. drought conditions are evident in records from North America, as well as increasing aridity in the Mediterranean, the Middle East, the Red Sea, the Arabian Peninsula, Africa, South America, Australia, India, the Tibetan Plateau, and China (Walker et al., 2012). Additionally, a weakened South Asian monsoon is recorded at 4 ka cal. B.P. in the Arabian Seas, China, and India. A strengthened East Asian summer monsoon at 4.2 ka cal. B.P. is recorded in Taiwan (Walker et al., 2012). Cooler and wetter conditions at this time are recorded in Europe, especially in Britain and Ireland (Walker et al., 2012). This aridification event may have led to the development of the desert environments, as they are present today (Yang et al., 2011; Wanner et al., 2008).

3.7.2 Regional Indicators

This period corresponds to a brief period of glacier readvances and solifluction (enhanced rainfall and lower temperatures) in the Tibetan and Mongolian Plateaus (Grunert et al., 2000, Felauer et al., 2012, Mischke et al., 2005, Van Geel, 2004). This led to increased desertification and accelerated aeolian processes (Felauer et al. 2012; Grunert et al., 2000). Permafrost declined and river incision was dominant across Mongolia (An et al., 2008).
Humid conditions continued at Telmen (Fig. 3.21, Valley of the Lakes) at 4390 cal. B.P., with greater effective moisture than at present, including higher lake levels (Peck et al., 2002). At 4.1 ka cal. B.P., drier conditions prevailed at Gun Nuur (Fig 3.21) (Zhang et al., 2012) while Orog Nuur (Fig. 3.21, Valley of the Gobi Lakes) records increased aridity, aeolian processes and lake desiccation at 4 ka cal. B.P. (Felauer et al., 2012). Zhang et al. (2012) see these conditions as significant because they correspond to wider regional lake changes across Mongolia and Eurasia. Drier conditions are recorded around the same time in other lake records, with several intermediate phases of short-term wet and dry periods. The drying phase is also confirmed in the Dunde Ice Core from 4 ka cal. B.P. onwards (Mischke et al., 2005).

3.7.3 Local Indicators

In Mongolia and the Altai and Gobi Altai Mountains, Rudaya et al. (2009) and Miehe et al. (2007) hypothesise that human activities intensified aridification. They support this with evidence from the Gobi Gurvan Saikhan mountain range in Omnogovi province, which exhibited evidence of deforestation and the presence of livestock before 4350 cal. B.P. Despite aridification, this area remained wet with a large vegetation cover (Miehe et al., 2007). Today, the Gobi Gurvan Saikhan
remains an isolated forested area in the desert steppe, where the nearest forested area is over 320 km away in the Gobi Altai. The presence of *Tribulis terrestris*, a weed associated with animal husbandry in the Old World Desert belt, was already widespread in the Gobi Altai before the 4350 cal. B.P. (Miehe et al., 2007). At this time, drops in precipitation and human activities caused the decline of the Gobi Altai drought resistant *Larix sibirica* forest, which was once connected to the larger taiga forest, at 4350 cal. B.P. and 3800 cal. B.P. (Miehe et al., 2007).

Miehe et al. (2007) note that in other arid regions, there are similar patterns of decreasing forests, caused by both widespread aridification and evidence of increased grazing pressures. These patterns are also observed in Pakistan, Nepal, southern Tibet, and southern Central Asia. Additionally, they may have been similar to patterns observed in the Saharan woodlands and the western desert belt (Miehe et al., 2007).

In northern China, Lake Yainhaizi (Fig. 3.21) records a humid phase between 4.3-3.2 ka cal. B.P. (Chen et al., 2003a; Mischke et al., 2005). Likewise, the Badain Jaran remained humid until 6 ka cal. B.P., followed by increased desertification to present day conditions (Chen et al., 2003a; Yang et al., 2011). Eastern Juyanze lake levels dropped at 4100 cal. B.P. Local and regional pollen production and sparse vegetation cover at 3200 cal. B.P. may indicate a shift to arid conditions (Mischke et al., 2002; Mischke et al., 2005).

In the Gobi, OSL dating of sediments at the Khongoriin Els dune field confirms a shift to increased aridification and dune remobilisation, with evidence of deposition during the Late Holocene (Hulle, 2011; Hulle et al., 2010). Dunes were reactivated as lacustrine sources, such as Bayan Tokhomiin (Fig. 3.21), diminished. These desiccated lakes provided new sources for aeolian sediments (Hulle, 2011; Hulle et al., 2010; Grunert and Lehmkuhl, 2004).

It is evident that specific local sites responded in different ways. Many of these sites retained wet conditions, despite general increased aridification. The Dunde Ice Core demonstrates this uncertainty. There are indications of periods with enhanced precipitation, which show the aridification trend was not consistent in all regions (Yang et al., 2011). The weakening of the summer monsoon and increased solar radiation may have led to an increase in humidity, and a decrease in evaporation in response to dropping temperatures (An et al., 2008).

For example, Chen et al. (2003a) say the interval between 4.3-3.2 ka cal. B.P. was actually the coldest phase during the Holocene, in which evaporation decreased as temperatures dropped. This corresponds to the wet phase observed across the Alashan Plateau. This is possible at some sites, where patterns could indicate wetter periods around 2.5 ka cal. B.P., in contrast with
regional trends. Several lakes retained high lake levels, while others exhibit desiccation. This demonstrates that, because of their unique characteristics, lakes respond in nonlinear and unpredictable ways to stress (Zhang et al., 2012).

An et al. (2008) cite the summer monsoon as moving northwards as the main cause behind aridification in wet regions, while Yang et al. (2004) cite changes in the Westerlies as the main cause. In these regions, the rate of precipitation remained high, but the rate of evaporation exceeded the rate of precipitation, even under the expanded monsoon (An et al., 2008). This change in the summer monsoon around 4350 cal. B.P. explains the decrease of forests in the desert steppe (Miehe et al., 2007), including the end of the *Larix sibirica* forest in the region of the Gobi Altai.

The climate systems, affected by solar output, solar activity, and the redistribution of solar energy, may have been the cause of the southward shift of the Intertropical Convergence Zone. Accompanied by a weakening of monsoon systems in both Africa and Asia, this may have led to increased dryness and desertification on both continents (Gupta et al., 2003, 2005; Wanner et al., 2008).

### 3.8 Summary of All Indicators

The following cumulative charts (Fig. 3.22, 3.23, 3.24) illustrate some of the most relevant indicators mentioned in the text. The major global indicator is the Greenland Ice Core. The regional indicator includes the Dunde Ice Core in the Tibetan Plateau. Local indicators come from lakes and dune fields across Mongolia and northern China.

Fig. 3.22 demonstrates global indicators in comparison to the local trends seen across the Gobi Desert. The Greenland Ice Core (Fig 3.22) and the Dunde Ice Core (Fig. 3.23) indicate periods of wet and dry in temperature and humidity. This is consistent across all global indicators, where all exhibit rising temperatures. The first, modelled insolation, shows temperatures beginning as higher during the Younger Dryas between 15°-65° N latitudes (Fig. 3.22; after Berger and Loutre, 1991). The Gobi Desert lies between 40° and 45° N. This is consistent with the last graph, temperature reconstruction for 30°-90° N, which shows that global temperatures are slightly cooler in comparison to the Gobi (Fig. 3.22; after Marcott et al., 2013). This means the area of the Gobi Desert was warmer than the global average.

Fig. 3.23 shows three kinds of lake data. The first is geomorphological (Grunert et al., 2000), the second is modelled (Zhang et al., 2012), and the third is salinity (Hartmann et al., 2009). This lake
data may be compared, but it is difficult to synchronise, in part, due to local conditions, different sampling techniques to evaluate the data and the gaps in the data, the number of calibrated C14 dates, and the uncertainty of the C14 dates. Evaluation of the reliability of this data is in the order of geomorphological, modelled, and salinity, where geomorphological is the most reliable, and salinity is the least reliable.

Relative heights are modelled levels, while the heights in meters (seen in Grunert et al., 2000) are from dated indicators, such as grain size. Relative heights are not as accurate as these dated heights. The dated heights are a better indicator of how the lake actually was, rather than the modelled relative heights, so it is possible that these models are not correct. In this case, the geomorphological based data of Grunert et al. (2000) is more reliable than the modelled data of Zhang et al. (2012).

Fig. 3.24 demonstrates periods of dune activation and stabilisation from two major dune fields in Mongolia: Mongol Els and Khongoriin Els (Hulle, 2011). Periods of deglaciation since the Last Glacial Maximum is depicted on the bottom (Lehmkhul and Lang, 2001; Owen et al., 1997).
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Fig. 3.22: Global indicators of Greenland Ice Core records, using carbon, sodium, and oxygen, and modelled insolation. The global controls demonstrate variations during the Holocene. These are compared to local climatic trends in the Gobi.
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Fig. 3.23: Regional (Dunde Ice Core) and Local (Lakes) indicators. Continued from Fig. 3.21. This chart demonstrates local lake indicators, using dated geomorphological shorelines, modelled heights, and salinity. Lake salinity includes data from China (Yanhaizi and Juyanze) and Mongolia, and compared to the Dunde Ice Core in Tibet, which is a regional indicator.
The Holocene is generally more humid than the preceding Younger Dryas, with higher lake levels, lower salinity, and higher temperatures. Fig. 3.23 indicates higher lake levels mean higher precipitation, more dunes mean more aridity, and higher salinity means more aridity. Both Bayan Nuur and Uvs Nuur exhibit higher lake levels, which indicate higher precipitation. There is a drop at 9-10 ka cal. B.P., before the 8.2 ka cal. B.P. boundary event. This could have two meanings. First, there is possibly a problem with the dating methodology, or the drop is real and indicative of a warning signal of the impending cooling period. At Gun Nuur, dates start at 9.8 ka cal. B.P., and not before. High lake levels are going down during the Early Holocene where a high period is between 10-7 ka cal. B.P. Juyanze exhibits lots of instability during the first part of the Holocene. This may be due to a problem with proxies.

These are largely in agreement with events occurring at Ulaan Nuur, where the lake also experienced higher levels, along with a wide watershed, and several active tributaries, including the Ongi and the south-east channel. Forest steppe was the dominant vegetation, particularly between 11500-10500 years ago.

Fig. 3.24 indicates deglaciation. Since the Last Glacial Maximum, there has been warming globally, as indicated in Fig. 3.22 (Marcott et al., 2013). In Mongolia, glaciers in the Khangai Mountains

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Fig. 3.24: The top figure indicates periods of dune activity and stabilisation. Dune fields are stable until the end of the Mid Holocene. On the bottom, periods of deglaciation since the LGM are depicted from the Khangai Mountains, where the Ongi River originates, and in the Gobi Desert.

Dune fields

- Mongolia
- Khongorin En

Deglaciation since Late Glacial Maximum (LGM)

- Khangai Mountains
- Gobi Desert (South Mongolia)

21 000 BP = Maximum extent of Pleistocene glaciers at 2200m (Lehmkuhl and Long, 2001)

Development of permafrost

22 000 BP

Degradation of permafrost

(after Ouwien et al., 1997)
reached to 2200m (Lehmkuhl and Lang, 2001). During the Late Pleistocene/Early Holocene, these glaciers were melting and most likely bringing lots of glaciofluvial water and sediment discharge to Ulaan via the Ongi River. With conditions warming in the Gobi in southern Mongolia, soils are also affected by these rising temperatures. The Gobi soil in southern Mongolia was unfreezing, with a degradation of permafrost between 13000 cal. B.P. and 10000 cal. B.P. (Owen et al., 1997). Water from melting glaciers, permafrost, and precipitation may have contributed to the larger Ulaan Nuur size.

At 8.2 ka cal. B.P., temperatures drop across all records (Fig. 3.22). This is consistent with the boundary-cooling event occurring at the end of the Early Holocene. Uvs Nuur and Bayan Nuur (Fig. 3.22) drop, consistent with this event. Dunes fields (Fig 3.24) remain stable. Gun Nuur shows a drop at the boundary event, with drier conditions between 6-7 ka cal. B.P. This exhibits a trend with local variation, although this may have to do with the methodology of relative heights. Juyanze exhibits instability for the last 5000 years, but this is information about humidity rather than actual height.

The Early Holocene’s high lake levels would have set optimal conditions in arid and semi-arid areas around the Gobi. Advanced palaeohydrological networks may have existed, while dune fields were stabilised. Holocene evidence shows there is a persistent link between the North Atlantic climate and the East Asian monsoon, which affected the global climate and contributed to changes over Mongolia. Additionally, the Holocene North Atlantic is characterised by repeating but less severe cold spells, suggesting a link between the Southeast Asian monsoon and the East Asian monsoon, accompanied by small amplitude changes in the North Atlantic (Gupta et al., 2003).

Changing conditions during the end of the Mid Holocene saw a gradual decrease in lake levels (Fig. 3.23). Some lakes have small increases, while others are stable. Mischke et al. (2010) show conditions gradually become more arid. Telmen is wetter through time, while Khovsgol is unstable. The Dunde Ice Core shows an increasing trend towards aridity.

Ulaan Nuur records increasing aridification, in agreement with the trends seen at other lakes. This is accompanied by slightly more humid conditions and vegetation cover, predominately steppe, than it is currently. The influence of the Ongi and other tributaries were decreasing, and the lake was slowly shrinking (PADM: Fig. 3.3, Sternberg and Paillou, 2015).

The major event of the Late Holocene is the aridification event at 4.2 ka cal. B.P. Global records show this is not synchronous (Fig. 3.22), although there is a general trend of decreasing...
temperatures since the Early Holocene. There are slight dips in temperatures at this time. Dunes are activated at the end of the Mid Holocene into the Late Holocene, another possible warning signal of the coming aridification event.

This also corresponds to increased small drops in lake levels. However, some lakes, like Telmen in the Valley of the Lakes and Eastern Juyanze in northern China, exhibit extreme fluctuating periods of stability and instability. Bayan Nuur remains stable, while Uvs Nuur dramatically drops. At 3000 cal. B.P. all lakes levels experience sharp drops. Some manage to stay stable probably due to local factors like groundwater tables, or microclimate variations, but others enter desiccation.

At Ulaan Nuur, the lake was much smaller, with a shrinking watershed, and only the influence of the Ongi River ending at the middle of the lake. Vegetation was desert steppe with increased arid conditions, comparable to those existing today. At the same time, deglaciation and reduced precipitation indicates a lack of water (Fig. 3.24), when combined with increased aridity, this contributes to lake desiccation and shrinking lakes, observed not just at Ulaan, but also at other lakes in the region. It would be necessary to establish when the permafrost and glaciers finished melting.

Solar variability from orbital forcing may be one of the most important factors affecting climate change, but further study needs to be completed (Mayewski et al., 2004). Additionally, changes in the poles affect climate. When the poles cool and polar atmospheric circulation intensifies, the distribution of moisture bearing winds, like the Westerlies, and their capacity to carry moisture are affected (Mayewski et al., 2004). The aridity observed during the Late Holocene could be due to several factors including weakening monsoon systems, reduced evaporation from cooler oceans, and weaker thermal convection over tropical landmasses (Mayewski et al., 2004).

Overall, this environmental review has established that the local Ulaan Nuur area experienced more hydrological activity between the Early to Mid Holocene (Epipalaeolithic/Mesolithic-Neolithic) which would have affected the landscape, including vegetation. This demonstrates that hunter-gatherers would have occupied a landscape that was not very marginal compared to present day conditions (Chapter 1).

However, Ulaan Nuur and other environmental proxies during the Mid Holocene indicate a gradual trend towards aridification. This aridification was not pronounced until the end of the Mid Holocene around 4.2 ka cal B.P., with proxies indicating increased dune activity directly before and after (Fig. 3.24; Hulle, 2011). Ulaan Nuur records a shift towards a desert steppe environment coinciding with this (Lee et al., 2011). This would have corresponded to the Eneolithic/Early
Chapter 3: The Mongolian Holocene

Bronze Age, when groups were gradually shifting their subsistence strategy to herding. Conditions reached almost comparable present day environmental conditions during the Late Holocene around 3000 cal B.P., while herding was adopted as the primary subsistence strategy by at least 3.4 ka cal. B.P. (Janz et al., 2017).

Sternberg and Paillou (2015) have shown that Ulaan Nuur was a larger lake, influenced by several tributaries, including a major south-east channel, and a reinterpretation of the ULB core in the PADM (Fig 3.3; pg. 60) within the context of a larger lake and wider watershed supports this. To visualise what sort of hydrological conditions may have prevailed between the Early and Late Holocene, and how hydrological changes may have affected the anthropogenic landscape, the next chapter will examine the dynamic processes that have shaped the landscape and introduce the methodologies used to evaluate these. This will primarily focus on identification of the potential hydrological corridors in which people around Ulaan Nuur operated. This will be accomplished through an analysis of the landscape and identification of the major palaeochannels using satellite imagery (Chapters 4 & 5), a GIS based hydrology model (Chapters 4 & 6), which presents a potential scenario of the past hydrological landscape, as well as the identification of the potential palaeoshorelines of Ulaan Nuur (Chapter 6). These are mapped in relation to the known local archaeological proxies presented in Chapter 2. Finally, these results are integrated into the field survey design (Chapter 7).
Chapter 4: Methodologies

4.1 Introduction

The previous chapter reviewed environmental proxies and how these may be tied to the archaeological proxies reviewed in Chapter 2. This chapter introduces the analytical methodologies used to evaluate the modern landscape morphology and the past landscape morphology.

The purpose of this is twofold. First, these methodologies will aid in shaping the field survey strategy, further discussed in Chapter 7, while the results of these methodologies are discussed in more detail in Chapters 5 and 6. The archaeological fieldwork will be conducted as a non-destructive survey and will allow for later analysis and interpretation of the identified archaeological areas of activity within the theoretical framework.

Secondly, these methodologies will provide an improved understanding of local environmental and hydrological contexts in which to understand the past regional human activity. This further addresses the sub-questions posed in Chapter 1. The results will create the link between the hydrological and geomorphological evidence to the surface artefact distribution of the past and present landscape, and thus allow an examination of local human-environment relationships. To begin to do this, it is necessary to understand regional landscape processes.

An evaluation of regional human-environment interactions requires a strong understanding of the regional landscape. The landscape is shaped by four major dynamic processes: human activities, animal activities, particle flows, and hydrological flows (Forman, 1995a: 216). Human-landscape interaction is a constant temporal and spatial flux necessitating approaches that consider both the archaeological and geomorphological landscape. Archaeological evaluations of site setting and economic area must consider ecological tenets like geomorphologic and taxonomic processes, climate, soils, and vegetation (Butzer, 1971). This includes how sites are related on local and regional scales that enable the creation of a regional mosaic consisting of corridors of movement.

Corridors of movement are paths of migration closely linked to ecological corridors. In desert landscapes, these are hydrological corridors (Forman, 1995a; Hiscock and Wallis, 2005; Veth, 1989). These corridors represent routes and structures of cultural and economic exchange shaping the spatial arrangement of human activities (Conolly and Lake, 2006; Forman, 1995a). A deeper historical understanding of areas of less accessible resources and transitional and
boundary areas creates a better representation of the spatial patterns in human movements across varying scales.

Scale is important as varying degrees of spatial variation create different realities depending on the scale of the spatial sampling dataset (Atkinson and Tate, 2000). Environmental processes are scale dependent and resulting patterns are nested (Burrough, 1987, 1993) or hierarchical (De Boer, 1992). At one scale, patterns may be homogenous but at another they may appear heterogeneous, or regular and irregular, where different scales are controlled by different factors. This is why it is extremely important to carefully choose the appropriate scale that fits the research question (Tate and Atkinson, 2001, De Boer, 1992).

From an archaeological viewpoint, surveys of regions are influenced by scale. The choice to examine landscapes at micro (bottom up) or macro (top down) resolutions and intensively or extensively influences the archaeological interpretation of spatial patterns (Atkinson and Tate, 2000; Caraher et al., 2006; Sanders, 1956; Wilkinson, 2000; Adams, 1965).

For example, intensive surveys are not able to address macro levels of human patterns because they focus on fine spatial resolutions and contribute to creating fuzzy ideas of regions, where movement is not confined to a single analytical scale (Kantner, 2008; Kowalewski, 2008; Matthews and Glatz, 2009). A multi-scale approach is more inclusive because of its ability to examine several spatial scales, completed through an integrated survey; however, it is necessary to know the dataset extremely well in order to determine these scales (Tate and Atkinson, 2001). Such multi-scalar approaches include statistical methods like the modified Whittaker multi-scale sampling plot of Burger and Todd (2006), and Bevan and Conolly’s (2006) Ripley’s K method.

Keeping scale in mind, landscape thus becomes accessible to spatial interpretation, spatial analysis and modelling, and field measurement. In this chapter, these multi-temporal approaches are implemented through remote sensing, GIS, and field survey methodologies.

The first methodology, remote sensing, analyses geospatial imagery to identify key hydrological and geomorphological processes present in the current landscape. These analyses identify potential corridors of movement, particularly around the palaeoshoreline, palaeochannels, and spring belt, which will contribute to a model of movement of people within the landscape based on these hydrological corridors. Secondly, a GIS-based hydrology model presents a potential scenario of how the past hydrological landscape may have appeared. The model will allow for an examination of where water may have flowed in the past, including the hypothesised location of the major river mouths. The results of this model may be compared to the results of the remote
Chapter 4: Methodologies

sensing work. Using the results of the satellite imagery and GIS based hydrology model, it is possible to track the spatio-temporal evolution of Ulaan Nuur, from a large lake to a small one. Based on this evolution and mapped alongside known archaeological sites in the area, a hypothesis of the location of the Holocene coastline is formed. The final methodology, a field survey strategy informed by the results of the previous methodologies, is created. This takes into account the hypothesised palaeoshoreline, palaeochannels and river mouths, spring belt corridors, and identified key landscape processes and features.

4.2 Remote Sensing

This section has two purposes. First, it focuses on identifying geomorphological processes and hydrological corridors within a portion of the Ulaan Nuur regional mosaic. A mosaic examines all elements in the landscape structure. Satellite imagery provides an excellent method to examine and create a landscape mosaic because it is possible to measure how the landscape changes over space, time, and scale. Like other regions, the Ulaan Nuur region has a single microclimate, but contains ecologically dissimilar landscapes (Forman, 1995a, b).

Secondly, human activities tie this region together and this material culture can be traced in the archaeological record. Using remote sensing in the study allows for an examination of how useful it is to understand the complexities of the landscape by identifying areas of interest and high potential for archaeological activity, to explore areas where past fieldwork is limited or non-existent, and to evaluate the topographical contexts for sites, including landscape characterisation and visibility.

To begin this regional evaluation, several scales are examined from fine to coarse focusing on the spring belt, the palaeochannels, and the hypothesised palaeolake shoreline. The fine scale examines the pattern of a small area, while the coarse or broad scale examines a larger area. These are evaluated over a large temporal scale through a space-time principle approach. This idea holds that patterns at broader resolutions are more stable than those at fine resolutions, which are more variable over space and time (Atkinson and Tate, 2000; Forman 1995a: 8-9).

In archaeology, site relationships and chronology are often interpreted through stratigraphy and material culture. In the Gobi Desert, this is extremely difficult as sites are heavily eroded and deflated. Additionally, artefacts from many archaeological periods are often found mixed on the surface. Using geomorphology as an index is an alternative approach to the evaluation of site
relationships. Examples of geomorphic evidence include hydrological and aeolian processes (Butzer, 1971).

In arid and semi-arid environments, the majority of water is subsurface, and surface water is scarce or episodic. Corridors of water may be defined as strips of vegetation that encloses a channel with flowing water, including the channels themselves, the adjacent banks and the floodplain, where the spring, stream, or river is the major landscape feature (Forman, 1995a). In the Ulaan Nuur region, this includes vegetation indicative of groundwater flow centred around the spring belt, palaeochannels, and the palaeolake shoreline. These hydrological corridors provide drinking water, animal dispersal routes, important riparian habitats, flood control, sedimentation and soil erosion controls, desertification prevention, and windbreaks (Forman, 1995a). Connectivity and width of these corridors provide the most dynamic areas of the landscape, but may be adversely affected by gaps or breaks, droughts, erosion, sedimentation, and fluctuating vegetation and fish populations (Forman, 1995a).

These corridors are spatially identifiable as unique structures because they provide five major landscape functions. According to Forman (1995a) corridors provide diverse habitats for animals; function as conduits where entities such as humans move along it (often along meanders rather than the entire channel length); create a filter or barrier where humans may find it more difficult to pass between patches on opposite sides, leading to cultural cohesion and higher cultural diversity on one side of the corridor; act as a source or an area that exudes objects; acts as a sink or an area that absorbs objects, such as dune accumulation.

ENVI¹ 5.3 imagery software is used here for the two major analyses (Fig. 4.1). First, a visual analysis² of landscape features, including band manipulation was completed with GeoEye-1 imagery obtained through a grant from the DigitalGlobe Foundation and imagery freely available online at varying resolutions from open source map websites³. Secondly, image classification of the landscape was completed using the GeoEye-1 imagery. These images all demonstrate temporal and spatial differences affecting visibility and landscape conditions.

¹ Exelis Visual Information Solutions, Boulder, Colorado. A software that extracts information from geospatial imagery.
² A visual analysis simply means visually examining and interpreting the images. This requires the user to have excellent background knowledge of the study area.
³ The main open source map sites used were Bing Maps (www.bingmaps.com/maps) and Google Maps & Earth Pro (maps.google.co.uk).
Fig. 4.1: Summary of the data types used in this section, what software was used, and the key features examined. Geo-Eye 1 imagery and open source maps were used in ENVI 5.3 to examine visual indices, while Geo-Eye 1 imagery was used in ENVI 5.3 to create an image classification, aiding in analysis of topography.

4.2.1 Geo Eye-1

Geo Eye-1 (Fig. 4.2) is a commercial fine-resolution satellite system owned by DigitalGlobe (www.digitalglobe.com), providing highly detailed coverage for small image footprints. It acquires data across the optical and infrared regions of the spectrum and is technically comparable to World View 2, Ikonos, and Quickbird sensors.
Fig. 4.2: GeoEye-1 acquired imagery spectral wavelengths compared to general spectral wavelengths and general information about XS and PN acquired imagery. Spectral profile: ENVI 5.3.

Eight strips of several tiles (Fig. 4.3) of the Ulaan Nuur study area were received in geotiff format (4 panchromatic (PN) at 0.5m resolution; 4 multispectral (XS) at 2m resolution pansharpened), but consistent with the chosen survey area of this study, in this dissertation only 2 of these (1 PN; 1 XS) covering the south west area of Ulaan Nuur will be examined in detail. These tiles were received as both a composite (.til) and individually (.tiff).
Fig. 4.3: Location of the composite strips received of the study area, taken at different times during the year. 4 XS strips at a resolution of 2m, and 4 PN strips at a resolution of 0.5m resolution were received of the study area. Two strips overlap in some areas. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

4.2.2 Band Function

The GeoEye-1 imagery has four bands. This includes two near infrared at resolutions of PN 0.5m and XS 2m. Each wavelength and band combination is applicable to different landscape questions. The blue-green wavelength is applicable to water studies including water depth and quality, soil and vegetation differentiation (such as differentiation between coniferous and deciduous), penetration of clear water, bathymetry, mapping of coastal waters, and chlorophyll absorption (Adams and Gillespie, 2006; Campbell and Wynne, 2011).

The green wavelength reflects healthy vegetation and is applicable to the assessment of plant health and turbid water reflectance. Similarly, the red band is also applicable to vegetation studies because it absorbs chlorophyll and allows for plant species differentiation. The near infrared (NIR) band is useful for biomass surveys, water body delineation, and the complete absorption of water aids in distinguishing the delineation of shorelines (Adams and Gillespie, 2006; Campbell and Wynne, 2011).
Chapter 4: Methodologies

Water absorbs near infrared and this band is particularly useful for examining water and land boundaries that are not obvious in visible light. Areas of water and high soil moisture content appear darker than surrounding areas. In arid landscapes, this is useful because it will show the moisture content and indicate areas with groundwater potential. Vegetation in NIR reflects light, where healthy vegetation reflects more strongly than stressed vegetation. NIR also penetrates haze and smoke, so this band discerns details in these conditions better than the other bands.

The major features to be examined here through a visual analysis of imagery are sand and dune areas, green areas (high concentration of vegetation), shorelines and channels, red cliffs, yardangs, and areas of similar high iron oxide content (soil is bright red). This allows for the assessment of the potentiality of various ecosystems for past human activity. The second step is the creation of a hybrid landscape characterisation with the ISODATA algorithm.

The first step, a visual analysis of imagery is completed through examination of several band combinations, optimised for the desired purpose. Because of the imagery source, the time the imagery was taken, the season, and Gobi landscape properties, not all bands will equally identify all desired research objectives. In general, there are several band combinations that are effective for general purposes. The two major band combinations used here are 4-3-2 (NI-R-G) and 3-2-1 (R-G-B) (Fig. 4.4).

<table>
<thead>
<tr>
<th>Band Combination</th>
<th>Features</th>
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<tbody>
<tr>
<td>4-3-2 Near Infra-red-Red-Green</td>
<td>WHAT: False colour composite&lt;br&gt;Similar to traditional colour infrared aerial photography&lt;br&gt;USEFUL FOR: Vegetation studies, monitoring drainage, soil patterns&lt;br&gt;IN THE GOBI: Vegetation Red&lt;br&gt;Deep red: Broad leaf &amp;/or healthier vegetation&lt;br&gt;Light red: Grasslands or sparsely vegetated areas&lt;br&gt;Sol: Dark to Light Brown&lt;br&gt;Snow/Clouds: White or Light Cyan</td>
</tr>
<tr>
<td>3-2-1 Red-Green-Blue</td>
<td>WHAT: Natural colour composite, visible bands saved&lt;br&gt;Ground features appear similar to appearance as observed by the human eye&lt;br&gt;USEFUL FOR: Vegetation studies, water studies, salt scald, potential fluvial sediment remnants&lt;br&gt;IN THE GOBI: Healthy Vegetation: Green&lt;br&gt;Unhealthy Vegetation: Brown or Yellow&lt;br&gt;Cleaned or sparsely vegetated areas not as easily detected as 4-3-2&lt;br&gt;Best water penetration &amp; bathymetric info&lt;br&gt;Shorelines are white&lt;br&gt;Clouds &amp; snow both white and difficult to distinguish</td>
</tr>
</tbody>
</table>

Fig. 4.4: The two major band combinations (4-3-2 and 3-2-1) used in the analysis. These combinations are used to examine different landscape questions.

Other useful band compositions include bands in the mid infrared wavelength, which are particularly advantageous for visual interpretation (Campbell and Wynne, 2011). However, as only Bands 1-4 are supplied here, analysis will only utilise these bands. Future work would be
enhanced with the acquisition of other bands, particularly those in the mid infrared. Bands 4-2-1 (NI-G-B) proved useful in highlighting topography as well as areas of heavy sand, and particularly areas of archaeological sites in context of creeping dunes.

The second step in analysis is image classification. The purpose of image classification is to produce a map of land cover types or earth surface features by converting spectral information into data. This is done by assigning pixels to classes where each pixel is treated as an individual unit composed of values across spectral bands. Groups of pixels are assigned to major categories of interest through the creation of ROIs (regions of interest) which then form regions on an image, so that classification of the image is presented as a mosaic of uniform parcels, identified by a colour or symbol. Theoretically, these classes are homogenous, but in reality there is overlap between classes of pixels in other classes.

There are two approaches to classification, unsupervised and supervised (Campbell and Wynne, 2011). Unsupervised classification is created automatically by the software, which creates classes from pixels without any prior information of the region. This is done by examining a large number of unknown data points and dividing them into classes based on properties inherent to the data itself based on spectral groupings and distances, while the user specifies the number of classes to be created. This method requires minimum user interaction, requiring user interpretation after classification.

While it can be advantageous for the user because no previous knowledge of the area is required, there are several problems with unsupervised classification. There is limited control over classes and identities, the comparison of data is spatially and temporally difficult, and there is little difference between spectral classes and information classes. Additionally, without previous knowledge of the area, it is hard to know if the classes created by the software are accurate.

The second approach is supervised classification. This approach requires a strong knowledge of the study area because it requires the user to identify training sites of ROIs. The software then imposes a class structure by identifying spectrally similar areas on the image by identifying training sites of known targets and extrapolating their spectral signatures to other areas of unknown targets. The training data should be typical and homogenous as well as good quality so that the software can recognise similar patterns in the imagery. There are some disadvantages in that the training data choice can significantly impact the classification results. Overall, this approach aims to provide a quantitative description of the appearance of each thematic class of interest in the image.
Chapter 4: Methodologies

The approach used here is a hybrid classification, utilising methods from both supervised and unsupervised classification. The ISODATA algorithm (Duda and Hart, 1973) produces results often considered superior to both methods because it chooses initial estimates of class means (like supervised), while all other pixels are assigned to the class with the closest mean (like unsupervised), while class means are recomputed to include effects of pixels that may have been reassigned (Campbell and Wynne, 2011).

4.3 GIS & Hydrology Modelling

The second desk-based analysis used here is GIS-based hydrological modelling. This presents a potential modelled scenario of how the past hydrological network may have looked, and provides information about the connectivity of the network. Results of this are further used to evaluate how the hydrological landscape has changed over time.

Across Central Asia and peripheral zones, GIS, remote sensing, and spatial analysis are successfully implemented in research aimed at broadening the understanding of the human-environment relationship framework; however, overall the use of these methodologies is far behind in comparison to other global regions. The best examples of successful integration between these methodologies and archaeological research comes from Turkmenistan. The Archaeological Map of the Murghab Delta (AMMD) combines analyses between settlement, hydrology, and irrigation to create a geomorphological and settlement pattern framework in which to evaluate evolving interactions between humans and environment (Cattani et al., 2008; Cerasetti, 2002; Cerasetti et al., 2008; Rouse and Cerasetti, 2017). Other research by Markofsky (2011, 2014) and Markofsky and Bevan (2012) examines human-environment relationships in Turkmenistan, employing a variety of GIS, statistical, and remote sensing approaches. Research in Uzbekistan demonstrates the evolution of the hydro-social landscape at Samarkand (Mantellini et al., 2008), and similar approaches in the Tarim Basin are also notable (Debaine-Francfort et al., 2010).

In Mongolia, most examples of GIS in archaeological application focus on qualitative applications, primarily data management and visualisation. A popular analysis is the correlative predictive modelling approach, but the modelling rarely goes beyond basic environmental variables, such as basic vegetation indices or slope, or basic counts and distances. This methodology is also accompanied by a large set of theoretical problems (see Sanjuan and Wheatley, 1999; Lock and Stanci, 1995; Wheatley, 2004, for detailed criticism). The most comprehensive GIS example so far is Seitsonen et al.’s (2010) study on site catchments, after the methodology of Vita-Finzi and Higgs (1970), though this is also accompanied by its own theoretical deficiencies (Kvamme, 1999).
Chapter 4: Methodologies

The approach presented here evaluates the potential hydrological landscape of Ulaan Nuur, through hydrological modelling. Hydrological landscapes are intrinsically linked to anthropogenic landscapes, and because of this relationship, have several archaeological applications. This includes geomorphological characterisation of the past and present landscape to see how it has changed over time, the surface mobility of artefacts, the spatial organisation of landscape, and the potential decision making of people when deciding site placement (Bevan and Conolly, 2004). For example, delineation of watersheds and flow accumulation may be applied to settlement location analysis, and curvature and hydrology may be applied to impact strategies. Site placement next to water is not necessarily indicative of preferential site placement (Kvamme and Jochim, 1990), and the assumption that water sources of the present are spatially and temporally the same as palaeowater sources is problematic.

In archaeology, modelling hydrology is particularly useful in arid and semi-arid environments, where past drainage networks are not immediately identifiable. Bevan (2002) explored this in semi-arid Kythera through DEM channel extraction in relation to site catchments, while Harrower (2010) and Harrower et al. (2012) modelled the hydrology of pastoral and agricultural landscapes in arid Yemen. Extensive hydrology modelling has been completed by the Palaeodeserts project centred in arid Arabia (Breeze et al., 2015, 2016). Additionally, hydrology modelling has also been used for palaeoenvironmental reconstruction of the Hungarian Tisza plateau (Gillings, 1995), as it provides several indices, many of which are derived from drainage direction maps (Conolly and Lake, 2006).

There are limitations to this approach. The GIS is not able to model at what points the channels dried or when the channels were active, and does not show at what point the lake became saline (Breeze et al., 2015). Despite this, modelling and ground-truthing palaeoshorelines and palaeohydrological networks, in conjunction with archaeological sites, may be used as indicators of landscape change (Holguin and Sternberg, 2016; Vora et al., 2006), and prove an effective tool in both the reconstruction of potential past landscapes and shaping survey strategies.

In the geosciences, hydrological modelling is a common methodology, especially after the 1980s when GIS programmers and hydrologists launched a combined effort to improve the capabilities of GIS based hydrological modelling (Rogerson and Fotheringham, 1994; Goodchild et al., 1992; Singh and Fiorentino, 1996; Sui and Maggio, 1999). Currently, there are several algorithms and GIS software that provide hydrology modelling capabilities (DeVantier and Feldman, 1993; Maidment, 1993, 1996; McDonnell, 1996).
Hydrological modelling has a subset of theoretical issues apart from other environmental modelling (Goodchild et al., 1993, 1996; Karimi and Houston, 1996) mostly relating to the how the movement of water is represented in the GIS. Water, as a dynamic multi-dimensional and complex spatio-temporal entity, is represented as a one-dimensional geographic feature in the GIS (usually in vector), which conflicts with the reality of water itself where time and space are important variables (Sui and Maggio, 1999). Hydrological models are classified according to their conceptualisations and assumptions in randomness, space, and time (Chow et al., 1988). Water, then, must be defined over space rather than area (Maidment, 1996). In GIS terms, this includes networks of points like pits, passes, summits; edges like channels and ridges; and defining areas like watersheds and hills.

Hydrology has many features not related to elevation. Examples include catchments areas, flow lengths, and land cover. In this case, topographic data aid in the characterisation of topologic concepts, such as watersheds. In example from Devantier and Feldman (1993) show that while topographic data from an urban drainage network demonstrates the direction of movement of water, the hydrological attributes relate to the mode of transmission.

Two variables to factor when modelling are groundwater and surface water. Groundwater is divided into unconfined and confined flow, where the former occurs near the land surface for which the water table is the upper boundary of the saturated aquifer. The latter is influenced by surface hydrological conditions, particularly seepage from streams crossing the region where the aquifer outcrops at the land surface. In contrast, surface water occurs in streams, lakes, wetlands, and reservoirs. This is more complex than groundwater because it interacts with atmospheric water, soil water, and groundwater. Land surface characteristics and the environment also influence the surface water flow (Maidment, 1996). In the archaeological application here, it is this surface water network, which is most applicable to the research question.

4.3.1 Study Design

The most important objectives to keep in mind are the purpose and scope of the hydrology model. The main objective of this study is to identify the potential drainage network, including the major river mouths, around the palaeolake, and further ground truth it in conjunction with archaeological field work. This will also aid in interpretation of the archaeological and environmental landscape space.

Factors usually calculated in hydrology models, such as sediment flow, soil water balance, water flow, constituent transport, impact of water utilisation, land use, and land cover (Maidment,
Chapter 4: Methodologies

1996) are not calculated for this study. Because the model presented here is intended for archaeological purposes, this model will not need to be as detailed as if it were designed for a run off model, or for use in urban construction or dam placement. This purpose influences the variables and the scope of the system to be processed, particularly terrain and a DEM derived surface drainage network.

An erosion model is applicable to archaeological questions modelling how the landscape has eroded over time in relation to changing drainage networks, or how it has been covered over time, in relation to archaeological sites, but is currently out of the scope of this study. Secondly, because this study examines Ulaan Nuur evolution during the Holocene, present-day environmental variables, such as vegetation index, are not the same as Holocene variables, and thus, are not calculated here.

4.3.2 Geographic Information Systems

There are several GIS packages currently available to model hydrology. SAGA 2.2.7 (Conrad, 2006), an open source software, best fit the needs to generate the model and was used for this study. SAGA (System for Automated Geoscientific Analyses) has a toolset designed explicitly for the geosciences. Therefore, the commands here are SAGA focused, but the steps are the same in any GIS. There are differences in names between GIS for tool operations, but overall, results are generally similar, with varying degrees of accuracy and detail.

The datum used in this analysis is WGS 1984 UTM Zone 48N. WGS is the World Geodetic System, and UTM is the Universal Transverse Mercator. Mongolia falls within four UTM zones. Because Ulaan Nuur and Omnogovi province are centred in 48N, this datum was chosen.

4.3.3 Digital Elevation Models (DEMs): ASTER and SRTM

An accurate representation of topography is fundamental to the analysis of the hydrology model (Devantier and Feldman, 1993; Wang and Liu, 2006). In this study, a raster based DEM is used to represent elevation. The DEM is also used to extract several topological indices, such as watershed boundaries, flow direction, and channel networks (Devantier and Feldman, 1993). There are limitations, however, in using GIS derived hydrology models to evaluate past landscapes, particularly in regards to the nature of the DEM data itself (see O’Callaghan and Mark, 1984; Tarboton, 1997, Wood, 1996). There is error in a DEM no matter which is used, mostly originating in the various methodologies used during post processing of the imagery, such as interpolation (Forkuor and Maathuis, 2012: 220).
All hydrology models rely on some form of overland flow simulation to define drainage courses and watershed structure (Garbrecht and Martz, 1997; Wang and Liu, 2006). A DEM represents a spatial distribution of elevations on a regular grid (Burrough and McDonnell, 1998), and are the easiest and quickest data set by which to determine these drainage structures, as each cell in the DEM contains a numerical value. The dimension of the DEM cell determines the resolution at which the data is represented, and any information with a smaller resolution than the cell cannot be determined. Because of this, it is important to choose a resolution consistent with the desired analysis and research question, as well as the best that will accurately represent the topographic and morphological variability of the landscape.

The DEM used in this analysis is grid based, differing from TIN (triangular irregular network) or contour based DEMs, in that altitudes are stored in a regular grid in digital format (Planchon and Darboux, 2001; Tarboton and Ames, 2001). Grid based DEMs are readily accessible and available to researchers, though the grids themselves have some drawbacks (Tarboton and Ames, 2001).

Two of the most accessible and popular grid formats are SRTM and ASTER DEMs (Fig. 4.5). When deciding how to select a DEM, the most important features to consider are slope and accuracy, as these directly affect the way in which the study region will be represented, and therefore affect all modelling processes. The Ulaan Nuur region is devoid of detailed topographic maps and is generally inaccessible, and because of this, GIS based analysis becomes a useful tool to study this area’s geographical and archaeological surface processes. Both ASTER and SRTM DEMs were considered here, and both were found to have pros and cons.

### Comparison of ASTER and SRTM

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<thead>
<tr>
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<th>ASTER</th>
<th>SRTM</th>
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<tbody>
<tr>
<td>Technique</td>
<td>Satellite ortho stereo imaging</td>
<td>Space shuttle radar</td>
</tr>
<tr>
<td>Generation and Distribution</td>
<td>METI/NASA</td>
<td>NASA/USGS</td>
</tr>
<tr>
<td>Release Year</td>
<td>2011</td>
<td>2003</td>
</tr>
<tr>
<td>Data Acquisition Period</td>
<td>2000-ongoing</td>
<td>11 days in 2000</td>
</tr>
<tr>
<td>Posting Interval</td>
<td>30m</td>
<td>30m</td>
</tr>
<tr>
<td>Vertical Accuracy</td>
<td>7-14m</td>
<td>7-16m</td>
</tr>
<tr>
<td>DEM Coverage</td>
<td>83°N-83°S</td>
<td>60°N-56°S</td>
</tr>
</tbody>
</table>

Fig. 4.5: A comparison of ASTER V2 30m and SRTM 30m DEMs. Sources: Tachikawa et al. (2011); USGS: https://lta.cr.usgs.gov/SRTM1Arc.
ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an advanced multispectral imager. ASTER has three spectral bands in the visible near infrared (TIR) regions, with 15, 30, and 90m ground resolution. The first version of ASTER GDEM, released in 2009, in cooperation between the Ministry of Economy, Trade, and Industry of Japan (METI) and the United States National Aeronautics and Space Administration (NASA), was a product of the ASTER satellite. In 2011, METI and NASA released ASTER GDEM V2, an improvement over the first through better coverage, reduction in artefacts, and improved water masking (Tachikawa et al., 2011). ASTER GDEM V2 30m is used in this study.

SRTM (Shuttle Radar Topography Mission) aboard the space shuttle Endeavour was a joint effort between NASA and the National Geospatial Intelligence Agency (NGA). The SRTM DEM uses information from a C-band space borne imaging radar, an x-band synthetic aperture radar (X-SAR) collecting interferometric radar, and data from the United States Geological Survey’s GTOPO30 data set. It provides interferometric radar data in both 30m and 90m resolution formats (USGS https://lta.cr.usgs.gov/SRTM1Arc).

Rodriguez et al. (2006) showed that SRTM has an absolute height error that exceeds 16m, or 90%. Hofton et al. (2006) showed that SRTM accuracy was better in bare earth conditions, while in vegetated areas there was increased error. This is in contrast to ASTER, where Slater et al. (2009) showed an absolute accuracy assessment.

Accuracy is dependent on how well a catchment’s terrain is represented by the DEM. To evaluate this, the geomorphology of the region must be considered. The geomorphology measures the hydrological response of a catchment to rainfall. This is dependent on topography of overland regions and transmission surfaces (Forkuour and Maathius, 2012). Forkuour and Maathius (2012) showed that DEM quality has a large effect on the accuracy of results of hydrological and environmental models. DEM topography must be accurately represented, as DEM resolution affects land surface slopes, channel network topology, catchment sizes, and stream networks. This is particularly the case where localised elevation errors potentially affect topologic processes. An example of this is when a major streamline is directed in the wrong direction (Walker and Willgoose, 1999).
Fig. 4.6: A side by side comparison of ASTER GDEM V2 30m (left) and SRTM 30m (right) in SAGA 2.2.7. For ASTER the mean is 1446.61 and the standard deviation is 234.37. For SRTM the mean is 1453.04 and the standard deviation is 238.30. The mean indicates the elevation of the grid cell in relation to the others. The standard deviation is the elevation values of all grid cells. The lake basin extent is the large dark depression in the middle of the photo, with connecting channels. Calculated in SAGA 2.2.7.

The differences between SRTM and ASTER are not huge (Fig. 4.6). However, for the local lake basin of Ulaan Nuur, the SRTM showed pixel errors in some places by 30m or more, compared to the ASTER. Some differences in height were up to 217m. These differences are mainly concentrated in the mountain ranges to the east and south of Ulaan Nuur and most likely related to local topography, notably extinct volcano fields, and volcanic outcrops. The ASTER appeared to represent the real world topography slightly better than the SRTM, which was verified during fieldwork. Because the differences are not major, either DEM would work for the research question, but ASTER was chosen for it slightly better accuracy around the lake area. In other areas across Mongolia, the SRTM may be a better choice. Here though, the ASTER DEM is used.
4.3.4 Modelling the Drainage Network: Pre-processing

To create the drainage network, it is first necessary to take several steps to complete a local drainage map (Fig. 4.7). This is a surface topology map showing how cells are connected by the direction of water into each other (Conolly and Lake, 2006). The first step in this is pre-processing.

An inherent problem in hydrological modelling with grid DEM data is the production of nonphysical depressions due to noise in the elevation data. A depression is an area surrounded by higher elevation values, also referred to as a pit, sink, or pothole. These surface depressions prevent simulated water flow from draining into outlets so water is not able to flow out again (Devantier and Feldman, 1993; Jenson and Domingue, 1988; Jenson, 1991; O’Callaghan and Mark, 1984). The GIS takes the cell with the lower level to the same level of the lowest surrounding cells so that water flows past the cell. If not pre-processed, depressions may cause several undesirable effects such as disconnected stream flow patterns, false sub watersheds, and unwanted termination of drainage paths in depressions (Devantier and Feldman, 1993; Wang and Liu, 2006). The last effect is particularly problematic in flat areas, such as lakes, where the flow ends and flows are undetermined, so it becomes impossible to route flow towards the outlet of the catchment (Maidment, 1993).
There are several proposed algorithms to get rid of these depressions. Some utilise smoothing filters (O’Callaghan and Mark, 1984), hydrologically enforced interpolations (Hutchinson, 1988), or corrective measures applied only to surface depressions (Mark, 1984). The algorithm of Jenson and Domingue (1988) is most widely used, which accommodates both complex depressions and flat areas in DEMs; however, it is computationally intensive. Several of these algorithms were tested in Arc GIS 10.5.1, SAGA 2.2.7, and QGIS 2.14.3. The running times are slow, and ultimately the GIS was unable to handle the fill algorithm, took days to complete, and either crashed or created an incomplete fill.

Instead, newer techniques accomplish sink filling with one pass. For example, Wang and Liu (2006) uses spill elevation and least-cost search for optimal flow paths to determine flow paths and spatially partition watersheds with one pass of processing, thus creating a more time efficient algorithm. In this case, the Planchon and Darboux (2002) algorithm was used. This method works by flooding a layer of water across the entire DEM, then draining the edge cells of excess water. The DEM is then scanned to find the border of the drained and undrained regions. The undrained cells adjacent to the border are then drained and increased in elevation by a small amount. The algorithm terminates when all cells have been drained (Planchon and Darboux, 2002). The major criticism of the Planchon and Darboux algorithm is its running time (Barnes et al., 2014; Wang and Liu, 2006). In this case study, when used in Saga 2.2.7, running time was very fast and not an issue.

How an algorithm performs in an academic paper versus how it performs in real world situations are very different. The methodology of Planchon and Darboux (2002) was compared to that of Wang and Liu (2006), but in the end, there was not much difference between the results (Fig. 4.8). The main differences are in the way the GIS implements the algorithm.
Fig. 4.8: The images above show the differences between the fill algorithms in the Ulaan Nuur area. On the left is the fill using Planchon and Darboux (2002) and the centre is the fill using Wang and Liu (2006). The algorithm of Wang and Liu (2002) overfills the sinks. On the right is the differences between the two algorithms. The mean is 48.18 and the standard deviation is 69.08. These are large differences. Calculated in SAGA 2.2.7.

After looking at the images in Fig. 4.8, the differences are mainly around the lake basin and channel areas. Grid cells that are not within the depressions have exactly the same elevations as the input DEM. Both have the same range of elevation values. This is reflective of the small value used to enforce flow on flat surfaces left behind by the filling operation, and likely somewhat affected by the scale of the rounding errors when representing such small numbers with floating point values.

The Ulaan Nuur area and surrounding topography is extremely flat (Fig. 4.9). Truly flat landscape with zero slope rarely occurs in real life (Vieux, 2001), but the representation in the DEM of a flat surface may be the result of inadequate vertical resolution, quantization of elevation data, or by pre-processing, when depressions are removed by raising their elevation (Vieux, 2001). For Ulaan Nuur, by only filling sinks and pits alone, the GIS had trouble distinguishing the channels within the immediate lake shorelines and compensated by overfilling the basins (Fig. 4.10).
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Fig 4.9: The slope demonstrates the flatness of the Ulaan Nuur region. In the representation of the image above, before pre-processing, using ASTER GDEM v.2 30m, the lake area itself does not reach more than 12°. This could be a result of the raster resolution or the quantization of the data. This flatness creates problems for the GIS. Slope calculated in SAGA 2.2.7 with 9 parameter 2nd order polynom (Zevenbergen and Thorne, 1987). Interestingly, in ArcGIS 10.5.1, the maximum slope calculated was 34°, showing the differences between both GIS.

To counter this, it was necessary to take a further pre-processing step of burning the stream network into the DEM with a threshold of 100 cells. Burning the stream network places emphasis on flow from known hydrological networks, by artificially lowering the cell values. This created a drainage route by excavating the borders at each sink (Olaya, 2004), and thus created a more accurate flow delineation path (Fig. 4.10). Because of the lake history, it is necessary to consider the entire area because the lake has shrunk in size, in order to get a better view of how the drainage network has evolved over time. It is also necessary to know the real life landscape to be able to compare how well it is represented in the GIS.
4.3.5 Catchment Area Creation/Flow Accumulation

The next step is catchment area creation, or an upstream element map, which determines the area that drains through each cell. The area is represented as an area unit, with a number of cells covering the area. The accumulation in a cell is defined as the number of cells that drain through the cell, resulting in the accumulation value stored in each cell (Tarboton et al., 1991). The stream network and potential drainage network is extracted from the accumulation. Cells with a higher flow have a larger value. These represent an indirect way to determine drainage paths (Quinn et al., 1991; Tarboton et al., 1991). The assumption is that conditions are steady and the ground water table is roughly the same as the topography (Quinn et al., 1991).

A contributing area (upflow area) and local slope defines channels according to a threshold number of contributing grid cells (Tarboton et al., 1991). Thresholds are calculated at various levels, as each level distinguishes varying hierarchies of stream networks (Bevan, 2002; Llobera et al., 2011). It is up to the user to decide which threshold is most appropriate (Tarboton and Ames, 2001).
The results show the relative volume of water that would drain through each map cell (Conolly and Lake, 2006). However, this map does not take into account other factors such as evaporation, infiltration, subsurface flow, or varying amounts of water.

### 4.3.6 Catchment Network/Flow Direction

Using the processed DEM, flow direction determines the direction of flow, or the catchment area, from every raster cell. There are several algorithms to compute this, including Deterministic 8 (O’Callaghan and Mark, 1984), multiple flow direction (Freeman, 1991), and Deterministic Infinity (Tarboton, 1997). Deterministic 8 (D8) is the most common method where each cell has 8 possible flow directions, relating to the 8 adjacent cells into which flow may travel (O’Callaghan and Mark, 1984). The criticism of the D8 method is that it tends to produce unrealistic straight and parallel flow paths and does not model dispersion well (Erskine et al., 2006).

The algorithm used here, Deterministic Infinity (D∞) of Tarboton (1997), codes each cell according to the direction in which water would flow out of it. This allows for dispersion of water proportionately over several cells (Tarboton, 1997). The resulting raster has the value of every cell corresponding to the flow direction of water through the cell.

### 4.3.7 Channel Delineation/Stream Networks

Finally, to trace the channels and obtain a vector of the network, the Channel Network tool was initiated, using the Catchment Area/Flow Accumulation as the Initiation Grid. This defines cells above a certain flow accumulation with a threshold as a stream. The threshold is either user defined or automatic. The value of the threshold affects the stream density. The threshold divides the stream network into individual stream links. After finding the outlet cell at the end of each link, a watershed is delineated. The result is a raster Channel Network map, with a No Data value for areas without streams, and a value of 1 where streams may be delineated (Conolly and Lake, 2006; Garbrecht and Martz, 1997; Tarboton et al., 1991).

Several thresholds were tested but all produced roughly the same results with varying degrees of detail. If the value chosen is too small, errors are detected along those channels that are correctly determined. These errors disappear after increasing the threshold value, which, in turn, decreases the number of detected channels. Often discrepancies are observed between the digital network and the actual topography. This is because the GIS is not able to detect detailed topography below the DEM resolution, and thus, the GIS derived channel will not match exactly with the real world channel (Garbrecht et al., 2001).
4.3.8 Delineation of Watersheds and Basins

The topographical watershed represented in the GIS portrays the physical landscape, particularly runoff and rivers. The hydrogeological watershed is the true watershed - the one below the surface that is controlled by infiltration of water inside the strata and geology. The topographical watershed may gain or lose depending on the hydrogeological watershed. Watersheds can also change depending on tectonics. In the Ulaan Nuur region, tectonic changes occurred during the last Quaternary (Owen et al., 1997). For the resolution of the Holocene in this study, the topographical watershed is sufficient for the research question.

Delineation of watersheds is calculated through an 8-direction pour point model. This is where each cell is connected to one of its 8 neighbour cells according to the direction of steepest direction. This can also be done manually, by selecting pour points at the edge of the grid, or downstream of major confluences (Conolly and Lake, 2006). For purposes of this study, watersheds are delineated automatically (Chapter 6).

Building on the channel delineation, the GIS assigns a value to each cell that corresponds to the closest drainage segments that drain the cell, where points represent specific outlets for each watershed delineated. The outlet cell at the lower end of the stream link is delineated as a watershed for each outlet. By changing the threshold drainage area, sub-watersheds may be delineated within the larger watershed; however, there is only one stream for each watershed (Conolly and Lake, 2006).

4.4 Summary

These methodologies enable the formation of preliminary hypotheses about the past and current landscape morphology. The satellite imagery allows for the identification of particular landscape features that are potentially pertinent to site location identification and the results are presented in the next chapter. This includes the underlying topography aided by the ISODATA algorithm, as well as the river channels and the spring belt corridors. Results of the hydrology model are presented in Chapter 6. These are integrated with the results of Chapter 4, including the identification of the lakeshore corridor, and a hypothesis of the Holocene Ulaan Nuur coastline. These both contribute to the survey strategy formulated in Chapter 7.
Chapter 5: Satellite Imagery Results

5.1 Introduction

Using the methodology described in Chapter 4, this chapter presents the results of the satellite imagery methodology, introducing a broad regional geomorphological overview of Ulaan Nuur. This geomorphological perspective illustrates the current and past landscape morphology, highlighting geomorphological processes that have contributed to temporal landscape change, particularly along hydrological corridors. Areas that were once hydrologically active are identified, and when coupled with the hydrology model results of Chapter 6, the field survey strategy is formed in Chapter 7.

First, the results of the visual analysis methodology are presented. This is then accompanied by the results of the image classification, and finally followed by the identification of two of the three major hydrological corridors: the spring belt and channels. The third major corridor, the lakeshore, is examined in more detail in Chapter 6.

As explained in the previous chapter, the visual analysis examines several landscape features through the manual examination of the 4-3-2 and 3-2-1 band combinations, creating a general overview of the current landscape morphology. By doing this, an assessment of potential areas of past human activity is formed, contributing to shaping the field survey strategy.

5.2 Visual Analysis

The first step in analysing the satellite imagery is a visual analysis of the imagery. The major categories of features examined here are vegetation, soil, water, dunes, and man-made features (modern and archaeological). Although imagery for the entire study area has been supplied by the DigitalGlobe Foundation, for the discussion here, only a small portion will be addressed, highlighting a few detailed case studies and examples. Open source maps with lower resolutions (often 10-30m) available for public use are useful to track seasonal changes in the landscape as well as to compare features also present in the GeoEye-1 imagery.

5.2.1 Vegetation

The spectral reflectance of vegetation is based on the chlorophyll and water absorption in the leaf. In the visible and NIR, chlorophyll absorbs blue and red light and relays information about
the internal structure of the plant. In the red wavelength, there is a sharp reflectance. There are various shades of vegetation based on type, leaf structure, moisture content, and health of the plant. For example, needles have a darker reflectance response than leaves. Background factors affecting the spectral reflectance of vegetation include soil background, humidity, solar and sense elevation, canopy geometry, and phenology (Escadafal and Bacha, 1996).

In the Gobi, the dominant vegetation type is saxaul, which is often associated with highly sandy areas. Saxaul is able to survive in drought like conditions and salty soils, and remains the dominant plant of this area and is visible in both PN and XS imagery. In XS imagery, this is easier to see with the 4-3-2 band combination (Fig. 5.1) where vegetation reflects red and vegetation health is easily discernible. In this area, most vegetation is unhealthy. This could be due to the time of year when the imagery was acquired (November), or due to prolonged drought conditions.

![Fig. 5.1: Saxaul and desert shrubs on top of a dune field presented in the false colour composite. The right presents the natural colour composite with the vegetation indicated by light brown. Light red and light brown indicates weak plant health, and consistent with the vegetation in reality. Geo Eye-1 imagery modified in ENVI 5.3.](image)

Bright red areas show where groundwater is closer to the surface and vegetation is marshier in appearance (Fig. 5.2). These dark red areas coincide with marshy areas similar to salt marshes, or areas with high occurrences of reeds and grasses, whereas the light red areas indicate those areas of vegetation where water availability is minimal. Field survey showed areas with the highest concentrations of vegetation coincided with areas along palaeochannels, along the palaeolake shoreline, in former smaller palaeolakes, and areas with current springs and wells, indicating these areas all still contain groundwater, with water tables present near the surface.
5.2.2 Soil

In the context of hunter-gatherer sites, a soil map is not a useful index. Hunter-gatherers are most likely related to geomorphology, whereas agriculturalists are more soil quality dependent (Kamermans, 2000: 142). However, a brief examination of soil is useful to gauge topography, geology, geomorphology, hydrology, background vegetation reflectance, and soil properties.

The spectral reflectance of soil is influenced by several properties, including moisture content, organic content, texture, and iron oxide content. Generally, northern latitudes have black soils while tropical regions have red soils. Soil reflectance decreases as organic matter increases. As soil moisture increases, reflectance of soil decreases at all wavelengths. The texture of soil will cause increased reflectance with decreased particle size. For example, bigger particles like rocks cast a larger shadow, while smooth particles like dunes are more reflective.

Around Ulaan Nuur, imagery in the NIR spectrum is useful for detecting differences in moisture content. When coupled with the GIS based hydrology model (Chapter 6), the imagery provides an interesting validation to the model. Soil with higher moisture content is darker in visible and NIR. This potentially indicates areas where groundwater is close to the surface.

Further combined with Bing imagery, it is possible to locate the spring belt corridor prevalent in the landscape that relates to the palaeochannels and modelled network. The amount of reflectance has a positive relationship with wavelength, and there is an inverse relationship between moisture content and spectral relationship. This also corresponds to humid areas observed during field survey.
Areas of former fluvial activity leave behind sediments, which reflect white in PN imagery (Fig. 5.3). These are potentially palaeolake deposits and are found elsewhere in other arid environments, such as the Nefud (Breeze et al., 2017). In the Ulaan Nuur area, palaeolake deposits in interdune areas are prevalent around the south-west channel. There are also several areas, particularly around the archaeological sites identified during the field survey, which have large areas of fluvial sediments.

Areas high in iron oxide content indicate an increased reflectance in the red wavelength, and absorb the blue, green, and near infrared wavelengths. These areas seem to have a higher occurrence of archaeological material compared to other areas. The Central Asiatic Expedition (Berkey and Nelson, 1926; Fairservis, 1993) also recorded this observation.

![Fig. 5.3: Fluvial sediment deposits highlighted in the blue circles in NIR PN 0.5m imagery. These indicate where water may have flowed in the past. Fieldwork verified the presence of these. Geo Eye-1 imagery modified in ENVI 5.3.](image-url)
5.2.3 Water

The visible bands highlight surface water and a small amount is absorbed or reflected. The NIR and mid infrared demonstrate the groundwater or phreatic levels and there is strong absorption. Water bodies are highly reflective in the visible, but clear water is less reflective than turbid water. Large amounts of inorganic matter shifts the visible reflectance toward red from the green, where green reflects clear water.

Water around the Ulaan Nuur region is present between interdunes and in episodic and ephemeral deposits, most likely from recent rainfall. Using a combination of bands 3-2-1 confirms that the water bodies in this area are shallow and ephemeral (Fig. 5.4), fed by groundwater and rainfall, where the small lake bottoms are highlighted by lighter blue. Water reflects some blue light, as water is lighter in the blue band and darker in red and green bands. Areas of high salt content and fluvial sediment remnants reflect bright white. These white areas may be interpreted as those areas where there are more salty soil lake deposits. The NIR shows areas of soil moisture content. This provides a good correlation to the hydrology model (Chapter 6).

Fig. 5.4: Water body composites from left to right: 4-3-2, 3-2-1, NIR. These images convey information about the water quality around Ulaan Nuur. Water here is saline, shallow, and ephemeral. Geo Eye-1 imagery modified in ENVI 5.3.
5.2.4 Dunes

There is little seasonal variation in dune fields because of the lack of vegetation (Escadafal and Bacha, 1996). This region has several areas of shifting dunes, with most ranging between 3-5m, including dune fields, barchans, and coppice dunes. Areas with dunes and extensive dune cover have a higher level of reflectance and are easily discernible, as they appear light and bright in the PN. The PN shows the topography and individual vegetation of the dunes better than the XS (Fig. 5.5). The 4-3-2 shows these coppice dunes better than 3-2-1, where it is more difficult to ascertain individual dunes and vegetation. A comparison of these band combinations exposes areas where sand is encroaching onto archaeological sites.

Fig. 5.5: The topography of dune fields of vegetated coppice dunes and sand sheets are more easily discernible in the NIR PN 0.5m. Geo Eye-1 imagery modified in ENVI 5.3.
5.2.5 Man-Made Features

Modern man-made features include seasonally occupied current and former ger\(^1\) camps (visible as round ger impressions and white gers). Associated with these, animal paddocks and corrals are easily discernible; usually as a half circle (Fig. 5.6). There is a higher density of highly degraded vegetation around areas of current and past herder camps. This correlates with the occurrence of *Artemesia adamscii* and *Carex duriuscula*, a grazing tolerant sedge preferred by animals (Tuvshintogtokh, 2014). Both thrive in degraded conditions (environmental stress, drought, poor soil), and both species dominate in overgrazed and trampled areas, particularly around settlements and ger areas, replacing local plants otherwise not tolerant to environmental degradation (Hilbig and Opp, 2005; Tuvshintogtokh, 2014).

All roads in the region are unpaved dirt roads and are represented in the imagery by lines. These are more visible in PN imagery rather than XS. Man-made saxaul forests such as one near the site of Bayanzag are discernible in imagery, as are areas of hydroponic agriculture located farther in the south near Dalanzadgad.

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1 Ger (гэр) literally translated as “home”, is the Mongolian traditional nomadic home, characterised as white and round, covered by felt. Across other areas of Central Asia, it is referred to as yurt.
Wells are difficult to ascertain in the imagery, but in PN 0.5m resolution they are more easily identified (Fig. 5.7). They are represented as an L shape; however, often lack heavy vegetation, most likely because animals use these wells and destroy vegetation around the area. The soil moisture content around wells is reflected as darker compared to surrounding areas, indicating groundwater. Wells become extremely visible if the imagery is transformed through Principal Components Analysis, which is an alternative approach to feature selection (Campbell and Wynne, 2011:317).

![Fig. 5.7: An L-shaped well in the centre of the image. The structure next to it is a trough. The soil around the well is darker compared to surrounding areas, indicating groundwater directly below. There is a lack of vegetation here, and at this particular well, goats have destroyed most of the area. This area is part of an archaeological site. Geo Eye-1 imagery modified in ENVI 5.3.](image-url)
Hunter-gatherer sites (e.g. lithic scatters and hunting blinds) are undetectable and require field survey for investigation. There are few large-scale archaeological monuments in the Ulaan Nuur region. Of the few, Bronze Age slab burials are distinctly discernible in satellite imagery (Fig. 5.8). Smaller burials are undetectable in the satellite imagery and require field survey. Modern man-made features like ovoos\(^2\) are particularly detectable, and to the untrained eye may be easily confused with archaeological sites.

![Satellite Imagery with Bronze Age slab burials and modern man-made features](image)

*Fig. 5.8: Bronze Age slab burials are discernible in satellite imagery. Round burials and smaller burials are more difficult to ascertain. These structures may be easily confused with local religious structures, ovoos, and require field survey for verification. Hunter-gatherer sites are not visible in imagery. Geo Eye-1 imagery modified in ENVI 5.3.*

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\(^2\) Religious structures
5.3 Image Classification

The second analysis used here, image classification, is created in ENVI 5.3 using the ISODATA algorithm, which was discussed in detail in Chapter 4. The ISODATA algorithm is a hybrid classification, which borrows elements from both supervised and unsupervised classifications. ISODATA was chosen because compared to K Means and Minimum Likelihood, it was found to produce better results and represented the Ulaan Nuur region the best (Fig. 5.9). There are two purposes of the image classification. First, it creates a map of land cover type or major landscape features, and secondly, exposes the morphology and topography, which are hidden under sandy surfaces, and are otherwise difficult to ascertain in the visual analysis.

Fig. 5.9: An excerpt of the ISODATA classification created for the Ulaan Nuur area in ENVI 5.3 with Geo Eye-1 imagery. This algorithm produced superior results to other methods, like K Means and Minimum Likelihood. The program creates classes, which must then be interpreted, which requires an advanced knowledge of the study area. In the image above, magenta/fuchsia represents areas of dunes and dune fields, yellow represents sandy areas, and blue represents rocky and volcanic areas.

ISODATA created several categories that were then reclassified based on knowledge of the region. Shadows played a significant role in confusion of classes, particularly between identification of water and shadow spectral signatures. The time of day the image was taken plays a role in this, as noon is when shadows are at a high peak. Many shadows were treated as water features and vice versa (Fig. 5.10). Water in this area is extremely shallow, ephemeral, and tepid so has a different
spectral signature compared to marshy/wetland water areas found closer to the former shoreline of Ulaan Nuur.

Fig. 5.10: In the image above, red pixels represent shadows. In the middle are two inselbergs with their shadows at noon. However, these shadows have the same spectral signature as shallow water bodies in the area, and are treated as the same category by the algorithm. This easily creates confusion during the user analysis, unless the user has prior knowledge of the area. Geo Eye-1 imagery modified in ENVI 5.3.

Fig. 5.11: A close up of the ISODATA classification. This image shows the river mouth of the south-west channel (in red), leading to the major western river of Ulaan Nuur, now buried under a major dune field (in blue). This channel location was verified during field survey. The bottom of the image shows the many alluvial fans and channels draining into the now buried and dry south-west channel. This image beautifully shows the topography of the area, which is otherwise hidden in the visual analysis of the satellite imagery. Geo Eye-1 imagery modified in ENVI 5.3.
Topography of the channels and lake showed extremely well in the classification (Fig. 5.11), and details were more easily discerned compared to imagery from other methodologies. As expected, sand covers most of the area, including desert steppe. These are classified as sand sheets. There are significant dune fields along the former south-west channel, while the south-east channel has less dune coverage and more dispersed sand sheets and individual and small fields of coppice dunes. Details of these sand covered channels were more easily discernible after the classification, particularly the south-west channel and its major river mouth (Fig. 5.11).

These details, which are otherwise difficult to see with the naked eye, demonstrate that this analysis is particularly useful to discern detailed landscape morphology and topography. This landscape morphology and topography, along with features highlighted in the visual analysis, contributes to the identification of hydrological corridors.

### 5.4 Identification of Corridors

The final analysis, identification of corridors, is based on the results of the visual analysis and the image classification. Using the results of these two methodologies, some observations about corridors may be formed. The first discernible corridor is the spring belt. The spring belt corridor is visible from large patches of vegetation and high soil moisture absorption. These patches demonstrate the connectivity of the stream network (Forman, 1995a), or in the case of the Ulaan Nuur region the connectivity of groundwater flow. Natural springs are usually seeps where water seeps from the pore spaces over a small area, rather than from a single discharge point (Pigati et al., 2014). These may form first order streams\(^3\), or may enter a lake or river underwater (Forman, 1995a).

The major southern spring belt in the study area is connected to the Gurvan Saikhan Mountains, where there is a change in topography (Fig. 5.12). Small palaeochannels running north from this belt reach the Ulaan Nuur palaeolake shoreline, as well as the south-east channel, passing through the Bayanzag archaeological site. There is considerable erosion in the area. It is possible that sometime in the past, the spring belt was more north than it is presently and has moved more south due to regressive erosion.

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\(^3\) Hierarchy of streams is determined by quantitative classification indices such as drainage density, stream length, and basin area. For example, first order streams are those with concentrated flow. Second order streams receive at least one tributary from the first order streams. When two second order streams meet, they form a third order stream, and so on (Horton, 1945; Shreve, 1966; Strahler, 1952).
Fig. 5.12: One of the springs along the southern spring belt, seen in satellite imagery in the top picture. This spring is directly after a series of badlands and gullies, on the way to the Flaming Cliffs and the archaeological site of Bayanzag. The spring has been modified and dammed with a system of pipes to transport water to the family living here for their household and small farm. The second image shows an overview of the spring. The spring seeps into the surrounding porous earth creating saturation and capillarity (capillary) mounds, as well as thick vegetation like reeds. Base Map: Bing Maps, 2017 Microsoft, www.bing.com/maps: Earthstar Geographics SIO.
Other spring points are visible in the northwest area of the study region in the Gobi Altai Arts Bogd Mountains, feeding the former south-west channel. The environment around these freshwater springs is characterised by thick vegetation, including reeds (Fig. 5.12). Capillarity (capillary) mounds appear as small green hills, providing evidence of an underground stream network (Fig. 5.12).

The second discernible corridor is the river/stream system, or in this case, the palaeochannel network. The stream and river corridors, including the upslope, hillslope, floodplain, and stream bank, are critical to the geomorphology and hydrology of valleys. Alluvial environments are characterised by their own unique resources and hazards (Brown, 1997). A river and stream mosaic corridor is evident in the Ulaan Nuur region primarily through palaeochannel corridors. These palaeochannels exhibit a rich structural and functional pattern varying in width and depth. In an active river/stream corridor, several ecological gradients are present and several features, such as fish populations, gradually change from the headwaters to the river mouth. These extend across the corridor from the upland to the river channel, with several patchy areas (Forman, 1995a). These corridors, when faced with erosion and deposition, as they are presently in the Gobi, create specific spatial patterns between the water table, the land surface, soil type, and slope, which determine the types of vegetation and habitats present (Forman, 1995a).

Hydrological networks are extremely sensitive to changing climatic conditions (Brown, 1997) and when a river/stream network is exposed, particularly first order rivers/streams (major tributaries), processes and influences like erosion, nutrients, and pollution are transported into second and third order streams (minor tributaries), breaking the connectivity of the network (Forman, 1995a). Vegetation patch size is correlated to water quantity and if there is a loss of vegetation with increased erosional processes, there is an alteration to the stream structure, and an increase in other factors such as higher velocity and sediment flows, increased temperatures and oxygen levels, algae production, and toxins (Forman, 1995a).

Most of this region is characterised by braided and meandering palaeochannels, marked by extensive erosion, demonstrating the region has experienced a range of stream networks through time. However, Sternberg and Paillou (2015) identified ten major and minor tributaries connected to Ulaan Nuur. The most important first order river/stream corridors in the study area are the Ongi River (introduced in Chapter 1) and a south-east channel (both deeply incised into the landscape), as well as a south-west channel, which is harder to discern because it is now covered in extensive dune fields (Fig. 5.14). Portions of the Ongi, portions of the south-east channel and
the south-west channel, and their corresponding river mouths were surveyed for this dissertation. The results are presented in Chapter 8.

The Ongi is the largest sediment-bearing channel evident in satellite imagery (Fig. 5.13) and forms a delta where it meets the lakeshore (Lee et al., 2013; Sternberg and Paillou, 2015). There is evidence of extensive alluvial sedimentation, indicating the Ongi has evolved over a large distance over time. Similar to other alluvial environments across Central Asia, the nature of the Ongi is a potential deterrent to archaeological survey and site detection.

Fig. 5.13: The Ongi River begins in the Khangai Mountains and ends in Ulaan Nuur. There is a delta where the lake meets the shoreline. Satellite imagery shows the river has evolved over a long distance and time, including substantial deposition around the lower Ongi (above). Alluvial environments such as the one found around the lower Ongi could make it more difficult for archaeological site recovery. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.
Alluvial fan sediments often decrease towards the margin of the alluvial wedge, where deposition decreases towards the fan’s fringes. These deposition patterns lead to potentially higher levels of archaeological recovery on or near the modern surface towards the fringes of the delta (Brown, 1997). However, erosion from active and braided streams often destroys or damages small sites. The exception is if sites are quickly reburied (Brown, 1997). Across Central Asia, inverse relationships between alluviation and archaeological visibility has been suggested (Cremaschi, 1998), and may act as a deterrent to archaeological survey and site recovery (Cattani et al., 2008). Improved archaeological visibility is more likely a result of reduced aggradation of alluvial sediments (Markofsky, 2011).

The south-east channel is deeply incised into the landscape and particularly visible in satellite imagery (top image, Fig. 5.14). This incision suggests it was an important river in the region and was extremely active at one time. The channel river mouth originated at the southern edge of Ulaan Nuur and flowed over 160 km. It flowed past the province capital Dalanzadgad and the smaller Ulaan Bagalsiin Nuur, and ended in the eastern area of the province. Ulaan Bagalsiin Nuur is today sustained by freshwater aquifers (Basandorj et al., 2007). In the study area, the channel is mostly covered by dune fields; however, there are wells in the vicinity indicating some groundwater is still available.
Fig. 5.14: The south-east channel (top) and the south-west channel (bottom). The south-east channel is more visible in satellite imagery compared to the south-west channel. While both are covered in dune fields, the south-west has significantly larger dunes and sandy areas, while the south-east channel has minor dune fields. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

Unlike the deeply incised and visible south-east channel, the south-west channel (Fig. 5.14) is harder to discern because it is now an area of extensive dune fields. In the 1960/1970s the south-east channel still had significant wetland areas, as evidenced in maps from this period; however, these have mostly disappeared. The south-west channel is not as large as the Ongi and south-east channel. The southern fringes of the south-west palaeochannel still have areas of significant
Chapter 5: Satellite Imagery Results

vegetation and several wells dot this area, indicating the water table is still close to the surface. This water originates from several spring sources in the Gobi Altai Arts Bogd Mountains.

5.5 Spring Belt, Channels & Archaeological Proxies

The spring belt and the three major channels may be mapped in relation to the known archaeological proxies in the Ulaan Nuur study area (Fig. 5.15). The major sites were briefly introduced in Chapter 2, including Bayanzag, Khoyor Khairkhan, Eregiin Khooloi, and Flint Valley. However, the majority of archaeological activity is scatters.

Fig. 5.15: The spring belt and palaeochannels mapped in relation to known archaeological sites and scatters. The Central Asiatic Expedition’s site and scatter locations were provided by Lisa Janz, based upon Nelson’s original 1925 notes, with coordinates derived from topographic maps. Other site locations provided by Bruno Marcolongo, director, Italian-Mongolian Expedition. Sites identified by the Joint Mongolian-Russian-American Archaeological Expedition were used with permission from John Olsen. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.
Without an idea of the lake palaeoshorelines or surface network, it is difficult to see how these sites may be related to the broader Ulaan Nuur hydrological landscape. To clarify this, the next step constructs the hypothesised surface network, which also identifies minor tributaries. From this, the third major corridor, the lakeshore corridor, including the major potential lake palaeoshorelines, is examined.

Identification of the lakeshore corridor, including shoreline detection and evolution of the coastline is more difficult. This is discussed in more detail in the next chapter. Additionally, Chapter 6 discusses the results of the modelled hydrological network described in Chapter 4, which are then compared to the results of the satellite imagery of this chapter. A hydrology model presents a scenario of what the past landscape may have looked like when it was hydrologically active. The results of all of these methodologies are used to form the field survey strategy in Chapter 7. Additionally the results of this chapter and Chapter 6 are compared to the anthropogenic landscape, which demonstrates the connectivity of the overall hydrological landscape to the anthropogenic one, and allows for a closer examination of how people may have functioned in these corridors.
Chapter 6: Hydrology Modelling Results

6.1 Introduction

The last chapter presented the results of the satellite imagery, while this chapter presents the results of the hydrology modelling. The steps of this methodological approach were detailed in Chapter 4. The purpose of the hydrology model is to provide a modelled hypothetical scenario of how the landscape may have appeared when it was hydrologically active. It also provides information about the connectivity and relationships of the hydrological networks in the study region in relation to known archaeological areas of activity. This aids in the design of the field survey (Chapter 7). Along with the results of the field survey, the accuracy of the modelled stream networks and the satellite imagery morphological analyses are discussed in detail in Chapter 8.

The second major analysis discussed in this chapter is the identification of the lakeshore corridor. This combines the results of the satellite imagery and the hydrology model to track the potential coastlines and the temporal and spatial evolution of the lake. With the additional inclusion of previously identified archaeological site locations, a preliminary hypothesis of the potential location of the Holocene shoreline is presented.

6.2 Hydrology Model

Following the methodological steps described in Chapter 4, a potential scenario of the past hydrological landscape is modelled (Fig. 6.1), outlining the Ulaan Nuur watershed. In the literature, this watershed is attributed to the Ongi River, called the Ongi watershed. However, it is renamed here in the context of the Ulaan palaeolake. This model also demonstrates the landscape as more hydrologically dynamic, which is in contrast to conditions today, where there is currently no active surface network.
When the results of the hydrology model are overlaid with the identified spring belt and channel corridors (Fig. 6.2), an evaluation of the model shows it has modelled these areas correctly and these may be used as positive controls. The south-east palaeochannel corridor and the Ongi River are comparable to the channels identified in the satellite imagery. Because the south-west channel is hidden under dune fields in the satellite imagery, it is more difficult to know if the model has accurately portrayed this channel. This will need to be verified through ground truthing. The minor tributaries are also unknowns, and it will also be necessary to verify these through ground truthing to evaluate if the model has correctly identified these.
Chapter 6: Hydrology Modelling Results

Fig. 6.2: The results of the modelled network are overlaid on top of the visual analysis, including the identified spring belt and channels, and areas with significant dune or sand coverage. Combined with the known archaeological proxies, some patterns between site/scatter locations and hydrology are beginning to emerge. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

When examining the location of archaeological sites/scatters in comparison to the major channels and surface network, it is evident that all are located away from the first-order rivers, and along minor tributaries. The potential reasons behind this will be evaluated during the field survey.

The results of the hydrology model will be used for two major applications. First, the results highlight potential palaeochannels (Fig. 6.1). In combination with the satellite imagery results of the last chapter, this will be used to determine areas along these channels for survey, particularly the major river mouths of the south-east and south-west channels (Fig. 6.2). This will be discussed in more detail in the next chapter.
The second major use of this model, discussed in the next section, is the identification of the lakeshore corridor. Combined with the satellite imagery results of the last chapter, the DEM, and the modelled stream network, a hypothesis about the Holocene lakeshore is made and will further aid in shaping the field survey design of the next chapter.

6.3 Lake Corridor Identification

In an active system, a lakeshore corridor is similar to a river corridor but with two major differences. First, rivers are more likely to be crossed than lakes, so lake vegetation connectivity becomes more critical to the conduit movement of species. Secondly, lakes are like micro seashores because both experience high wave activity and energy. When hit by storms, the lake shoreline/coastline, like the sea shoreline/coastline, changes form and location (Forman, 1995a), and therefore is more unpredictable than a river corridor.

Lakes are dynamic entities with contracting and expanding shorelines that constantly change form and location (Forman, 1995a). These shoreline properties present difficulties when attempting to identify change, and traditional ground survey will not always prove reliable, particularly for large areas and inaccessible areas where it is often impossible to ground truth (Ouma and Tateishi, 2006). For sea shoreline detection, visual analysis and proxy shoreline features not detectable by the human eye extracted with image processing techniques (Boak and Turner, 2005; El-Asmar and Hereher, 2010; Gens, 2010; Loos and Niemann, 2002; Mason and Davenport, 1996; Yamano et al., 2006) are commonly used. Similar techniques work in detection of coastlines of lakes.

Sternberg and Paillou (2015) identified the larger Ulaan palaeolake and its shorelines using a combination of SRTM imagery coupled with ALOS/PALSAR imagery. They recreated three potential palaeolake shorelines using the topographical modelling technique of Komatsu et al. (1991) by flooding the present day topography. The first corresponds to a surface area of 19500 km², the second to a surface area of 6900 km², and the third to a surface area of 1700 km², suggesting that over 3150 km² of water was available and would have lasted during the Holocene (Sternberg and Paillou, 2015).

The methodology here utilises visual analysis in combination with image processing techniques in GIS to extract contours from the ASTER GDEM V.2 30m. These are further examined and compared with Geo Eye-1 XS 2m and PN 0.5m to identify potential shorelines. These are then artificially flooded within the GIS and extracted, indicating three possible distinct shorelines. The

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1 The term shoreline is used by coastal research specialists, while the term coastline is used by remote sensing specialists. Both refer to the physical interface of land and water (Gens, 2010).
NIR band proved most effective in this analysis. Additionally, comparisons between Sternberg and Paillou (2015), Mongolian government maps from 1960 and 1970, and recent work by Lehmkuhl et al. (2017; Frank Lehmkuhl compared and verified the results of this model to the work completed independently by his team, personal communication) showed the shorelines identified here match extremely well.

The main Ulaan Nuur depression is highly visible in the ASTER GDEM v.2 30m of the area, as are the contours of the various shorelines. In the ASTER GDEM v.2 30m data, three distinct shorelines are detectable. The smallest shoreline corresponds to a shoreline in 1960/1970, seen in digitised maps from this period. The second largest shoreline is also visible in satellite imagery. Manually reclassifying the DEM allows a better view of the lake topography and provides an excellent visualisation of these potential shorelines (Fig. 6.3). Combined with Geo Eye-1 satellite imagery, it is possible to track the spatio-temporal evolution of the lake, from a large one to the almost non-existent ephemeral lake of present.

Older maps of the area were produced by the Mongolian government during the 1960s and 1970s (completed through ground survey), forming the basis for current digitised shapefiles used by the Mongolian government today. Additionally, reports indicate the lake was 65 km² (surface area) in the 1960s (Lee et al., 2013), and local residents claim that Ulaan Nuur was a year round water source in the past, but is now characterised by ephemeral ponds and playas (Sternberg and Paillou, 2015). The smallest shoreline visible in the DEM matches the shoreline from the government maps. This is useful as a known confirmed shoreline area, and allows an evaluation of the spatio-temporal evolution of the lake, demonstrating the lake has become much smaller over time.
Fig 6.3: Three potential shorelines are discernible in the imagery. Shorelines 1 and 2 (top image) correspond to the shorelines identified by Sternberg and Paillou (2015). Shoreline 2 is hypothesised here as the potential Holocene shoreline. Shoreline 3 (bottom image) corresponds to the lake in the 1960 and 1970s and is the same as it is represented on maps created by the Mongolian government during these time periods. The lake highlighted in blue in both images is the seasonal lake at its modern level. These images show that Ulaan Nuur has decreased in size over time. Base Map: ASTER GDEM v.2 30m.
6.4 The Holocene Coastline Hypothesis

Based on the identification of the potential shorelines, a potential Holocene shoreline hypothesis is formed, aided by mapping the known archaeological data in conjunction with the modelled shorelines and hydrology network (Fig. 6.3), which will provide a starting point when deciding where to base the field survey (Chapter 7). It is important to note that none of these shorelines are dated so it is currently not possible to know at what point they existed. Lehmkuhl et al. (2017) recently published results of a radiocarbon dated shoreline roughly corresponding to Shoreline 1, as 4414 +/- 153 cal. B.P., which suggests that this shoreline possibly existed during the archaeological periods of interest.

Fig. 6.4: Known archaeological sites in the Ulaan Nuur area mapped with the modelled hydrological system and shorelines. Known archaeological materials fall within shorelines 1 and 2. The area around the hypothesised Holocene shoreline is a good starting point to plan a survey strategy. The Central Asiatic Expedition’s site and scatter locations were provided by Lisa Janz, based upon Nelson’s original 1925 notes, with coordinates derived from topographic maps. Other site locations provided by Bruno Marcolongo, director, Italian-Mongolian Expedition. Sites identified by the JMRAAE were used with permission from John Olsen. Base Map: ASTER GDEM v.2 30m.
Chapter 6: Hydrology Modelling Results

The shoreline of 1960/1970 is known (Shoreline 3 in Fig. 6.3). This information comes from paper maps, digitised maps, and shapefiles depicting Ulaan Nuur at this time. A hypothesis is formed that the shoreline in 1960/1970 is not the same as the shoreline during the Mesolithic/Neolithic periods, because it is clear the lake has shrunk substantially over time, and therefore we will find no archaeological areas of activity from Neolithic or older periods directly around this shoreline. This will be tested during field survey (Chapter 8).

As indicated in Fig. 6.4, Holocene areas of archaeological activity fall within Shorelines 1 and 2. Shoreline 1 in Fig. 6.3 corresponds to the smallest palaeoshoreline identified by Sternberg and Paillou (2015), estimated at 1700 km². Lehmkuhl et al. (2017) further correlate this shoreline. Geomorphological investigations conducted by Lehmkuhl et al. (2017) suggest Mesolithic/Neolithic areas of activity were in use when the lake level depth was at approximately 3m (lake level provided by Frank Lehmkuhl, personal communication).

Shoreline 2 corresponds to the palaeoshoreline identified by Sternberg and Paillou (2015) estimated to be 6900 km², and further correlated by Lehmkuhl et al. (2017). Only Palaeolithic areas of activity fall within this shoreline (not pictured), where the maximum lake level depth was 13m (lake level provided by Frank Lehmkuhl, personal communication), while the Mesolithic/Neolithic areas of activity are closer to Shoreline 1.

Based on these observations, it is probable that Shoreline 2 existed pre-Holocene, and Shoreline 1 as the most probable shoreline present during the Mesolithic/Neolithic. This hypothesis will be tested during field survey. Additionally, portions of the current Ulaan Nuur will also be surveyed to examine if any Mesolithic/Neolithic areas of activity are found around the more recent 1960/1970 and current shorelines. If so, this means that Shoreline 1 was not the Holocene shoreline.

When combining the results of Chapter 5, with the results of this chapter, in combination with known archaeological areas of activity, it is apparent there is a spatial patterning within the landscape centred around areas along the palaeohydrological landscape. Field survey and ground truthing is necessary to further explore these results. Using the Holocene coastline hypothesis, along with the results of the satellite imagery (Chapter 5), and the hydrology model (Section 6.1), the next step is the development of the field survey design. The field survey will provide a preliminary assessment of the area, and evaluate how well the methodology has helped to identify potential archaeological areas of activity. This is discussed in the next chapter.
Chapter 7: Field Survey Design

7.1 Introduction

Using the results of Chapters 5 and 6, the next step in analysis described in this chapter is the field survey design. The goal of the survey is to conduct a preliminary, exploratory, non-exclusive and non-destructive surface assessment of the area, and evaluate the potential for the viability of more extensive work to be conducted in the future. Artefacts are recorded, but none are collected. For the scope of this project, it is not realistically possible to systematically survey the entire region. Determining the areas to survey will rely heavily on the previously discussed desk based methodologies described in Chapter 4-6.

Because of the complexity of the landscape, the material distribution across the landscape is examined according to the non-site and distributional methodology proposed by Dunnell and Dancy (1983) and Ebert (1992); however, a fuzzy notion of site is retained (Bevan and Conolly, 2004; Dunnell and Dancy, 1983:272; Markofsky, 2011, 2014). Here, the primary dataset is a continuum of surface artefacts (Ebert, 1992), where the entire landscape is regarded as a potential space of archaeological activity, void of defined and discrete boundaries. However, the landscape presents several challenges, particularly related to visibility, which creates issues during survey. These challenges, or biases, are briefly reviewed next, followed by a brief overview of the differences between a site and scatter, and how they are considered during the field survey.

7.2 Biases

Interpreting the archaeological record in the Gobi landscape presents several challenges. These challenges include the coverage and technique of the survey (van Leusen, 2011; Markofsky, 2011, 2014), and the environmental setting (Allen, 1991), which is particularly influenced by heavy erosion and deflation. Chief among these biases are conceptual (Wilkinson, 2003), visibility (Brown, 1997), observer (Markofsky, 2011, 2014; van Leusen, 1996, 2002), and accessibility (Markofsky, 2011, 2014). While all are valid and important, visibility and accessibility are particularly applicable.

The first bias, conceptual, classes data under preconceived ideas (van Leusen, 2002). This causes archaeological investigation to focus only on specific chronological, typological, and geographical components (van Leusen, 2002). Both Wilkinson (2003) and Talmage and Chester (1977) discuss
conceptual bias when small sites are used to address broader regional issues, such as population demographics or resource procurement.

The second bias, visibility, applies where landscapes obscure detection of sites and thus determines how and what surface data is recovered (Markofsky, 2014; van Leusen, 2002). Consequently, this affects the recorded distribution of sites in a landscape. Visibility may be influenced by anthropogenic factors, such as agriculture or urban development, as well as large-scale reoccupations of sites that obscure chronology and stratigraphy of earlier occupations, or taphonomic, geomorphological, and hydrological factors (Brown, 1997; Howard and Macklin, 1999), including erosion and deflation (Rick, 2002). Quantitative approaches like regression analysis (Shennan, 1985) address visibility issues.

In arid and semi-arid landscapes like the Gobi Desert, aeolian deposits, dune cover, deflation, and erosion particularly obscure the archaeological landscape (Rick, 2002). In these settings, local factors become more important, especially in areas under extreme alluvial or colluvial deposition where the extent of sites and assemblages, usually indicative of substratum archaeological landscapes in most settings, remain undetected, thus creating a hidden landscape (Bintliff and Howard, 1999). This is problematic across Central Asia, where dune cover affects recovery. For example, in Turkmenistan, up to 30% of sites are obscured by dunes (Sarianidi cited in Kohl, 1988: 144).

Some alternative strategies have been proposed to overcome this, most of which require a deep understanding of local environmental contexts (Bintliff and Snodgrass, 1985; During and Glatz, 2010; van Leusen, 2002). These include anisotropy, which separates directional biases from spatially prohibited patterns (Markofsky, 2011, 2014).

Observer, or research bias, is rooted in the perspective of the researcher and their ability to record information (van Leusen, 2002). This manifests in the field, as well as in desk based survey, such as remote sensing, where the researcher does not or cannot identify pertinent features, such as shapes in the imagery or artefact types (van Leusen, 2002). Van Leusen (2002) says this is indicative of weaknesses in the larger research process and the reliability of the researcher’s appropriate observation skillset.

Markofsky (2011) introduces a fourth bias, accessibility, and defines it as the preference to survey certain areas over others because of the ease of access to the landscape. Accessibility bias in the Gobi, besides visibility, is most relevant. Areas of dune fields, gravel (gobi) landscapes, and lack of infrastructure and roads make it difficult to access areas that otherwise remain unexplored and
Chapter 7: Field Survey Design

overlooked. The Gobi Desert as a region remains largely unexplored compared to other areas in Mongolia.

Van Leusen (2011) suggests changes to overcome these biases. First, he recommends conducting surveys in what is perceived to be difficult, uninteresting landscapes. Secondly, he recommends developing survey methodologies designed to detect smaller units through adaptive collection methods, such as Orton’s (2000) adaptive sampling approach.

7.3 Site vs. Scatter

The basic and most important archaeological unit is the site (Tainter and Lucas, 1983; Orton, 2000; Plog et al., 1978). However, the descriptive methods and site formation, as well as the theoretical basis on which site is defined are often criticised (Dunnell, 1992; Dunnell and Dancey, 1983; Ebert, 1992). Some consider site as any place with traces of human activity or where significant cultural material remains are present (Banning, 2002; Hole and Heizer, 1965). Others say objects are not sites, rather the site is the horizontal and vertical boundaries that identify functions as units of association (Willey and Phillips, 1958), and scatters do not necessarily qualify as sites (Renfrew and Bahn, 1991). Binford (1964) believes sites are similar to assemblages, where artefacts and their spatial relations are variable and not homogenous, while Gallant (1986) considers site to be where the density of artefacts are higher than surrounding areas.

In Central Asian archaeology, deflated landscapes often yield palimpsests of surface pottery with little or no evidence of sub-surface material. This disconnect gives rise to doubts whether these are evidence of occupation (Markofsky, 2011, 2014). Early explorer Aurel Stein (1921) recognised this issue during his surveys around the Tarim Basin.

Dunnell (1992) and Dunnell and Dancey (1983) propose the archaeological landscape should be viewed as a continuous distribution of artefacts, where all variability in artefact density is explanatory, and that spatial distributions of artefacts, features, and material remains offer a better approach to interpreting the archaeological record. This is a siteless or non–site view (Foley, 1981; Dunnell and Dancey, 1983) commonly employed in landscape archaeology or distributional archaeologies, where human behaviour may be reconstructed by observing patterns in the material record across many contexts (Cherry, 1986; Dunnell, 1992; Dunnell and Dancey; 1983; Ebert, 1992; Foley, 1981; Rossignol and Wandsnider, 1992). A fuzzy concept of site presents an alternative framework where sites are not defined by boundaries, and reflect complex patterns of occupation intertwined with geomorphological influences (Gallant, 1986;
Banning, 2002). In this way, the entire archaeological record is a continuous artefact of the landscape (Sanjuan and Wheatley, 1999; Wheatley, 1995).

In Turkmenistan, recent research has adopted a distributional approach while also incorporating geomorphology and hydrological investigation. This has resulted in the successful discovery of hundreds of unknown sites, leading to a reinterpretation of the organisation of the Bronze Age landscape through examination of the continued distribution of surface material (Cremaschi, 1998; Cerasetti et al., 2008; Markofsky, 2014; Salvatori, 2008). This contrasts with the idea of discrete sites clustered around micro-oases (Hiebert, 1994; Markofsky, 2014).

In the approach used in the field survey here, the material distribution across the landscape is examined according to the non-site and distributional methodology proposed by Dunnell and Dancy (1983) and Ebert (1992); however, a fuzzy notion of site is retained (Bevan and Conolly, 2004; Dunnell and Dancy, 1983: 272; Markofsky, 2011, 2014). Here, site refers to a specific area of archaeological activity within the Ulaan Nuur region, while a subsite refers to an explicit density of archaeological material, distinct from surface scatters, which are found in small densities. The entire landscape is regarded as a potential space of archaeological activity, void of defined and discrete boundaries. This is similar to the approach used by Bevan (2002) in the Greek Kythera landscape, by Markofsky (2011) in the Turkmenistan Bronze Age landscape, and by van Leusen (2002, 2011) in examination of Roman landscapes.

7.4 Ground Survey Strategy

For this field survey, I chose to focus on portions of the south-east and south-west palaeochannel corridors and a portion of the southern hypothesised lakeshore corridor. The channel corridors and lakeshore corridor were determined using the results of the satellite imagery and hydrology model in Chapters 5 and 6. Using a stratified random sampling approach, the survey tracts within the corridors were determined using the locations of known sites and scatters in the area, and combined with the hypothesised Ulaan Nuur shoreline and the major river mouths. This is pictured in Fig. 7.1. The first step in creating a field survey plan was mapping the potential Holocene shoreline. These shoreline points were input into a Garmin ETrex 10 Global Positioning System (GPS), using a datum of UTM zone 48N, in conjunction with cardinal points.
Fig. 7.1: A map of the areas originally planned to survey. Some areas proved to be inaccessible or had low visibility, so alternative areas were surveyed instead. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

The next step flagged the identified areas by examining fine scale areas from the geomorphological modelling on a small scale. These were mainly ponds, depressions, green areas, and other relevant geomorphological features (Fig. 7.1). These were mapped in context with the potential shorelines and river mouths. This also included the current extent of the modern Ulaan Nuur.

From these points, the region was divided into grids for preliminary survey (Fig. 7.1). Survey sampling highly depended on ground visibility, and accessibility. The first area marked to survey was the Mesolithic/Neolithic site of Bayanzag. The second areas were the south-east palaeochannel, the south-west palaeochannel, and the major river mouths associated with these. Finally, the eastern and southern hypothesised lake shoreline and areas with and without identified geomorphological features were surveyed.

Some designated points identified during the planning phase were inaccessible in the field, and it was necessary to improvise and survey alternative areas that had not been originally planned. These inaccessible areas will be revisited in future surveys, but it will be necessary to plan alternative routes in advance to reach these areas.
This was the case in two instances around the palaeolake, which is now covered in coppice dunes, making it impossible to drive through. The survey vehicle became stuck in areas of sand. In one case, where it had recently rained, a survey area was blocked by sand that had turned to mud, between a giant barchan and a rocky hill, with no other way around. In another instance, the vehicle was stuck in a sandy extinct volcano field overnight.

In the field, the GPS, maps from the Mongolian government at a resolution of 1:50,000, printed satellite imagery maps of all points, and a laptop powered by a solar battery charger, were used to guide the survey. Future surveys would benefit from bringing a smaller compact device, such as a tablet, rather than a laptop.

The survey began at the south-eastern channel (Fig. 7.1), the most prominent in satellite imagery, which connects Bayanzag to the Ulaan Nuur system. Bayanzag was chosen as the starting point. This also provided the opportunity to examine the archaeological sites in relation to the geomorphological context at Bayanzag, described by the Central Asiatic Expedition (Berkey and Nelson, 1926; Nelson, 1926; Fairservis, 1993). The results of the Bayanzag survey will be discussed in the next chapter.

Then driving from the point where the south-east palaeochannel passes Bayanzag, towards the hypothesised southern shoreline of Ulaan Nuur, geomorphological features too small to be seen on topographical maps, the GIS, and satellite imagery were identified. These were mainly deflated erosional areas, yardangs, eroded cliffs, depressions, and green areas. Survey took place along the south-eastern channel, the southern shoreline of the palaeolake, along the south-western channel, and areas in the north-east around the Ongi River alluvial fan.

It was impossible to survey the entire region for this dissertation, especially with the limited three-person team and limited time frame and budget. Future fieldwork would benefit from surveying other areas along these corridors, as well as the southern spring belt corridor. With this methodology, it is possible that sites were missed during survey. However, survey results using this methodology were incredibly successful, leading to the discovery of several sites and surface scatters, which are presented in the next chapter.
Chapter 8: Field Survey Results

8.1 Overview

Continuing from Chapter 7, which described the field survey design, this chapter will review the major results of the field survey (Fig. 8.1). The survey was completed through a systematic approach using designated points recorded in a Garmin Etrex 10 GPS. These were reached by car, but points identified while in the field were also investigated. Several areas of archaeological activity were identified and an overview of these results is presented here. The results will be discussed according to area (Fig. 8.1).

![Fig 8.1: A map of the areas surveyed, indicating the location of sites, scatters, and tombs located. Each area is accompanied by the section in Chapter 8, which will discuss these. Base map: ArcGIS 10.5.1.; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.](image)

A complete list of the archaeological materials recorded at all sites may be found in the Appendix. However, because of the overwhelming size of some of the locations, combined with the limited team size, not every single artefact at each site was recorded. At some areas, there were literally...
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thousands of artefacts. The materials in the Appendix represent only a small sample. Intensive site survey for each area is required in the future to accurately record all materials.

The first area to be discussed in Section 8.2 is the largest of the identified areas of archaeological activity, Khoyor Khairkhan. This site is discussed first because it has the most diverse geomorphological processes of all of the sites. The in-depth explanation of these processes at this site will establish a geomorphological framework, also applicable to all of the other areas identified during the survey. Okladnikov and Dorj first discovered Khoyor Khairkhan in the 1970s. However, our survey has broadened the original archaeological area of activity to extend over a much larger area than their original survey, and has identified new peripheral areas of activity in the vicinity, which I have considered here as an extension of Khoyor Khairkhan. These areas are in proximity to the south-east palaeochannel river mouth and the Ulaan Nuur palaeoshoreline. We also identified major areas of jasper and chalcedony/agate raw resources. Early analysis indicates this was most likely an area of wetlands and small lakes (Chapter 9).

Section 8.3 will detail the site of Bayanzag (also detailed in Chapter 2), which was the starting point of the field survey. Starting here provided an excellent opportunity to re-examine the geomorphological contexts, last reviewed by Charles Berkey in the 1920s, with the added insight of the existence of the Ulaan Nuur complex, which is connected to Bayanzag by the south-east palaeochannel and secondary tributaries.

Next, Section 8.4 introduces a new site, Zulegtiin Khud, in proximity to the south-west palaeochannel corridor. This is the best preserved site identified during the survey, with diverse artefacts, and holds the most potential for future intensive archaeological survey and excavation. This site also could potentially provide an excellent record of environmental chronology. Early analysis indicates this site’s ecozone may have been predominately wetlands with a small lake when it was inhabited (Chapter 9).

Section 8.5 introduces a new area identified at the junction of the south-east palaeochannel river mouth and the Ulaan Nuur palaeoshoreline, along a large palaeo riverbank of the south-east channel. This is dubbed Right Palaeo Riverbank. This section will also describe an area of scatters, which may have been connected to the artefacts located at the bottom of the riverbank.

Finally, Section 8.6 documents the survey along the southern lakeshore, which mainly identified areas of small scatters. This area also includes the small abandoned hamlet of Mandal Baga. In proximity to an extinct volcano field, and close to the Ulaan Nuur shoreline of 1960/1970, the survey identified a later period cemetery, which will also be discussed briefly.
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8.2 Khoyor Khairkhan/Хоёр Хайрхан

8.2.1 Overview

Khoyor Khairkhan (Хоёр Хайрхан) translates in English as the “Two Sacred Mountains” and in a flat landscape such as the Gobi these two inselbergs (Wainwright and Brazier, 2011) stand tall and imposing like fortresses (Fig. 8.2). The two sisters are a family of inselbergs; the largest one is a mesa outlier—where at one time (millions of years ago) it may have been a vast connected volcanic landscape, much like its larger vulcan cousins in the northeast. Several ovoos\(^1\) dot the area around the inselbergs, and on top of the inselberg chain itself.

Fig 8.2: On the left, a view in the distance of the Khoyor Khairkhan inselberg family. On the right, one of the smaller ovoos at the top of one of the inselbergs, where the earth and sky meet. The blue scarves (khadag, хадаг) represent the eternal blue sky, as well as respect to the god Tenger.

At the top of the inselbergs, the Flaming Cliffs and Bayanzag are visible in the south, the Gobi Altai Arts Bogd Mountains and Flint Valley loom in the distance to the west, and the mega barchan next to Zulegtiin Khud is visible in the foreground. The large Ulaan Nuur depression in the east and north is separated from Khoyor Khairkhan by dry hilly areas.

The site was first surveyed in 1971 by the Mongolian-Russian Expedition led by Okladnikov and Dorj (1978), and was referred to as Baruun Zuun Khairkhan (Western, Eastern Mountain), but has since been renamed as Khoyor Khairkhan (D. Odsuren, personal communication).

The materials collected by the 1971 expedition have been extensively studied by D. Odsuren (2014) and further discussed by Janz et al. (2017). The assemblages found here are earlier than

\(^1\)An ovoo, like the one above (Fig. 8.2), is a stone structure dedicated to the great sky spirit, Tenger. It is a mix of Buddhist and shamanistic elements. One must walk around the ovoo three times, adding a rock to the ovoo at each turn. In this way, blessings are bestowed on the traveller. Often other offerings are left like money, vodka, or milk tea.
those found at Eregiin Khooloi, with core forms including boat-shaped and wedge-shaped preforms and microblade cores, along with microblades, scrapers, projectile points, and denticulate tools (Janz et al., 2017; Odsuren, 2014). Occupation of the site is estimated between post-LGM/Mesolithic to Late Neolithic/Early Bronze Age (Janz et al., 2017).

The field survey described here examined a more extensive area than the original site. Adopting a non-distributional approach, three major areas of activity were identified, in addition to archaeological scatters across the entire landscape (Fig. 8.3). This significantly broadens the scope of the original 1971 study area. At the original 1971 site, this current field survey identified material strewn over 4 km, two times larger than the original survey. Further artefacts were found strewn over an area of over 8 km.

The area of Khoyor Khairkhan is an interesting landscape of mixed environments (Fig. 8.3). At one time, big rivers, now palaeochannels, ran through the area in which dune fields now prevail. The dune-covered south-east palaeochannel is the largest visible in satellite imagery, while the south-west channel, equally as large, is now totally covered by an even larger dune field. Dune fields are not only around these channels, but are also at the foot of the eastern inselberg itself found together with fixed palaeodunes in erosion. Together with the wind, voles and hedgehogs contribute to the erosion of these palaeodunes and burrow holes into them. The voles chirp and call to each other incessantly, while the only evidence of the hedgehogs are their unfortunate mummified remains above ground.

Additionally, two palaeochannels related to springs originating in the southern spring belt close to the city of Bulgan, run along this site (Fig. 8.3). The palaeochannels are evident of their past reach, as is their presence on Mongolian government maps from the 1960/1970s, which terminate at the hypothesised Ulaan Nuur shoreline in alluvial fans. These secondary channels are now ephemeral, bringing water to the area during heavy rains in the summer.
Palaeoenvironmental and palaeogeomorphological studies would be necessary, but in a more humid period, the Khoyor Khairkhan area could have been in a key location with a welcoming environment. This area could have been close to the southern part of a large lake (most likely Ulaan Nuur) in an area where two main rivers were coming from the east and the west, and two secondary rivers coming from the south flowing along its eastern and western sides.

The geomorphological characteristics of the landscape are equally important, because they have shaped the archaeological landscape on which material is distributed, and are reviewed next.
8.2.2 Geomorphological Landscape

The geomorphological landscape is strongly influenced by fluvial and aeolian processes which control erosion and deposition. The major landscape features are lakes and palaeolakes, rivers and palaeorivers, and dune fields and palaeodunes in the form of yardangs (Fig. 8.4).

Fig. 8.4: An example of a yardang, a fixed palaeodune, surrounded by active dunes. These yardangs are shaped by abrasion from strong aeolian processes.

An important geomorphological characteristic of this landscape, are the dune fields (Fig. 8.5). The dune fields seem to be related to remobilisation of sediments deposited in the palaeochannels. Dune field #1, north east of secondary channel 1 is formed from sediment transported by the intermittent river (Fig. 8.5). This dune field is related to the south-west wind, which is the most important wind that shapes the landscape. The only wind record comes from the province capital Dalanzadgad, where the Westerlies are the prevailing winds. However, local factors are relevant in this area. Here, the prevailing winds are actually south-west. Dune ripples particularly demonstrate this wind direction best. Strong evidence for this is indicated in the geomorphological landscape, where the winds are most likely related to the corridor between the Gobi Altai Arts Bogd and the Gurvan Saikhan Mountain ranges.
The second major geomorphological process affecting the landscape is fluvial. The secondary channels come from the eastern and southern plateaus and end in alluvial fans in the Ulaan Nuur depression, which was possibly the Holocene lake. The presence of many alluvial fans ending here fits well with the Holocene lake extent modelled in the GIS. There are many alluvial fans and channels at the mouth of secondary channel 1. This demonstrates the possibility that this channel has most likely evolved over a wide range of movement through the Holocene.

To the east of the study area is a plateau (Twidale, 2014). At the edge of this plateau, there are gullies and rills (Fig. 8.5), which are evidence of irregular precipitation that commonly erodes arid landscapes (Wainwright and Bracken, 2011; Wainwright and Brazier, 2011). At the bottom of the plateau currently in erosion is a green area. There are also gullies all around the hilly areas to the
north of Khoyor Khairkhan, where there is the formation of a pediment (Twidale, 2014). A good example of this is near Area 3 (Fig. 8.6).

Fig. 8.6: The three major areas surveyed during the field survey. Area 1 corresponds to picture a; Area 2 corresponds to picture b; Area 3 corresponds to picture c. Base Map: Google Earth; Imagery 2018 DigitalGlobe, 2018 Google; www.google.com/maps.
8.2.3 Archaeological Landscape

There are three major areas surveyed with varying geomorphological characteristics (Fig. 8.6). The first is the immediate area around Khoyor Khairkhan (the eastern inselberg), referred here as Area 1, which is the site of the original 1971 survey at Subsite 1.A (Janz et al., 2017; Odsuren, 2014; Okladnikov and Dorj, 1978; Fig. 8.6, 8.10). The second area, Area 2 (Fig. 8.6), is the alluvial fan of the secondary channel 2, and the third area, Area 3 (Fig. 8.6), is a green area north of the hills at the junction of all of the channels, along the southern edge of the palaeo Ulaan Nuur.

Area 1 is further divided into subsites according to where archaeological material was found. The subsites and their corresponding material will be presently discussed, after a brief explanation of the processes of deflation and erosion that dominate this local landscape.

8.2.3.1 Area 1

Khoyor Khairkhan (Area 1) is part of a family of inselbergs. There are several types of inselbergs, and the landscape here exhibits all of them (Bremer and Sander, 2000). Khoyor Khairkhan is what is known as a mesa outlier (see Appendix). The top hard layer consists of volcanic deposits, while subsequent layers consist of different beds of volcanic layers. The top layer protects the underlying layers from erosion (Bremer and Sander, 2000; Wainwright and Brazier, 2011).

Area 2, along the alluvial fan of secondary channel 2, is close to the palaeoshoreline of Ulaan Nuur, and at the edge of the south-west channel. This area shares similar features as Area 1, namely the presence of dune fields associated with yardangs. These yardangs are eroded, with the south-west side formed by wind abrasion. There are troughs in between the yardangs, which are most likely eroded palaeodunes (Fig. 8.8.; Appendix). These are formed in the direction of the south-west prevailing wind. The yardang surfaces are deflated, and directly in front of these are yardangs in an advanced eroded state. Beyond these, a gradient in landscape is evident (Fig. 8.7). The front of the yardang area has an area of distinctive white, sandy, silty, deflated deposits. After this area of white deposits, desert pavement and scrubs stretch into the distance (Fig. 8.7).
Fig. 8.7: The major landscape characteristics around the Khoyor Khairkhan area, including extensive yardangs. The bottom two rows with letters on the top left of each image (a, b, c) correspond to areas with the same letters on the top image.

Behind the northeast area of Khoyor Khairkhan, there are active dunes composed of sand from yardang erosion (Fig. 8.7). On the north side of Khoyor Khairkhan, active sand dunes diminish towards the northeast. At the end of the dune field is a humid area, called Subsite 1.C, because of the archaeological material found here (Fig. 8.10). This humid area was most likely formed by a blow out of sediments (see Appendix). Subsite 1.B is another blowout (Fig. 8.10), but is located in front of the yardang. Deflation reaches either desert pavement (Laity, 2011), like the southeast of Subsite 1.A, or in the case of a blowout (Hesp, 2002; Hesp and Hyde, 1996), goes deeper towards the groundwater table, and creates a humid depression. Deflation on pavement does not go
deeper because the desert pavement material is too coarse and cannot be transported, thus protecting the underlying finer deposits.

Archaeological material was found on top of the yardangs, but not observed inside the layers (Fig. 8.8). Based on this observation, these yardangs most likely predate the Holocene occupation of the site. This would be consistent with patterns of dune activity introduced in Chapter 3, and may also be related to pre-Holocene Ulaan Nuur shorelines. The most important site of the area was found just in front of these yardangs. The archaeological materials lay mixed on the deflated surface, and most of the stratigraphy has disappeared. In the active sand dunes, only scatters were found. If material is present in the area of the active dunes, it is most likely covered. Other sites are around the blowouts in the humid areas, such as Subsite 1.B and Subsite 1.C. (Fig. 8.10).

![Fig. 8.8: Artefacts are organised as either small surface scatters, scatters with high densities, or isolate artefacts on top of the yardangs. The letters on the top left of each image (b, c, d, d,) correspond to locations with the same letters in Fig. 8.7.](image)

It is important to note, that the main site (Area 1; Subsite 1.A; Fig. 8.10) was investigated by Okladnikov and Dorj (1978). Additionally, the main area sits next to a road and there is evidence that many people have visited the site over the years, as the area is littered with trash. Keeping this in mind, it is highly probable the integrity of the site has been disturbed, and classifying
areas of the site by use is not reliable. Some of the outlier subsites are potentially more reliable because they are much further from the road, considerably more difficult to access through heavy sand and dune coverage and only by foot, and most likely have not been heavily visited.

Even though the area is heavily eroded and deflated, archaeological materials present on the surface reveal several distinct patterns. Density is chief among these (Fig. 8.8, 8.9), where some areas exhibit higher densities of materials than others do. Similar artefacts and similar materials are grouped together according to subsite; however, for the main area (Subsite 1.A) this could be because of the 1971 expedition or from people disturbing and collecting materials over time, and therefore is not necessarily a reliable index. Keeping this in mind, lithics are grouped with lithics of similar material and type (e.g. bifaces with bifaces, jasper with jasper). Pottery is mostly only present in humid areas, and beads were found together; however, these all sit on the badly deflated surface. The site has probably been heavily deflated between the time of the 1971 expedition to the present, and this explains why there are more diverse artefacts observed on the surface today, compared to the original investigation.
Fig. 8.9: Artefacts range in density from high to low, and continuous to isolated. Artefacts of similar types and materials seemed to be grouped together. This may have been the results of the 1971 expedition or people visiting through the years, and the integrity of this distribution may not be reliable.
Area 1 is divided into subsites based on where archaeological material was found (Fig. 8.10). A brief description of the major landscape characteristics of these subsites is now discussed, along with a brief description of some of the identified artefacts. A complete list of artefacts recorded at this site may be found in the Appendix. However, this does not represent the total number of artefacts identified, which ranged in the thousands.

**Subsite 1.A**

The largest inselberg on this site is potentially a major raw resource for chalcedony and agate in the Ulaan Nuur area. Provenance testing would confirm this. Chalcedony is a silica precipitate from a liquid, and is formed from hot springs or volcanic fluids or high thermal temperatures. It is normally associated with volcanic areas. The inselbergs here are weathering features consisting of volcanic rock, and are thus consistent with conditions under which chalcedony is normally found (Mike Searle, personal communication). If this area is indeed a raw material procurement site,
then it would explain the range of artefacts from multiple time periods. This indicates this site has most likely been an important area for local groups for many millennia.

Additionally, jasper raw resources were identified approximately 12 km northwest on the other side of the south-west channel. In this area, there are low hilly areas covered in raw jasper. This may have also been a raw resource procurement area and is in close to proximity to all of the sites identified during the field survey (discussed in Chapter 9).

**Lithics**

The primary lithic materials at this site are red and yellow jasper, agate, and chalcedony. These are typical materials also found at other local Gobi sites. Lithic types range between Mesolithic and Late Neolithic /Bronze Age. However, other material not typical of the region, like mossy flint is rarer but present at this site and also in very limited quantities at the other sites. This is possibly a transported material from another location outside of the Ulaan Nuur region. There is a diversity of lithic types across the entire site, including particularly excellent examples of bifaces and bullet cores.

**Pottery**

Pottery found in this area ranges between many periods. This includes Neolithic through the much later Mongol period, although pottery from later periods is rarer, with very few later period sherds found across the site. The majority of sherds in this site are Bronze Age or earlier.

**Beads and Ostrich Eggshell**

Broken pieces of ostrich eggshell was found exposed on the surface, with much of it still buried in the stratigraphy, most likely from recent rains (Fig. 8.11). Additionally, two beads were identified (Fig. 8.11), sitting openly on the deflated surface, also most likely exposed from recent rains. One of these is crafted from an ostrich eggshell. Ostrich eggshell beads are also found at Bayanzag and across other sites in Mongolia. They are seen commonly in sites dating to the Late Palaeolithic, and continue into the Bronze Age. Janz et al. (2009) has established ostrich occupation in the Gobi until the Early Holocene.

A red stone bead was also identified next to the ostrich eggshell bead (Fig. 8.11). Based on the craftsmanship and style of these beads, they most likely date to the Late Neolithic or Early Bronze Age.
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Fig. 8.11: The top image depicts the red stone bead. The bottom image shows the ostrich eggshell bead. To the far right of the ostrich eggshell bead, ostrich eggshell was recently exposed by summer rains and found in pieces, though much of it remained buried in the stratigraphy.

**Subsite 1.B**

Subsites 1.A and 1.B are close to each other. Subsite 1.B is currently a particularly marshy and humid area, covered with thick grasses and reeds. This is potentially the area of a former small palaeolake. This area has higher concentrations of pottery compared to all other areas surveyed around Khoyor Khairkhan. The pottery found here all roughly belong to the Late Neolithic/ Bronze Age. A potential hearth was also identified, but would need to be excavated to confirm.

**Lithics**

A higher density of lithics (thousands) was found in this area compared to Subsite 1.A. Many of the lithics in this area were grouped by material, though this may have been from the previous expedition or people visiting the site. There are several thousand lithics in varying stages of production (Fig. 8.12), as well as flakes. Based on this, this area may have been a major production area of the site.
The blade flakes found in this area are potentially Upper Palaeolithic, while the tools are possibly either post-LGM or Bronze Age (Lisa Janz, personal communication). The majority of tools were of red jasper, but agate and chalcedony were also common.

![Figure 8.12: Projectile points in area Subsite 1.B of the site. Some of the tools potentially range from the post-LGM, more detailed photos of all artefacts in Subsite 1.B may be found in the Appendix. Artefacts 42, 43 in the Appendix, Khoyor Khairkhan.](image)

Pottery

This area contains an overwhelmingly large amount of pottery sherds, compared to Subsite 1.A., which has considerably less. The pottery is black and red ware, ranging between coarse and finer consistencies. There are also a few decorated sherds. Most of the sherds are most likely Late Neolithic to Bronze Age, with later periods interspersed throughout.

The majority of the sherds are red-ware. A few sherds have decorations, consistent with cord marked pottery (Fig. 8.13). Janz et al., (2015), have dated cord marked pottery from other archaeological contexts across the Gobi, where dates range between 8010-2990 cal B.P. (from 3 samples). Fine red-ware pottery has been dated to between 4590—3350 cal B.P. by Janz et al. (2015).
Fig. 8.13: Example of cord marked pottery. Sherd 17 in the Appendix, Khoyor Khairkhan.

Fig. 8.14 is diagnostically Neolithic. It is white and black of a fine consistency with a slight curvature on the back (black side,) while the white side is net impressed. Janz et al. (2015) have dated net impressed pottery from Gobi sites to 7670-4750 cal B.P. (from 5 samples).

Fig. 8.14: Net impressed pottery is diagnostically Neolithic. Sherd 33 in the Appendix, Khoyor Khairkhan.
Fig. 8.15: A string paddled patterned sherd. Sherd 34 in the Appendix, Khoyor Khairkhan.

Another sherd is black and tan and of a fine consistency (Fig. 8.15). This pattern is similar to a string paddled pattern, dated to between 4973-1450 cal B.P. by Janz et al. (2015) (from 3 samples).

Subsite 1.C

This is the area of a small former palaeolake, and is still humid. The thick vegetation is indicative that groundwater is still present. In this area, bullet cores, spearheads, and flakes were the primary lithic types identified on the surface. The integrity of this area is has most likely not been compromised by outside sources.

Subsite 1.D

Subsite 1.D is on the other side of the mesa outlier, away from the main site (Subsite 1.A). There are large pieces of raw materials, as well as preforms in this area. The lithics found here are unfinished and more rudimentary compared to the other areas.

Subsite 1.E

Subsite 1.E is located on top of the major mesa outlier. There are raw lithic materials here that have been partially modified. This vantage point highlights the entire landscape. Bayanzag and the bright red of the Flaming Cliffs are visible, as are the large dune fields near Zulegtiin Khud, as well as the Ulaan palaeolake depression.
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Subsite 1.F

Burials

This area sits between two of the main mesa outliers. There is heavy sand coverage intermixed with volcanic outcrops. At least 10 burials and satellite features were recorded, but it is possible the sand is obscuring others, rendering them undetectable. One distinctive slab burial lies in the centre (Fig. 8.16). Slab burials are typically Late Bronze Age (Chapter 2). The other burials and features are potentially Bronze Age or earlier, based on the site chronology, but excavation would be required to positively place these into a chronological framework. Lithics and flakes found on the surface around these burials are possibly Neolithic to Bronze Age.

Fig. 8.16: The slab burial at Khoyor Khairkhan. For other views of the slab burial, as well as pictures of the other burials see Appendix, Khoyor Khairkhan.

Subsite 1.G

This area has many volcanic outcrops and sits within the transition of the inselberg zone and the plateau. Some features look as though they could be burials, but they are also potentially naturally occurring geographic features such as an advanced eroded inselberg. Sand obscures much of this area.
8.2.3.2 Area 2

Area 2 is approximately 3.5 km from Area 1 (Fig. 8.17), but because of the similarity in features, Area 2 is included here as part of the same archaeological landscape as Area 1. This indicates groups were utilising the entire landscape rather than focusing on a small constricted area.

Fig. 8.17: Area 2 is 3.5 km from the main Khoyor Khairkhan site at Area 1.

This area borders a humid depression, which was possibly a former small palaeolake. There is a secondary channel 3 flowing between the hilly area ending in an alluvial fan, now covered in dunes, which may have directly connected this area to the larger Ulaan Nuur. This site follows the secondary channel 2 and borders the south-west palaeochannel, close to the south-west river mouth, as well as the Ulaan Nuur depression. This is not far from the GIS modelled Holocene shoreline. There are two distinct sets of yardangs (Fig. 8.17) with active dunes in between the troughs, where artefacts have washed down from the tops. This site is badly eroded and deflated. Additionally, grazing goats have contributed to the overall degradation of the site.
Fig. 8.18: Two sets of yardangs intertwined with active dunes characterise this site. This area overlooks the Ulaan Nuur depression, and lies along the confluence of the south-west palaeochannel, close to the river mouth.

**Pottery and Lithics**

Pottery and lithics here are coarser compared to those at Area 1. Most of the pottery and artefacts are close in density, though the ground here is heavily deflated and there is evidence of recent heavy fluvial erosion (Fig. 8.19). This is most likely the result of heavy rains, which have moved the artefacts from their original positions. Recently cracked clay indicates this area is regularly flooded.
Fig. 8.19: Lithics and flakes cluster on top of recently cracked clay in high densities, indicating they have been recently moved by heavy rains.

Pottery at this area is stylistically limited compared to the diverse types found at Area 1. Based on their characteristics, these are most likely Bronze Age.

Again, there is a range of materials at this site, but in the absence of cores and large raw materials, there are more microliths, flakes, and small pieces of debitage. There is a higher occurrence of lithics made from white chalcedony here compared to the main Khoyor Khairkhan site. Again, jasper is also found in large quantities. Based on this, this was most likely not a major area of extended use, but is most likely associated with the larger site at Area 1.

**8.2.3.3 Area 3**

Area 3 is associated with a semi-permanent water feature. The water here is most likely a remnant of the palaeo Ulaan Nuur depression (Fig. 8.20). A few pieces of debitage were found here, however, the position of these may have been the result of fluvial transport. Because of the absence of any other major artefacts in this area and due to the nature of the current
environment here, it is unclear if this was a major area of use. It is possible that this area was either more extensively covered with wetlands, or entirely underwater, and was possibly connected to the water feature of Subsite 1.C.

**AREA 3**

View toward the North

![Area 3 view toward the North](image)

View toward the South

![Area 3 view toward the South](image)

Lake  Dry lake  Scatters

![Lake](image)  ![Dry lake](image)  ![Scatters](image)

Fig. 8.20: An overview of Area 3. Soft and saturated surfaces indicate this is a seasonal or interannual area of wetlands and water, which may experience variable expansion and contraction of water features. Some small scatters of flakes and debitage were found in this area.

The water here is shallow and brackish, evident by a white salty crust (Fig. 8.21). Birds inhabit the reeds and sedges and local animals use it as a water source. Mosquitos cluster around this area waiting to attack. The soil here is thick and soft, saturated by water just below the surface, making
it difficult to walk. After walking past this small water body, farther into the interior, the landscape becomes dominated by isolated brackish pools with low vegetation, without dunes, and is marshier in appearance. It is evident that this area once held a larger body of water and is probably today interannually and seasonally flooded. No evidence of archaeological activity was found deeper in the interior. There is a possibility that either the Holocene Ulaan Nuur covered this area, or this area has always been thick with wetlands and the shoreline was further away.

![Images showing the small water body and its surroundings.](image)

Fig. 8.21: The small water body in Area 3 is home to birds and small fish (top left), although the water is brackish and salty (top right), evidenced by a white crust on the shoreline. Animals use it as a water source, like the horses in the right middle photo. Farther in the interior, there are other isolated water bodies, some with small fish, but no archaeological material was found (bottom photo and left middle photo).

Based on the field survey, it is clear that Khoyor Khairkhan was an important site for local groups. Further intensive study of this site could provide more information about site use and site chronology. There could potentially be pockets of a preserved archaeological stratigraphy in some areas, particularly at Subsite 1.A and 1.B, and this merits further future investigation.
8.3 Bayanzag/Баянзаг

8.3.1 Overview

As discussed in Chapter 2, Bayanzag is well documented, with reports published by both the Soviet Mongolian Expedition (Okladnikov, 1978) and Central Asiatic Expedition (Berkey and Nelson, 1926; in Fairservis, 1993). Furthermore, Spock (1934), Janz (2012) and Janz et al. (2015, 2017) have examined and discussed many of the artefacts from this site in detail. There are currently still many artefacts on the surface ranging from several archaeological periods.

The goal of the survey of Bayanzag, besides providing a strategic starting point for the field survey because it is an established site, aimed to re-examine the geomorphological and environmental contexts first described by geologist and petrographer Charles Berkey (Berkey and Nelson, 1926; Fairservis, 1993), which have not been discussed in any detail since. Based on the new evidence of the existence of the Ulaan Nuur palaeohydrological system as well as updated environmental chronologies (see Chapter 3), this survey offers the added insight of the environmental setting in the context of the Ulaan Nuur system, with the additional advantages provided by satellite imagery and GIS. This analysis supplements Berkey’s original observations.

8.3.2 Geomorphological Landscape

As the crow flies, Bayanzag is about 19 kilometres from Khoyor Khairkhan. Both areas are visible from each other, aided by the flatness of the landscape, where major geographic features display themselves prominently in the landscape.

Bayanzag may have sat atop one of three distinct lacustrine shorelines modelled by Sternberg and Paillou (2015). However, to confirm this hypothesis and propose a chronological framework, a detailed geomorphological and sedimentological analysis of the landscape would be necessary to identify lake deposits related to the modelled lakes.

During the period relevant to this study, the Ulaan Lake was smaller, and the site of Bayanzag was away from it. During the Holocene, Bayanzag was probably a small depression, with a small lake connected to secondary channels and the spring belt coming from the southern mountain range, the Gurvan Saikhan (Fig. 8.22). Berkey hypothesised that Bayanzag must have been connected to a large hydrological system at some point in the past (Berkey and Nelson, 1926:7), and his hypothesis is confirmed with the knowledge we have about the area today, along with the GIS hydrology model.
A large plateau of Late Cretaceous sandstone overlooks the western and southern Bayanzag archaeological area and small lake. Regressive erosion affects this plateau, forming red cliffs and outcrops of the sandstone. A landscape of cliffs, badlands, and gullies characterise the erosion of the plateau. South of the Bayanzag archaeological area, the Flaming Cliffs (Chapter 2) are part of this plateau erosion. Intermittent small rivers run from the sandstone cliffs across a deflated alluviated pediment formed at the bottom. The intermittent river channel ends in different sized alluvial fans toward the Bayanzag depression. A drying lake sits into the depression and is associated with the Bayanzag archaeological area (Fig. 8.23).
Fig. 8.23: The Bayanzag Lake was potentially much larger in the past, with several rivers leading into it from the Gurvan Saikhan and south-east palaeochannel. Base Map: Bing Maps, 2017 Microsoft, www.bing.com/maps: Earthstar Geographics SIO.

[Diagram of the Bayanzag Lake area with labels for various geological features such as Dune field, Alluvial fan, Intermontane river, etc.]
Different lake levels have been identified along the lake. Fig (8.24) indicates at least three different seasonal and internannual lake levels reached in the past few months or few years. There are clear indications of expansion and contraction of the shoreline. Satellite imagery shows this best (Fig. 8.23).

Fig. 8.24: Landscape features from top to bottom: 1. & 2. Different shorelines recording contraction and expansion are visible at the Bayanzag Lake. 3. Different lake deposits from the southern edge of the lake. 4. Yardangs in the southern part of the lake recording the ancient lake, and fluvial and aeolian deposits.
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The lake expands periodically towards the east in interdunal areas. The lake sits in a small depression, which was probably created by a blowout formed by western winds. It results in deposition of the sand towards the east into an active dune field system. In addition to the channels, the lake itself is also a source of the dune sediments. A series of other small lakes and humid areas follow a north-south direction between the western deflated area and the eastern dune field.

In the western area of the dune field, sediments are deflated and now covered by a saxaul forest. Observations suggest this was once an area of interdune ponds. Palaeodune deposits are cross-bedded but estimating the date is problematic and unreliable because they could potentially be Pleistocene palaeodunes or Holocene palaeodunes. These are interspersed with active dune deposits. OSL dating is needed to establish the dune chronology of this site.

At some point to the north, the outcrops of sandstone from the plateau disappear under a large alluvial fan. Larger intermittent south-west channels coming from the Gurvan Saikhan mountain range and its pediment run on the plateau, leading to this alluvial fan. At some point in the past, channels might have been connected to the south-east palaeochannel. Now, a series of small lakes and humid areas continue to settle on the western fringe of the dune fields, where intermittent channels coming from the Gurvan Saikhan also continue to periodically flow.

In the past, some larger palaeochannel might have also come from the south-east leading to the Bayanzag depression. Now in its place are intermittent rivers, which no longer reach the south-east palaeochannel. These rivers probably passed in place of, or through, the current dune field, as suggested by geomorphological evidence on the satellite imagery, and further verified during the field survey, as well as with the GIS hydrology model. This observation is also consistent with Berkey’s observations.

At Bayanzag, the field survey revealed different lake deposits at different altitudes around the drying lake, which still has a small amount of water today. These deposits are now visible on top of the shore of the current lake (Fig. 8.24), as well as in the stratigraphies of yardangs sitting on the southern edge of the lake Fig (8.24). Dates of these deposits are unsure since no archaeological material has been found in them, and no absolute dates have been performed. However, many of the artefacts identified here were found on top of some of the lake deposits, suggesting the lake was at some point larger than the current lake, and was occupied by local groups.
Ground survey also identified lake sediments in the interior of the dune field, in more recent intermittent channels incised in the dune field. Stratigraphies up to 5 metres high were observed (Fig. 8.25; 1-3).

Fig. 8.25: Stratigraphies of the incised riverbanks. Some reach up to 5 metres. Exact locations of stratigraphies are indicated in Fig. 8.23.
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The right incised riverbank (Fig. 8.25; 2) contained mostly aeolian deposits with some small fluvial channels identified with gravel layers. The left bank is incised deeper and stratigraphies reveal at the bottom potential lake sediments made of dark silty sand (Fig 8.25; 1 & 3). Aeolian and fluvial deposits and palaeosols are deposited and formed on top of these palaeolake deposits.

If compared to general climatic trends, the last aridification period occurred during the Late Holocene (Chapter 3). However, the Bayanzag Lake’s shorelines would need to be dated to confirm this period of activity. Nelson also similarly noted that interdune ponds were non-existent until after the Late Holocene, and were not indicative of past conditions, as the dunes were not present (Nelson in Fairservis, 1993).

A detailed analysis would be necessary, but it seems that different generations of dunes (arid periods) and lake (humid period) succeeded in this Bayanzag depression. Generally, dune activation began during the Late Glacial Maximum, stabilised, and reactivated during the Late Holocene (Chapter 3). However, depending on the date of these dunes, it is possible most of the current dunes did not exist during the main habitation period of the site, and instead gradually covered and eroded the past landscape more recently. This agrees with the overall trend of increasing aridification and subsequent decrease and disappearance of fluvial activity.

Likewise, during a period of aridification, drying of the larger Bayanzag Lake most likely created smaller ponds, then dune deposits, until strong deflation eroded the western part of the substratum and created the extensive dunes. This is apparent in Fig. 8.25, in stratigraphies 1, 2, and 3, and the eastern part of the dune field with preserved lake deposits at the bottom in between older dunal deposits. This was then covered by a new dunal system composed of sands, then channel deposits composed of gravels and interdunal deposits composed of dark silts. Strong deflation could have progressively removed the front dune complex of the dune field and eroded the different generations of palaeolakes, fluvial and older dunal deposits at once. This explains why there is a high quantity of archaeological materials from different periods found along the eroded fringe. A detailed palaeoenvironmental study would provide a good idea of the lake extension, its date, and the landscape evolution, as well as the chronology of dune formation.

8.3.3 Archaeological Landscape

The proximity of the Flaming Cliffs and the importance of the area are significant to both palaeontological and archaeological research. There has been much scientific research in the area over the years, and the area is now protected. It is also a popular tourist stop, and one of the main tourist highlights promoted by Omnogovi province. Though illegal, on the roadside some
local people were selling artefacts from the archaeological site itself, mostly flakes and microblades. Field survey located several small flakes directly in front of the Flaming Cliffs area.

A tourist ger camp sits in close vicinity of the archaeological area near a well first indicated on maps by the Central Asiatic Expedition. The old caravan trail is also still visible. There are also many animals in the area, and overgrazing of the site has contributed to sediment removal and dune activation.

There is extensive deposition in the area, but there is an intermediary on the edge of the dune field where the bulk of artefacts were identified by the Central Asiatic Expedition on the fringes. Mesolithic/Neolithic habitation found by previous expeditions is located on stabilised dunes, directly below reactivated dunes. Artefacts currently observed in the erosion of dunes supports this.

Many of the artefacts identified during this field survey on the dune field fringe were mostly later period ceramics and pieces of iron. There are hundreds of artefacts spread around the site. Neolithic artefacts were actually located further in the interior of the dunal system (Fig. 8.26), in interdunal deflated areas on top of the palaeolake deposit, but decreasing towards the east. This suggests more artefacts may be found below the currently active dunes. Because there is a complex interplay between lake and dune formation across time, this leads to complex stratigraphies and interlocking of layers, and thus older material found in the dunal system suggests there is better preservation of older periods in these dunal areas.

Fig. 8.26: An example of one the artefacts located in the interior of the dune field, on top of palaeolake deposits.
Using the published map of sites surveyed by the Central Asiatic Expedition (in Fairservis, 1993:29), which was then georeferenced in GIS, and compared with the areas surveyed here, it is evident the Neolithic archaeological areas of activity follow a spatial pattern, centred around the local palaeohydrological system. The higher lake was not surveyed, and I currently do not have the excavation and survey locations of the Soviet expedition, so cannot compare that data to this survey. However, the pattern of all of the Neolithic areas of activity follow the two major rivers, and are centred around a larger Bayanzag Lake. This indicates this fluvial system was a dynamic area and an important resource for local groups.

Overall, there needs to be more work completed in the interior areas of the dune field and geomorphological and palaeoenvironmental analysis and datings would help to place this archaeological area of activity within a broader environmental framework.

8.4 Zulegtiin Khud/Зүлэгтийн Худ

8.4.1 Overview

Zulegtiin Khud lies 12 kilometres west of Khoyor Khairkhan, along the south-west palaeochannel and the northern reaches of the southern spring belt. The Gobi Altai looms in the distance where Flint Valley rests in the vicinity, at the end of the south-west palaeochannel. Zulegtiin Khud sits on the right site of the south-west palaeochannel, now occupied by an active dune field. This dune field is formed partially by reworked sediments from the bedload of the palaeochannel. Similar processes are also observed along the south-east palaeochannel.

![Fig. 8.27: The current geomorphological context of Zulegtiin Khud. Base Map: Bing Maps, 2017 Microsoft, www.bing.com/maps: Earthstar Geographics SIO.](image-url)
However, most of the aeolian deposits come from the erosion of white hills in the west. On Mongolian government maps, these hills are a source of agate. However, these were not surveyed during fieldwork so this cannot be totally confirmed. The origins of these white hills have still to be determined, but survey conducted around the bottom of the hills, as well as satellite imagery analysis, reveals important regressive erosion. Around the southern and western areas of the hill, sand accumulation is deposited by fluvial processes and subsequently transported by south-westernly winds. A massive barchan dune originating from the southern area of the white hills is currently moving towards the south-western palaeochannel (Fig. 8.27, Fig. 8.28).

Fig. 8.28 Barchan dune in the area of Zulegtiin Khud. Right image: A top view of the barchan in Geo-Eye 1 imagery.

The study area is located south of the active dune field of the south-west channel (Fig. 8.27). In this area, the pediment of the Gurvan Saikhan mountain range has been affected by lower regressive erosion. The regressive erosion was higher south of Bayanzag, as well as south of Khoyor Khairkhan. Because of this, the spring belt in the area is less marked in the landscape compared to other areas.

The archaeological area of Zulegtiin Khud lies in a small aeolian depression, caused by a blowout. During field survey in the middle of August, grass was growing on the western area of the depression, indicating groundwater levels close to the surface (Area 1.A in Fig. 8.29). Capillarity effect coupled with water content in the subsurface deposits stopped aeolian erosion. A well was built in the middle of this depression to reach the groundwater level. Next to the well, a single yardang reveals the deposits before the blowout (Fig. 8.29).

The northern, western, and southern areas of the depression are defined by low hills. Outcrops of rocks were observed in the higher southern hills. As common in blowouts, the Zulegtiin Khud depression is deeper towards the west, which is the origination of south-westernly winds. The
topography is gradually rising towards the northeast with a series of low rills (Area 1.E in Fig. 8.29).

Small palaeostreams have been observed towards the east coming from the south, confirming the GIS hydrology model. This area is characterised by deflated surfaces. On the north-east area of the depression, yardangs are facing the south-westerly winds and sand accumulation occurs behind (Area 1.F). Similar yardangs are observed at Khoyor Khairkhan.

8.4.2 Geomorphological Landscape

Along the rills and within the stratigraphies of the yardangs, a complex history of dunal deposits and lake deposits are revealed. Patches of white calcareous deposits are found at some places inside the western humid area, as well as further east. These are potentially palaeolake carbonates, but analysis should be conducted to confirm this. Darker palaeolake deposits in some areas may be interpreted as belonging to a more humid period (Fig. 8.31; B). In the eastern part of the depression, this dark black layer can be found in many places and is clearly visible in the stratigraphies (Fig. 8.31; D).

![Deposit types around the blowout of Zulegtiin Khud.](image)

Freshwater shells were also observed in stratigraphies towards the east and in the central yardang stratigraphy (Fig. 8.30, Fig. 8.31; E, F). These have been confirmed to be at least two species of freshwater gastropods, which would need to collected and analysed in the future. One positive identification places one species as *Lymnaeid radix*. *Lymnaeid radix* belongs to Lymnaeidae, a family of fresh water pond snails (Stift et al., 2004; Vinarski and Frolov, 2017; Vinarski and Serbina, 2012; Vinarski et al., 2017). This species thrives in calcium-rich standing or slow moving water, such as pools, small lakes, and rivers, with a diet high in water plants, including algae. In the central yardang these shells were found in association with a Late Neolithic/Bronze Age blade, and based on this, a hypothesis of the environment may be formed.

A ring of organic material around the palaeolake supports the presence of more vegetation in the past. In the central yardang, the matrix consists of fine sand pockets of fine shell debris, indicating water movement that may have crushed the shells. The associated layers vary in colour, from dark to light (Fig. 8.30, 8.31; E, F). This suggests the lake facies can be very different from place to
place, with more or less aeolian sand content. This may also be related to different gradients of organic matter content, sediment inputs, and hydrodynamics inside the lake.

Fig. 8.31: Varying stratigraphies observed at Zulegtiin Khud, including palaeolake deposits.
Some sequences in the stratigraphy indicate clear successions with bottom horizontal dark lake deposits covered by cross bedded dunal deposits, and finally eroded by wind action (Fig. 8.31; A). This would be consistent with a Holocene trend towards aridification (Chapter 3). In some areas, fossilised animals remain in the sandy matrix, and potentially belong to an even older layer predating the Holocene.

In the eastern area of the depression, the stratigraphies suggest they have been reworked several times by winds, creating different generations of yardangs. These indicate the possibility of an extensive lake, followed by periods of inter-yardang ponds (Fig. 8.31; C).

However, no dates are currently available. This area would benefit from closer palaeoenvironmental analysis with absolute datings. Because radiocarbon dates from the Ulaan Lake (Lee et al., 2011) proved unreliable with bad results, OSL dates would be more appropriate. This is a small system away from the larger Ulaan Lake, and would provide valuable information about the palaeoclimate variations in this area, and their influence on the landscape.

8.4.3 Archaeological Landscape

The archaeological area was surveyed by geomorphological area (Fig. 8.29). Areas 1.A, 1.C, 1.D, 1.E are areas that border and are inside the palaeolake. Areas 1.B are the surrounding low hills around the lake, and Area 1.F is inside the active dune field.

In addition to Areas 1.C, 1.D, 1.E, Area 1.A borders the palaeolake. Because of the position close to the operating well, goats have trampled much of the ground and stripped the vegetation bare, creating considerable movement of sediments in this area. The main yardang sits in this area. A Neolithic blade was found in the stratigraphy of the yardang (Fig. 8.32), in association with *Lymnaeidae radix* and other unidentified gastropod shells. The position of this artefact most likely fell to its current position when the yardang eroded. This allows for the creation of a hypothesis about the past lake level. Because the yardang is considerably eroded, it is possible the blade fell from the upper level of the yardang to where it was currently found. If this is the case, it means the top level of the yardang was the maximum Neolithic level, which means the Neolithic lake level was also much higher.
The low hills surrounding the palaeolake designated as Areas 1.B have less archaeological material compared to the other areas. These are mainly small microtools, flakes, and other debitage in a variety of materials. There is considerably less density of materials here.

Both Area 1.C and Area 1.D have similar types of artefacts as those found in Areas 1.A and 1.B, but with higher densities of jaspers. Small blades, microtools, cores, and some raw jasper materials were located here. The characteristics of these artefacts are similar to those at Khoyor Khairkhan.

Area 1.E is the area of the site that has the highest diversity of materials. At the eastern edge of Zulegtiin Khud, this area has several distinct deflated surfaces. Only pottery occurs inside these areas. Many sherds sit on the deflated surfaces, while others are still partially buried. Sherds are primarily red ware, with some decorated pieces (Fig. 8.33). These deflated areas may potentially be hearths or living areas, and further excavation and examination of these areas would be beneficial.
Chapter 8: Field Survey Results

Around the deflated areas containing pottery, various lithics and associated debitage in a variety of materials were found. This includes several blades, and a superbly crafted yellow jasper arrowhead (Fig. 8.34).

Fig. 8.33: Two decorated sherds found on deflated areas in Area 1.E. Sherds 48 and 52 in the Appendix, Zulegtiin Khud.

Fig. 8.34: A superbly crafted yellow jasper arrowhead found close to pottery sherds. These were all found exclusively on top of distinct deflated areas and in no other areas of the site. Artefact 43 in the Appendix, Zulegtiin Khud.
Area 1.F lies closer to the active dune field along several yardangs. This area has heavy sand coverage, with some active dunes. Many lithics were found in this area, including several underneath the sand. This suggests the sand activity in this area is relatively recent, and as suggested in Section 8.4.1, probably relates to the shrinking of the south-west channel.

Based on the preliminary survey results, particularly the sherds and lithics in the distinct deflated areas that have potentially preserved archaeological stratigraphies below, as well as the preserved palaeolake deposits, Zulegtiin Khud has the most potential for a preserved stratigraphy and could reveal important archaeological and environmental information if studied further.

8.5 Right Palaeo Riverbank

8.5.1 Overview

This portion of the survey follows the south-east palaeochannel to its river mouth and the area where it joined Ulaan Nuur. This was mapped using the GIS model and the satellite imagery, including the ISODATA derived imagery. The ISODATA derived topography (Chapter 5) combined with the satellite imagery was extremely useful in mapping the topography of this area, particularly alluvial fans that are now obscured by heavy sand coverage (Fig. 8.35).

The survey along portions of the south-east palaeochannel did not identify any evidence of archaeological activity in or immediately around the palaeochannel itself; however, this channel is now home to an extensive dune field and visibility was extremely challenging. Field survey, though, does confirm this channel was at one time a major river and a key hydrological feature in this region.
Near the river mouth and close to the projected Ulaan Nuur palaeoshoreline, two areas of archaeological activity were identified (Fig. 8.35). Scatters were identified in an area of low hills along the south-east channel. Approximately 1.5km away at the bottom of the palaeo south-east riverbank, a large area of artefacts was identified. Khoyor Khairkhan (10km away) is visible from this area.
8.5.2 Geomorphological Landscape

The surrounding low hills overlooking the riverbank where scatters were identified, is primarily Gobi desert steppe (Fig. 8.36). There is a herder’s well and animal corral in the vicinity, indicating the presence of groundwater. The landscape here is badly deflated.

![Fig. 8.36: The environment of the surrounding hills, 2.5km from the riverbank. The landscape here is a typical gobi pavement, with badly deflated and eroded areas.](image)

The palaeo riverbank position is close to the modelled river mouth of the south-east channel and the Ulaan Nuur shoreline. The level at which the artefacts were located is a dead riverbed, and also corresponds to the level of the hypothesised lake. Debitage is strewn all over the area. Visibility was an issue here because this area was covered in fluvial stones, making it difficult to see some of the lithics.

Deeper into the interior of the palaeochannel/palaeolake there is a clear transition to a capillarity system of mounds, indicating groundwater, with some vegetated coppice dunes. Beyond that, there are indications of an intermediary remnant pond of a bigger lake, where only mud and cracked clay remains. Following these green areas, sediments are sorted from large to clay, and no artefacts are present at this point. However, these sediments may not be from the Holocene lake, and could be from isolated seasonal marshy ponds.

8.5.3 Archaeological Landscape

The inselbergs of Khoyor Khairkhan are visible from this site, about 10 km away. Both are connected to the south-east channel, and share similar lithic characteristics. All lithics in this area are hunting related or production related, including cores, spearheads, blades, scrapers, flakes, and bifaces. Lithic typology suggests Mesolithic-Neolithic. Again, jasper is the predominant lithic material (Fig. 8.37). No pottery was found in this area.
Fig. 8.37: An example of a jasper biface found along the palaeo riverbank.

However, due to indications of heavy fluvial activity and the position of the artefacts within the juncture of the south-east channel alluvial fan, this is most likely not the original position of the artefacts. At the level that is regularly flooded, indicated by a distinctive strandline, there are indications of artefact transport. The artefacts may have been washed from the surrounding low hills to where they now rest at the bottom of the riverbank.

Survey of the surrounding hills about 2.5 km away uncovered some debitage and lithics. There was considerably less artefacts in this area compared to the base of the riverbank. Based on this, there is possibly a relationship between the scatters found in the surrounding low hills and the artefacts found at the bottom of the riverbank. It is strongly possible the artefacts found at the bottom of the riverbank may have come from these hills, and originally from a more concentrated area of production. Further survey in this area could potentially identify the original location of
these artefacts, but it is probable the site has been destroyed and heavily eroded due to fluvial processes.

### 8.6 Southern Lakeshore Corridor

#### 8.6.1 Overview

The southern lakeshore corridor runs along the hypothesised shoreline of Ulaan Nuur. The significant geographic features in this area are an extinct volcano field (Fig. 8.38). Several areas were marked for survey, including inside the volcano field and the low rocky hills. The model here projected the shoreline in this area to include the volcano field; however, this is problematic and the model for this area is most likely incorrect. These points were surveyed and no evidence of archaeological activity was found, though it is possible it was missed. The shoreline model, then, will be modified to exclude the volcano field and is more consistent with the shoreline placement presented by Lehmkuhl et al. (2017).

The others areas surveyed included areas along the edge of the hypothesised shoreline as well as areas further into the interior, including the current Ulaan Nuur, which is now mostly marshes and wetlands. This area was extremely difficult to access as there are fields of vegetated coppice dunes in some areas, and overly saturated soil in other areas. There is no current human occupation around the modern Ulaan Nuur.

![Fig. 8.38: The areas between the volcanos are incredibly sandy, so trying (and failing) to reach a survey point based on the modelled shoreline was impossible by car. Instead, the area around one of the volcanos was surveyed but no archaeological material was found. On the right, Altantsag is celebrating after we managed to free the car from the sand, after we built a stone road with rocks taken from the volcano base. I decided not to try to reach the planned survey point at this time because of the risk of being stuck again in the sand.](image)
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The second area surveyed was the small hamlet, Mandal Baga, chosen because it is close to the current Ongi River and its associated river mouth and alluvial plain, located in the interior of the modelled Holocene shoreline. The area around Mandal Ovoo, the major village and capital of Mandal Ovoo soum, was also surveyed. This included red hills directly outside of Mandal Ovoo, but no archaeological evidence was detected.

8.6.2 Scatters: Mandal Baga and Southern Lakeshore Corridor

Mandal Baga is a small hamlet, now abandoned with decaying Socialist era buildings (Fig. 8.39). The hamlet itself sits on the alluvial fan of the Ongi River and there is massive river deposition in the area, as the Ongi has changed course many times over many years. This area was chosen for survey because the hydrology model places the Holocene shoreline further away, and this was a good area to test if this placement is correct.

Fig. 8.39: On the edge of the Ongi River, Mandal Baga consists of a few abandoned and crumbling buildings from the Socialist area. Only a few pieces of debitage were found here.

Small pieces of debitage were found in and around an ovoo and a religious monument. This indicates people here collected the debitage from other areas and added it to the monuments. The marshy area close to the abandoned buildings held more water at one time than it does presently, and there are red eroded areas of the riverbank. Debitage and one small blade were found at the base of these eroded areas of the riverbank. Based on the position of the hamlet within the alluvial floodplain of the Ongi, and because artefacts were predominately limited to
small debitage (primarily jasper) with only one exception, it is most likely they were carried to their present location by fluvial processes. This means this was not an area of archaeological activity during the studied period. To further verify this, other areas around the hamlet and areas along the flowing Ongi were surveyed. No archaeological evidence was found. Therefore, the model at this area is most likely accurate as it was underwater and was part of the larger lake during the Holocene.

Areas along the hypothesised southern lake shoreline were surveyed and little archaeological evidence was found. Only one area had minimal debitage, mostly jasper, and evidence suggests this was carried here by fluvial processes. Indications would suggest this was not a major and regular local route of movement for local groups. Alternatively, if this was a regular local route of movement, all evidence of archaeological activity has been erased by fluvial activities and contraction or expansion of the shoreline.

8.6.3 Later Period Burials

The major archaeological feature identified during the southern lake shoreline corridor survey is a later period cemetery, located in the transition between the volcano field, the rocky volcanic area, and a sandy area with extensive dune coverage (Fig. 8.40). Conservatively, these burials are potentially Bronze Age or later. However, some suggestions place them at possibly Mongol Period (13th-14th centuries) or later (Ts. Odbaatar, personal communication); however, excavation would be needed to positively confirm the periods to which these burials belong.
Fig. 8.40: There are several burials along the southern lakeshore corridor. The extinct volcano field lies approximately 2km away.

Fig. 8.41: Placement of the burials are located in the transition between the volcano field, a rocky volcanic area, and a dune field. The 1960/1970 shoreline is nearby. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.
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The position of this cemetery lies within the modelled Holocene shoreline (Fig. 8.41). If the model here is correct, then the shoreline did not exist by the time the burials were placed. If they are indeed Mongol Period, this means the lake had shrunk significantly by then. However, the burials are actually closer to the shoreline of 1960/1970 (1.5km away), which suggests the shoreline was somewhere between the cemetery and the 1960/1970 shoreline. Vegetated dunes interspersed with wetland vegetation lie directly across from the burials, and indicate this area has experienced multiple fluctuations in water and shoreline levels.

8.7 Summary

Chapter 8 reviewed the major surveyed areas and identified archaeological areas of activity. These include Khoyor Khairkhan (8.2), Bayanzag (8.3), Zulegtiin Khud (8.4), the Right Palaeo Riverbank and associated scatters on overlooking hills (8.5), and finally, scatters along the hypothesised southern lakeshore corridor, and at the juncture of the Ongi River mouth at Mandal Baga (8.6). The potential implications of these finds are discussed in the next chapter, Chapter 9. This includes how these archaeological areas of activity relate to broader regional and local trends, including mobility, raw resources, and corridors, how they may be placed into the local environmental framework established in Chapter 3, and how they relate to the known local archaeological proxies introduced in Chapter 2. Finally, a model of landscape movement is presented, and how this may have influenced risk minimisation to increased aridification is discussed.
Chapter 9: Discussion

9.1 Overview

While Chapter 8 discussed the results of the field survey, this chapter discusses the potential significance of these findings, including interpretation within the established theoretical framework (Chapter 1). Based on the field survey, some patterns have emerged. A preliminary discussion of the identified archaeological areas of activity in the context of the local environmental conditions, both past and present, is introduced. The spatial patterning of sites on both local and broader scales is considered, following a discussion of sites in relation to the raw resources identified. This is followed by a general overview of the local archaeological chronology within the context of the broader Ulaan Nuur environmental chronology, followed by a discussion of the diversity of ecosystems. Finally, a model of movement within corridors is introduced, and what this means within the context of a broader Desert Transformation Model for risk management to increased aridification.

However, the first part of this discussion will introduce a brief evaluation of how well the methodologies used in this thesis were able to detect and evaluate areas of archaeological activity, as well as how well they provided an overall analysis of the environmental landscape. Following this, a brief discussion on challenges in interpreting the archaeological record of Ulaan Nuur, including scale, visibility, and the problems that come when interpreting chronology in areas with surface artefacts mixed from several archaeological periods.

9.1.1 Evaluation of Methodology

Satellite imagery, GIS, and field survey were used here to evaluate the environmental and anthropogenic landscape of Ulaan Nuur. Using these three methodologies together creates a more complete and well-rounded mosaic, and relying solely on one would have missed several important details that were detected by the others. Each were found to have their strengths and weaknesses, but it is ultimately better to combine all of these approaches to create a more inclusive understanding of the landscape.

*Satellite Imagery (Chapters 4 & 5)*

Hunter-gatherer sites are not detectable in satellite imagery. Instead, an alternative method to explore areas of potential archaeological activity is detailed examination of geomorphological
Chapter 9: Discussion

features. Visual analysis using 4-3-2 and 3-2-1 bands explored features such as humid areas, depressions, and yardangs, while the NIR band detected areas of palaeolake carbonates and groundwater.

The ISODATA algorithm was particularly useful to detect underlying topography, especially areas obscured by sand sheets and dunes, as well as river mouths. Identification of ecological corridors was also possible in the satellite imagery, particularly the spring belt and channels. The palaeolake shorelines were better estimated with a combination of the NIR band and a DEM, and further supported by GIS analysis.

However, there are some drawbacks. First, it is extremely important that the user knows the study area extremely well. Without this knowledge, it is possible for confusion between classes, and misidentification of landscape features. There are also some landscape features that are too small to be seen in the satellite imagery. To counter this, it is extremely important to ground truth and verify the results of landscape analysis. Nevertheless, when used in combination with GIS analysis, satellite imagery proved an excellent tool for evaluating the landscape.

GIS (Chapters 4 & 6)

The GIS modelled shoreline and hydrology network model from Chapter 6 was overall very accurate; however, there were a few problems. First, some of the palaeochannels and areas of the shoreline were inaccurately represented, particularly the hypothesised southern shoreline. As explained in Chapter 4, this could have to do with the resolution of the DEM. ASTER GDEM V2 30m was used here, and a DEM with a better resolution may have produced more accurate results. However, the inaccuracies were not major. Some of the palaeochannels verified during the field survey were only 5-10 metres away from the GIS projected results, while others were totally accurate.

For the southern hypothesised shoreline, especially the area of the volcano field (Section 8.6), there were inconsistencies. Based on field survey, this area was most likely not part of the Holocene shoreline, and the shoreline was probably in front of the volcano field. This hypothesis largely agrees with Lehmkuhl et al.’s (2017) geomorphological projections of the shoreline. Thus, the shoreline in this area was updated to reflect this.

Inaccuracies most likely have to do with the dunes. The GIS hydrology model does not work very well in areas where extensive dune fields and sand sheets cover the fluvial geomorphology, and the model experienced confusion in finding paths and thus used a broader estimation of these paths. Because dunes follow the palaeochannels, there is a broader estimation of these river
paths. This could have been the case for parts of the south-west channel, parts of the south-east channel, and parts of the lake shoreline. However, field survey coupled with the satellite imagery largely reconciled these differences.

A model produces a hypothesised scenario of the landscape, and while it may not be totally accurate, it still provides important information. This work has shown that it is extremely important to ground truth and verify the accuracy of the results of any model, rather than take it at face value.

Field Survey (Chapters 7 & 8)

The field survey design was a successful implementation of the methodologies and spatial consideration of the archaeological landscape, and led to the identification of new archaeological areas of activity. A non-distributional approach highlighted the importance of evaluating the entire landscape. This further demonstrates that hunter-gatherer groups were moving within, and using the resources over the entire landscape, rather than limited spaces.

In a challenging landscape like the Gobi, a multi-scalar multi technological approach employing a range of methodologies proved most successful, rather than relying solely on traditional field survey. Incorporating these methodologies with traditional field survey was more successful in locating sites. Additionally, the survey revealed that examination and consideration of geomorphological and environmental processes was integral to evaluating archaeological site chronology. This includes landscape deflation, erosion, and fluvial and taphonomic processes that affect the preservation and stratigraphy of these areas. Mixed artefacts from various periods create challenges to the interpretation of site chronology; however, important lateral spatial information can still be gained, despite a lack of stratigraphy.

9.1.2 Palimpsests, Surface Deposits, and the Issue of Scale

The challenge in reconciling the archaeological data with the environmental data lies in temporal and spatial scale and resolution. As seen in Chapter 3, environmental processes are ongoing over many thousands of years and are analysed along these large temporal scales. Three major scales should be considered which incorporate both archaeological and geomorphological evidence:

1. Site/Household scale

This scale entails the local and household scale of archaeological sites and geomorphology. To create this data, intensive site examination is necessary, along with intensive examination of environmental processes, like deflation, as well as local geomorphological features, like yardangs
and humid areas. To do this, more excavation and palaeoenvironmental work is needed, and if possible, identification of preserved stratigraphies. To produce a reliable chronology, dating geomorphological features and crossing these with site activities is needed. This is challenging, because most archaeological areas of activity are often open-air surface scatters.

Discrete archaeological data occurs on a small scale, where site use and artefact use functions within the lifetime of an individual or on a household scale. In this concept, archaeological data is a series of events that are spatially different, but are temporally indistinct (Bailey, 2007), but offers an opportunity to examine spatio-temporal variability (Fanning et al., 2009). This is particularly applicable to the survey data of Ulaan Nuur, and indeed across much of the Gobi (Chapter 2), which is primarily open-air surface scatters. This is one reason why evaluating the local geomorphological processes is so important, because there are many areas of archaeological activity with different temporal scales, but the geomorphological processes enable us to set limitations on the temporal resolution and address the problem of site and artefact contemporaneity (Bailey, 2007; Fanning et al., 2007, 2009).

Many of the identified areas of archaeological activity contain artefacts from a broad temporal range. This is especially apparent at Khoyor Khairkhan, where potentially post-LGM artefacts (flakes, bifaces) through post-Iron Age artefacts (horse saddle ornaments, pottery) were identified. On a site scale, this mixture of artefacts is a cumulative palimpsest, so that only the average of the palimpsest may be discussed (Bailey, 2008; Holdaway et al., 1998). For this reason, this discussion will not attempt to group archaeological areas of activity into site functions or types (e.g. base, hunting). Currently, there is not enough information to make those identifications, especially because all of the artefacts identified are surface deposits, requiring more detailed excavation and survey.

2. The regional scale of Ulaan Nuur and the Gobi

This regional scale includes the Ulaan Nuur region with all areas surveyed plus detailed palaeoenvironmental and palaeoclimate reconstructions. To create a chronology, more cores need to be drilled into Ulaan Lake. This must then be coupled with the local site/household environmental and geomorphological data, along with a composite of trends in occupation at all sites in the study area. Intensive study at the site/household scale allows for examination of the large-scale trends in this study area. While more intensive study of the Ulaan Nuur region is necessary, this thesis demonstrates that identification of corridors is a preliminary step towards accomplishing this.
Work currently underway in other areas of the Gobi is actively providing new data. When these results are combined with data from Ulaan Nuur, more precise trends in the Gobi may be examined and expanded, allowing for more comprehensive examination of broader global trends.

3. The broader global scale within the context of Mongolia and Central Asia

This scale addresses climate change and cultural change in a global context across Mongolia, Central Asia, and beyond. Broad cultural changes and trends may be examined, including migration. Cultural evolution between archaeological periods, like the transition between the Neolithic and the Bronze Age and the adoption of herding, along with broad environmental trends, like increased aridification, may be examined using a composite mosaic of all local and regional data. This requires much more extensive data than there is presently available. Collection of data at the site/household scale is the first step in this.

For now, the household and Ulaan Nuur regional scales are tentatively examined through comparison of the archaeological and geomorphological proxies identified in Chapter 8, along with the Ulaan Nuur regional environmental proxies identified in Chapter 3. To do this, the archaeological data is treated as a spatial palimpsest. However, the nature of these palimpsests also present challenges to interpreting the record.

9.1.3 Geomorphological Processes and Issues in Visibility and Chronology

Generally, in arid and semi-arid areas, the archaeological surface record is more visible in areas where there is an absence of vegetation, and hydrological and taphonomic processes expose artefacts (Fanning et al., 2009). As discussed in Chapter 7, this creates a visibility bias, particularly in favour of more recent archaeological episodes of activity compared to older ones.

In the Australian deserts, Fanning et al. (2009) observe artefacts are exposed on scalds when finer sediments are removed by unconcentrated overland flow. Slopes greater than 2 degrees tend to have overland flow that can move small artefacts, while lateral movement is much less discernible in large artefacts. Areas with concentrated fluvial flow (e.g. rills, gullies, channels) move all artefacts. This was the same pattern observed in the study area. For example, the artefacts at the bottom of the palaeo riverbank (Section 8.5) were obviously moved over a large distance. They mostly lay along the gullies and rills leading to the palaeolake bottom level. At the main areas of Khoyor Khairkhan as well as Area 3 (Section 8.2) was also obvious artefacts were not in their original position, especially after summer rainfall was observed to have recently moved artefacts, and recently uncovered previously buried artefacts. For example, recent fluvial and aeolian activity most likely recently exposed the two beads and the ostrich eggshell (Fig. 8.11).
Another challenge, observed at all sites in the study area, is surface exposure due to aeolian processes. It is often the case that archaeologists view surface scatters as less reliable than those preserved in stratigraphic context. It is true that the vertical integrity is lacking (Fanning et al., 2009), however; the lateral integrity is intact and can also provide important information. Spatial information like the patterning of archaeological areas of activity may be discussed. Alternative information can also be extracted. For example, Fanning et al. (2009) found success through establishing the age of the sediment through OSL dating. By determining how long the sediments have been exposed to light, it is possible to determine at what point they were buried, thus providing a maximum age of deposit for the surface artefacts. This method would potentially work for the study area.

The geomorphological processes also work in favour for site preservation. In Australia, areas within lunette dunes (Fanning et al., 2009) were found to preserve archaeological features better than other areas. At Zulegtiin Khud and Khoyor Khairkhan, areas within the dunes were found to be better preserved than the deflated areas. Here, sediment volumes exceed the volume of artefacts, which is also problematic because buried artefacts are essentially invisible (Fanning et al., 2009). This contributes to the creation of a hidden landscape, and reinforces visibility bias.

Another factor potentially affecting site integrity, particularly at Bayanzag and Khoyor Khairkhan, are the role that past expeditions and visitors to these sites have played in modifying the archaeological landscape. At Khoyor Khairkhan and Bayanzag, it is not known to what degree artefacts have been collected, or particularly at Khoyor Khairkhan, to what degree previous expeditions have modified the landscape. It is possible that many undocumented artefacts have been collected. However, it is evident that the landscape rapidly changes every year, and erosion and deflation constantly reveal new and important archaeological evidence. There is still important archaeological data at these sites and intensive study of these areas will provide crucial additional data for the archaeological record.

The majority of archaeological areas of activity in the Ulaan Nuur study area range between the Mid and Late Holocene (Neolithic/Eneolithic/Early Bronze Age). This creates a bias in the archaeological data in favour of these later periods. This could very well be related to the favourability of these landscape locations during later periods compared to those during earlier periods. Most likely, this has do to with the preservation of the surface. If earlier sites dating from post-LGM to Early Holocene are present, they are most likely buried and not visible or have been destroyed, while those from later periods are still visible on the surface. Therefore, this
distribution is not necessarily indicative of landscape use, occupation, or intensification, but more likely a function of the preservation of the surface itself (Fanning et al., 2009).

With these issues identified and discussed, it is with caution, that I proceed to describe the spatial patterning of identified archaeological areas of activity, location of raw material sources, and a general chronology relating both the environmental and archaeological proxies at a coarse resolution, based on initial observations and analysis, as well as from external research sources. This operates on the understanding that this data is a complex series of palimpsests. A description of environments and a proposed model of movement within the landscape then follow this.

9.2 Spatial Patterning of Local Sites

Through examination of the overall spatial organisation of the hydrological and anthropogenic landscape, the potential decisions behind site placement may be discussed (Bevan and Conolly, 2004). Site location in relation to water resources, intervisibility, and raw resources are evaluated next.

9.2.1 Site Location and Water Resources

In the broader Ulaan Nuur regional overview, there is a distinct pattern of local sites between Flint Valley and Bayanzag, following the palaeohydrological network (Fig. 9.1). The spatial pattern of these sites suggests a regional route of movement between the Gobi Altai Arts Bogd Mountains and Bayanzag. Based on this, the south-east and south-west river channels would have been major landscape features for this route. The south-west channel connects this area of the Gobi to the Gobi Altai, and to other major sites like Chikhen Agui (Derevianko et. al, 2008). This channel connects to western watersheds and would have facilitated movement along the river valley via Flint Valley. Additionally, mountain springs would have facilitated movement through the Gobi Altai themselves. This hypothesis for movement has also been advanced by Rybin (2014), as a major route for Upper Palaeolithic dispersal. The south-east channel would have been a major route further south towards Dalanzadgad and Ulaan Bagalsiin Nuur, but this requires further analysis and survey, which is currently out of the scope of this dissertation. Channels that are more northwestern connect Ulaan Nuur to the other Gobi lakes.
Likewise, the Ulaan lakeshore and the Ongi River would have provided routes of movement to the east and north towards the Khangai Mountains. Future surveys around the western, southern, and northern areas would contribute data to this hypothesis. However, ground visibility is an important factor as it is likely that most of the area around the eastern shoreline is destroyed or buried under alluvium, especially with the heavy alluviation and movement of the Ongi River over the millennia. This was apparent in surveys conducted around Mandal Ovoo and Mandal Baga (Section 8.6).

9.2.2 Site Location and Intervisibility

A local examination of site patterning reveals that major archaeological areas of activity appear mainly close to higher promontory points in the landscape. All areas are visible from the other.
Based on this, intervisibility may have been a factor in site placement and landscape navigation. In other desert areas, hypotheses of colonisation suppose that sites occur along corridors of distinct landscape features (Veth, 1989). This is similar to a maritime setting, where ships use the coastline and specific landscape features to navigate.

This may very well be the case here. For example, Khoyor Khairkhan is centred around the distinct family of inselbergs, Bayanzag is close to the Flaming Cliffs, and Zulegtiin Khud is close to a large prominent hill, while sites like Flint Valley are at the base of the distinctive Arts Bogd Mountains, and Ulaan Nuur would have been a massive water body looming within view of all of these locations. The extinct volcanoes in the northeast are also prominent landscape features, although only a later period cemetery was found at the base of these. However, future surveys may detect other areas of archaeological activity here.

The Gurvan Saikhan mountain range in the south and the Arts Bogs mountain range in the west would have been the constant orientating landscape features. These mountain ranges were even helpful orientating features during field survey.

On a smaller scale, with the exception of the palaeo riverbank assemblage, small geomorphological features, particularly yardangs are prominent at the major sites surveyed. These small geomorphological features are also visible on a smaller scale within the landscape.

9.2.3 Site Location and Raw Resources

The material culture is the main indicator of past activity and movement. Patterns of artefact dispersal and distribution is evident across the study area, and provides evidence supporting the model of corridors of movement. Raw resources are areas in the landscape that also provide archaeological evidence for movement within corridors, and are connecting features between sites.

There are four major sources for raw materials currently identified in the area (Fig. 9.2). These are Flint Valley (Derevianko et al., 1996), a major hill next to Zulegtiin Khud (agate; based on Mongolian government maps), Khoyor Khairkhan (chalcedony/agate; personally surveyed), and hills 13 km northwest of Khoyor Khairkhan (jasper; personally surveyed). To reach the jasper source it is necessary to cross the south-west channel. The south-west channel may have been a major geographical barrier, although satellite imagery and the GIS model indicates areas around the river mouth that may have provided easier access to the other side. Apart from that, these raw material sources are distance wise, easily accessible from all sites. These varied locations
suggest people had a deep local understanding of their landscape and operated and explored all areas.

Fig. 9.2: Raw resources in relation to sites and scatters, including both known sites and scatters and those recently surveyed areas. The Central Asiatic Expedition’s site and scatter locations were provided by Lisa Janz, based upon Nelson’s original 1925 notes, with coordinates derived from topographic maps. Sites identified by the Joint Mongolian-Russian-American Archaeological Expedition were used with permission from John Olsen. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

There were a few instances of materials with unidentified sources that may be classed as exotic. Among these were milky white flints, mossy flints, and white chalcedony. It is possible that they are local and their sources are yet to be identified. This could be reconciled with additional survey. Operating on the hypothesis that they are exotic, this is one indication that people were communicating and trading with groups outside of the Ulaan Nuur region.
Chapter 9: Discussion

9.2.4 Summary

In summary, even though the landscape experienced many environmental changes over the course of the Holocene, water remains the most important factor in site location. This is explored in more detail in Section 9.4.

Secondly, visibility is most likely an important element to navigate the landscape. This includes visibility between sites and visibility of larger landscape features within the broader Ulaan Nuur region. A large and central landscape feature, such as the inselberg family at Khoyor Khairkhan, may have quantified the importance and centrality of a site for local groups.

Finally, raw materials are important but may not necessarily have been a determinant for site location. However, if raw resources are present at a site, as they are at Khoyor Khairkhan, this may have increased the importance of a site. This would explain why Khoyor Khairkhan exhibits evidence of repeated use over millennia. This site would have been an ideal long-term base camp for local groups, and would have provided a constant landscape feature, enabling groups to explore other areas of the region in depth.

9.3 Preliminary Local Chronology

The Early Holocene (11500 cal B.P.) roughly corresponds to the Epipalaeolithic/Mesolithic. In the Gobi, advanced palaeohydrological networks may have existed, while dune fields were stabilised. At this point Ulaan Nuur is a large lake, coinciding with the general trend of lake boundaries filling across Mongolia at the onset of the Early Holocene, aided in part by the more northern boundary of the East Asian monsoon (Fig. 9.3). A wide watershed and several active tributaries, including the Ongi and the south-east channel were prevalent. The Ulaan Nuur core (Lee et al., 2011; 2013) indicates abundant vegetation cover 11300-8800 years ago coinciding with a warmer climate, primarily forest steppe, especially between 11500-10500 years ago. Mischke et al. (2005) also note more forests in the Gurvan Saikhan and Arts Bogd mountain ranges, supporting results of the Ulaan Nuur core (Lee et al., 2011, 2013).
A forest steppe marks the transitional zone between a forest biome, which consists of micromosaics of forests and moist grasslands at the northern borders. This is also sometimes referred to as a meadow steppe, with herbs and less drought tolerant grasses. This contrasts with a Mediterranean forest steppe characterised by more open woodlands (Wesche et al., 2016).

More abundant surface water in this region would have made it more accessible to hunter-gatherers and we would expect to find many sites from this period. However, there is more archaeological evidence for later period sites, and it is possible that this early landscape, due to geomorphological and taphonomic processes, has been buried or destroyed. This limits what can be said about patterns of landscape use during these earlier periods. In a Desert Transformation Model, initial colonisation would have taken place during the Pleistocene and continued through...
the Early Holocene, but more sites need to be identified to make any further assertions about this. This may potentially be reconciled with further survey in the region.

Khoyor Khairkhan is an exception to this. Previous research by Okladnikov and Dorj (1978) and Odsuren (2014) places the chronology of site occupation to this period, and observations in the field confirm this. Geomorphological observations indicate this site was surrounded by water, including small rivers from the south-east channel bordered by a small palaeolake. This would have created a wetland type of environment, similar to the wetland environment observed in Area 3 of the Khoyor Khairkhan study area. This hypothesis is further supported by the discovery of ostrich eggshell and an ostrich eggshell bead. Previous research by Janz et al. (2009) and Janz (2012:122) shows ostrich persisted until the Early Holocene and lived in wetland environments until their extinction after 8.3 ka cal B.P., which would have been a similar scenario at Khoyor Khairkhan.

At Bayanzag, similar wetland conditions would have also existed. Geomorphological field investigation and evaluation of satellite imagery (Section 8.2) support the presence of a more extensive Bayanzag Lake. Additionally, excavators from the Central Asiatic Expedition also discovered ostrich eggshell and beads at the site (Fairservis, 1993), similar to the one found at Khoyor Khairkhan (Section 8.1; p. 182). The presence of ostrich eggshell supports the hypothesis of a more humid and greener landscape, which would be consistent with a wetland environment. Janz (2012) and Janz et al. (2015) hypothesise that at Bayanzag, people were most likely reusing older ostrich eggshells and these are not necessarily a reliable indicator of the date of an assemblage. This is also most likely true as well at Khoyor Khairkhan. It also possible that the eggshell located at Khoyor Khairkhan was transported from another location. The ostrich eggshell bead at Khoyor Khairkhan is more stylistically developed compared to Upper Palaeolithic beads found in other areas across Mongolia and surrounding regions (Khatsenovich et al., 2017; Rybin, 2014). The Khoyor Khairkhan ostrich bead looks similar to beads found at Bayanzag (Fairservis, 1993: 50). Because it was found in association with the red stone bead of a similar shape and design, this supports the case that people were using old ostrich eggshells at this site for bead making.

Artefacts at Khoyor Khairkhan potentially range between post-LGM to later periods (Fig. 9.4). Combined with the inselberg as a raw material resource, as well as its visibility in the landscape, this site was most likely used over thousands of years, and explains the large range of artefacts. In a Desert Transformation Model, the post-LGM period would have represented a time of
exploration, but the challenge of interpreting chronology at Khoyor Khairkhan comes primarily from the mixing of surface artefacts from various periods. Also problematic, the site was previously explored by Okladnikov and Dorj (1978) and there is evidence that people have visited the site over the years, many leaving trash, and it is unknown to what extent artefacts have been taken or disturbed. It is evident that between the first discovery and the gap of 50 years to the present, even more artefacts have been exposed on the surface. The area of the small palaeolake (Subsite 1.C) along with the area where the majority of pottery was found (Subsite 1.B) are the best preserved areas, most likely because they are further away from the main site and do not seem to have been previously explored. The small palaeolake only had lithics, such as jasper bullet cores. The area where pottery was exclusively found lies in a humid area, thick with reeds and grasses, indicating groundwater is still present under the surface. The pottery found here is roughly Eneolithic/ Bronze Age. This indicates the wetlands were most likely still present during this period, and based on only pottery in this location, people most likely used this location to collect water, grasses, or other food sources.

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Fig. 9.4: A simple table indicating the absence or presence of certain diagnostic artefacts at each site discussed in this section.

Khoyor Khairkhan, along with Bayanzag, would most likely have supported a continued occupation since the Early Holocene. These sites would have supported various activities and acted as hubs for further exploration into the interior. This would support the hypothesis of a continued desert occupation since the Epipalaeolithic/Mesolithic. If the model of the maximum hypothesised Ulaan Nuur shoreline is correct, the lake would have been large between the Early to Mid Holocene. This means there would have been optimal patches in the area, and movement along corridors would not have been as necessary as they would have been during periods that were more arid. However, depending on local environmental dynamics, the boundary towards a more marginal landscape would have gradually moved through time. Early indications would be a gradual salinisation of water, fluctuating vegetation, and reduction in the abundance and diversity of species.
Mid Holocene (8.2 cal B.P.; Neolithic) occupation continued at Bayanzag and Khoyor Khairkhan. A distinctive sherd at Khoyor Khairkhan is typologically Neolithic (Fig. 8.14; Sherd 33, Khoyor Khairkhan in Appendix). Janz (2012) and Janz et al. (2015) have dated similar sherds. However, the paste of this sherd is not similar to the paste that Janz has examined before (Lisa Janz, personal communication). Based on this, it is possibly indicative of local groups adapting a common stylistic pottery as their own. This would potentially indicate intragroup communication, and this merits further exploration.

Another key archaeological area of activity was identified at the bottom of the Right Palaeo Riverbank of the south-east channel. This site presents some difficulties because the artefacts have been moved from their original positions by fluvial processes and most likely came from another larger site. Despite this, some observations can be made. The area of this site overlooks the former palaeoshoreline of Ulaan Nuur and currently humid areas with heavy vegetation indicate there is groundwater. All of the artefacts found in this area are lithics, primarily hunting and production related. Based on this, this area was most likely part of the lakeshore corridor and would have been fringed by wetlands. This would have provided an ideal ecological landscape for the movement of various species and would have provided a key area for hunting these animals. People most likely used the larger lake and the lakeshore corridor to track species movement rather than for prolonged occupation. It is not far from Khoyor Khairkhan, and it is possible these two areas were closely connected and people were actively moving between these areas.

The Ulaan Nuur core (Fig. 9.3; Lee et al., 2011, 2013) records a shift to a more steppe environment, along with a gradual trend towards aridification, but with slightly more humid conditions after 8600 cal B.P. A steppe environment is similar to a temperate Palearctic steppe biome, similar to the Eurasian Grassland belt existing today. This would have supported large migrations of ungulates, diverse fish and bird populations, specialised habitats for small mammals, and diverse species of graminoids and other herbaceous plants, with a 25-100% cover without shrubs or trees (Torok et al., 2016; Wesche et al., 2016).

The end of the Mid Holocene witnessed an overall gradual decrease in lake levels, and by extension, resources. Ulaan Nuur records increasing aridification, accompanied by slightly more humid conditions and steppe vegetation cover in comparison to conditions currently seen today. The influence of the Ongi and other major tributaries were gradually decreasing, along with the gradual recession of the shoreline. OSL analysis records the beginning of dune activation at Mongol Els in the Valley of the Lakes (Hulle, 2011), that would reach a peak during the Late Holocene at Khongoriin Els in Omnogovi (Fig. 9.3).
Both Bayanzag and Khoyor Khairkhan are centred around palaeodunes. These palaeodunes are most likely Pleistocene or earlier in origin. The source of the palaeodunes at Bayanzag can be traced to erosion of the Flaming Cliffs over millions of years, carried to Bayanzag by locally active rivers. At Khoyor Khairkhan, these palaeodunes are potentially evidence of the Pleistocene Ulaan Lake’s erosion. The more recent dunes most likely began slowly appearing at the end of the Mid Holocene, consistent with dune patterns in other regions (Hulle, 2011), and increased substantially to what they are now. Zulegtiin Khud shows a similar erosion pattern in its central yardang and surrounding areas of dunes. This would need to be confirmed with OSL dating.

The placement of these sites amongst palaeodunes indicates people situated themselves along the palaeodunes before they reached their advanced states. Palaeodunes are formed from erosion of previous humid areas. In this case, these humid areas would have existed during the Pleistocene. These humid areas would have reactivated during more humid periods, such as the Early and Mid Holocene. These would have been attractive environments for long-term occupation. Observations at Khoyor Khairkhan indicate Neolithic artefacts on top of the palaeodunes, but not within the stratigraphy, indicating they did not erode until after the Neolithic. It is difficult to say if these palaeodunes would have provided windbreaks because they are oriented in the main direction of the wind. However, these palaeodunes could have functioned as higher vantages in the landscape, or possibly as more secure areas not directly on the ground level.

Late Holocene (4.2 ka cal. B.P.; Eneolithic/Early Bronze Age) occupation continued at Khoyor Khairkhan and another site, Zulegtiin Khud. Zulegtiin Khud is interesting because it most likely has a preserved stratigraphy. On the surface, only artefacts from the Neolithic/Eneolithic/Early Bronze Age were identified. However, it is highly probable that there is an older occupation that is not visible, and excavation would be useful at this site to learn more about its history.

Zulegtiin Khud is centred around a small palaeolake, and cores and hunting lithics in the immediate vicinity of the palaeolake indicate this was most likely an area for hunting. The positive identification of *Lymnaeid radix* found in association with a Late Neolithic blade provides an opportunity to form a hypothesis about the environment. Other unidentified shells of pond snails were also discovered, but collection and analysis is needed to positively identify these species. Organic material and the remains of animals in the sandy matrix around the border of the palaeolake were also observed.
The *Lymnaeid radix* pond snail is commonly found in areas of the Palearctic temperate zone of distribution for species and vegetation (Vinarski, 2012). The habitat of the *Lymnaeid radix*, like other pond snails, prefers slow moving or permanent and stagnant fresh water and a diet high in aquatic vegetation (Vinarski, 2012). The habitat is a typical benthic zone, and vegetation in this ecosystem includes algae and marsh plants (Stift et al., 2004). This is consistent with a wetland environment.

The advanced erosion of the small palaeolake to its present state indicates that it has experienced episodes of heavy aeolian erosion, forming the current blowout and yarding. This would coincide with a fall in the water table and the lake level. Many of the shells were smashed and as discussed in Section 8.4, the Neolithic blade potentially dropped from the top to its present location among the shells indicating the lake level was much higher. This alone indicates that this area experienced more abundant surface water during the Neolithic/Eneolithic compared to present conditions, where there is no surface water, with only a well currently present to access the groundwater (which is only suitable for animals). This is also indicative that substantial erosion has occurred in this area between the Late Holocene to present day.

Zulegtiin Khud is an ideal candidate for further palaeoenvironmental analysis to determine the environmental chronology of the site and to establish the types of conditions present, as well as the water quality during occupation.

During the Late Holocene, the Ulaan Nuur core (Fig. 9.3; Lee et al., 2011, 2013) indicates a gradual shift from steppe to desert steppe vegetation with further increased aridification, reaching unprecedented levels between 4600-3100 cal B.P. This period is still slightly more humid with more vegetation cover than current conditions today (Chapter 1). Desert steppe is characterised by more open vegetation of 10-25% and more dwarf and low-growing shrubs. In the current semi-desert environment, vegetation falls below 10% (Wesche et al., 2016).

Ulaan Nuur was most likely fluctuating by this time. The lake was much smaller, with a smaller watershed and the influence of the Ongi River ending at the middle of the lake. This also coincides with the end of activity of the south-west and south-east channels. Deglaciation and reduced precipitation indicates a lack of water, when combined with increased aridity, this contributes to lake desiccation and shrinking lakes, observed not just at Ulaan, but also at other lakes in the Gobi region. It would be necessary to establish when the permafrost and glaciers finished melting.

Lehmkuhl et al. (2017) recently dated a southeastern shoreline south of Mandal Baga as present until at least 4414 +/- cal B.P. The location of this shoreline corresponds to the projected shoreline
in Chapter 6. The later period cemetery is placed inside the hypothesised model of the Holocene shoreline. If the model is correct, the shoreline by this time had reduced when the burials were placed, falling somewhere between the 1960/1970 shoreline and the cemetery (Section 8.6.3: 214-216). The period to which the cemetery belongs is currently unknown. Contraction of the shoreline and the lakeshore corridor would have had a negative impact on vegetation and animal species. Sites like Khoyor Khairkhan and Zulegtiin Khud may have been more stable because of the connection to the spring belt.

The slab burial at Khoyor Khairkhan presents additional questions. Slab burials are typically Late Bronze Age. The age of the other burials at this site are unknown. This site has an occupation until at least the Eneolithic/Early Bronze Age. If the site experienced occupation to the Late Bronze Age, then people either brought this slab burial connection through communication to local groups in the area, or there was migration into the area. At this time, the maximum chronology of occupation is unknown.

Based on preliminary field observations and geomorphological examinations of the local environments at each archaeological area of activity surveyed, some general trends are identified. The largest sites are centred around areas of former wetlands and lakes. Khoyor Khairkhan and adjoining areas are centred around humid areas and former small palaeolakes. Bayanzag is centred around humid areas and the current lake was much larger at one time. Zulegtiin Khud is centred around a former small palaeolake and wetland area, further supported by the discovery of pond snail shells, as well as organic carbonate and palaeolake carbonates. The site at the palaeo riverbank overlooks the former shoreline of Ulaan Nuur, indicating this area was most likely an area of wetland along a lakeshore setting. The significance of each of these microenvironments is discussed in the next section, and a model is proposed for landscape movement along hydrological corridors.

9.4 Model of Movement within Hydrological Corridors

Based on the location of major archaeological areas of activity, a preliminary model of landscape movement is introduced here based on hydrological and ecological corridors. This largely relies on Veth’s Barriers, Corridors, Refuges Model introduced in Chapter 1 and Forman’s concept of hydrological corridors introduced in Chapter 4. Using the concept of hydrological corridors as major corridors of movement, four major corridors are proposed for hunter-gatherer movement in the landscape:
These hydrological corridors are defined as heterogeneous conduits that determine the flow of movement through the landscape of humans, animals, energy, material, and disturbance. Patterns and processes both change over time (Forman, 1995a) and may be divided into structural patterns of patches, corridors, and matrixes. A coarse-grained landscape presented in Fig. 9.5 contains fine-grained areas that are optimal for provision of large patch ecological benefits, including multi-habitats for species and humans, accompanied by diverse resources and conditions.

Fig. 9.5: Comprehensive map demonstrating major areas of archaeological activity in the Ulaan Nuur region, ranging between the Early Holocene and the Late Holocene. These are superimposed into the proposed model of corridors indicating major rings of movement, based on surveyed areas described in Chapter 8, and areas analysed with the methodologies described in Chapter 4. Sites and scatters include those studied during the field survey in Chapter 8, with the exception of the later period cemetery, Section 8.6, which is not mapped. The Central Asiatic Expedition’s site and scatter locations were provided by Lisa Janz, based upon Nelson’s original 1925 notes, with coordinates derived from topographic maps. Sites identified by the Joint Mongolian-Russian-American Archaeological Expedition were used with permission from John Olsen. Base Map: ArcGIS 10.5.1; Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

The most important features belong to natural vegetation patches, which are structures that protect aquifers and connected stream networks. These vegetation patches are critical for interior
species, providing important habitats for large ungulates. These species move along ecosystems of the same types, and these ecosystems further promote flow and movement of these species across the landscape. Survival of species depends on habitat equality and patch size (Forman, 1995a). Wetlands provide some of the most significant habitats for these species. Local movement depends on the connectivity of these wetlands and small lakes, and these belong to ecologically distinct corridors.

9.4.1 Wetlands/Small Lakes & Spring Belt Corridors

Many of the main areas of archaeological activity studied during the survey are centred around these types of wetland and small lake environments (Zulegtiin Khud, Khoyor Khairkhan, Bayanzag) instead of the larger Ulaan Lake.

The presence of Lymnaeid radix supports this idea. Until recently (1960-1970), parts of the former south-east channel were areas of extensive wetlands. In other desert landscapes, lakes and marshes/wetlands were key to adaptations of these marginal environments. For example in the Great Basin in the United States, terminal Pleistocene settlement is centred around these ecosystems (Grayson, 1993: 242) and Mid Holocene economic adaptations may have concentrated around these ecosystems, especially as sites are established along wetlands and springs (Elston, 1982, 1986; Grayson, 1993). Late Holocene adaption to increasingly arid environments further emphasises the importance of wetlands (Kelly, 1997). The Nefud in the northern Arabian Peninsula also follows a similar pattern where wetland environments and small lakes were areas of essential resource patches and centres for dispersal and occupation, particularly during times of drought and environmental uncertainty (Breeze et al., 2017).

Across other areas of the Gobi, Janz (2012) also notes wetland use at sites. In the Eastern Gobi, occupation in these ecosystems are noted at 7.6 ka cal B.P., in the Gobi Altai at 4.9 ka cal B.P., and in the Alashan at 6 ka cal. B.P., which continued until the Early Bronze Age. The seasonal drying of small lakes, including shrinkage of key wetland habitats, particularly during the Late Holocene, would have promoted movement along the spring belt corridor, for both animals and humans.

People were most likely using the spring belt corridor for local movement and home-range activities (Forman, 1995a: 247). The spring belt connects the hydrological network to all of the major archaeological areas of activity (Chapter 8). It is likely people had an advanced local knowledge of this, and navigated along the spring belt.

The spring belt is more stable compared to other surface water sources, and people and species are more likely to move through these upland habitats rather than along stream channels. Further
survey of the spring belt may be able to identify other archaeological areas of activity. The spring belt may have played a role in reducing mobility clustering around areas with more surface water.

9.4.2 Lakeshore and River Corridors

The lakeshore and river channel corridors would have had floodplain and riparian vegetation, where the function is to protect the corridors from erosion and degradation. Lakeshore vegetation often follows a pattern where it is wetland at its formation, evolving to lake vegetation, then returning to wetland as it gradually dries again.

The purpose of this is to minimise downriver flooding, by controlling sedimentation and promoting high rates of evapotranspiration, including the sponge effect (Forman, 1995a). The soil here would have been important to river organisms, such as fish, and the creation of habitats for rare or uncommon species, through a continuous cover of native vegetation (Forman, 1995a: 249-250). Environmental change affecting vegetation, particularly relating to aridification, would have drastic effects on these local habitats and adversely affect all species. The presence of the site at the palaeo riverbank supports this idea that the lakeshore corridor would have been an important area for species, as all the majority of artefacts found in this area were hunting related.

For long distance intra-regional and regional movement, the major routes of movement would have been provided by the lakeshore corridor and the river channel corridors. The palaeochannels and lakeshore were not sufficiently surveyed during this field survey. Future survey around these corridors would be useful to shed light on potential routes of movement. All of the archaeological areas of activity fall along the major palaeochannels, but away from the main Ulaan Lake.

9.5 Risk Minimisation to Increased Aridification

Land degradation affects the productivity of an area and contributes to constriction of corridors. This has lasting consequences on vegetation cover, water quality, and soil erosion. This affects all people living in the local landscape, including the economic productivity of the area. Aridification coincides with increased mobility and decreased use of major archaeological areas of activity and would have necessitated changes and economic adaptations. This would have occurred gradually rather than suddenly, in pace with creeping aridity.

Influenced by larger environmental changes, some areas would have been more stable compared to others, and local groups would have concentrated their activities within them in reaction to this. The spring belt would have provided a network of relatively reliable water sources, which would have been critical during droughts, by providing refuges (Hiscock, 2008:203; Veth, 1989).
During the LGM and Early Holocene, these refuges would have promoted colonisation, particularly along corridors of distinct landscape features with favourable resource patches and raw resources. Because aridity was not an issue at this time, adaptations to aridity were not necessary. By the time aridity became a factor, people were already familiar with their local landscape (Hiscock and Wallis, 2005).

For example, in areas like the Nefud, Lower Palaeolithic sites are found clustered around areas of raw materials, despite the interior presence of water, while Early Holocene people periodically occupied areas in the desert interior, and Neolithic sites are distributed deep in dune fields, indicating increased mobility at this time (Breeze et al., 2017). Because of the lack of post LGM/Early Holocene sites, there is currently not enough data to make these conclusions for the Ulaan Nuur area.

Using the model of Veth (1987, 1993, 1996) a hypothetical model of a seasonal pattern of land use may be formed. After summer rains, people would have dispersed into small and highly mobile groups, moving between ephemeral water sources to exploit food resources in risky areas. In winter, hunter-gatherers would have focused on areas with more reliable water sources to establish long-term base camps. This would create a seasonal dispersal of people as they moved to use seasonal food resources.

This creates a pattern of risk minimisation where groups create variable spatio-temporal residential and logistical mobility patterns, including standardised technologies. Movement along hydrological corridors, including the spring belt, and wetlands and small lakes were potentially more stable than the larger Ulaan Nuur. Wetland and small lakes are also often more reliable and stable in times of environmental stress.

There are more sites supporting a Mid Holocene regional occupation along specific ecozones. This could indicate that Early Holocene groups were not as constricted in their use of corridors, while subtle environmental landscape changes during the Mid Holocene pushed groups to concentrate their activities along specific resource patches. There is for sure an established occupation at Khoyor Khairkhan and Bayanzag by the Mid Holocene. Position of major archaeological areas of activity along the wetland and small lakes extensions of the larger channels indicate these areas were relatively stable and most likely provided diverse habitats for species, within proximity to areas of raw resources.

As aridification increased during the Late Holocene, decreasing wetlands and drying of small lakes, including increased salinisation, would have forced a change in mobility patterns. The channel and
lakeshore corridors, with the exception of the Ongi, would slowly have become barriers to movement. By 3000 cal B.P. the Ulaan Nuur region changed to a desert steppe environment, and the lake records increased salinisation (Lee et al., 2011, 2013).

However, people did not abandon the area, as evidenced by artefacts from later periods, as well as current occupation today in these now marginal areas, but rather they followed the movement of the spring belt corridor. At Tamsagbulag and the Yamat complex (Chapter 2), reports indicate that sites moved closer to contracting lake shorelines. This pattern of movement is contrary to what is observed at Ulaan Nuur. Rather than moving towards Ulaan’s contracting shoreline, people abandoned the smaller satellite lakes in favour of the spring belt corridor. The spring belt corridor is the source of fresh and drinkable water, where the lake and wetland areas experienced salinisation. Salinisation is tied to aridification. This affects the health and the water quality of the lake, with adverse effects on vegetation, fish populations, and animals, and thus, affects the sustainability of the area to support local human populations.

Additionally, as Ulaan shrank, the former lake bottom eroded, and filled with dunes. The current area of the lake is unpredictable, as seasonal and interannual expansion and contraction of the shoreline creates soft and sandy soil. These are deterrents to occupation, and indeed, there is no current occupation around the modern Ulaan Nuur or around the current lacustrine or palustrine salty wetland areas (described in Chapter 1).

In contrast, the spring belt, including seepages and small surface water, provides a buffer against climatic change and would have played a more important role in mobility patterns. A greater reliance on seepages and small surface water would have increased. Hunter-gatherers, by then in contact with early herders, would have found springs and seepages more reliable for herding animals. For example, the Bulgan soum capital, the town of Bulgan, is located inside the southern spring belt corridor, while the Omnogovi province capital Dalanzadgad is located in another area of the spring belt corridor. Current local occupation of the Ulaan Nuur region is centred around groundwater wells, springs, and seepages that are connected to this larger spring belt.

This indicates that by the time aridity reached a maximum point, local groups were long ago already familiar with their local landscape and had already subtly shifted their mobility strategies, and adaptation to environmental change and desertification was comparably much easier. Based on this, a hypothesis is formed where we would expect to find a greater occurrence of later period sites along the spring belt and its peripheral areas. This may be addressed with future survey around the spring belt areas.
Now that these potential scenarios have been discussed, the next chapter, Chapter 10, will review the chapters of the thesis and the major findings of each. The research and sub-questions are reviewed and how well they have been addressed will be discussed. This is followed by suggestions for future research in the Ulaan Nuur study area, placing it within context of broader research in the Gobi Desert and other desertscapes.
Chapter 10: Conclusion

10.1 Review of Chapters

This final chapter will briefly review the preceding chapters of this thesis. Following this, a review of the main research question and the sub-questions, and a discussion of how well these questions have been addressed throughout the thesis, as well as the major takeaways from this research. This chapter, and thus the thesis itself, concludes with suggestions for future research and final thoughts.

To review, Chapter 1 presented an overview of the relationships between humans and water resources in Central Asia, introduced the Ulaan Nuur study area, and the major theoretical frameworks used throughout the dissertation. Chapter 2 presented an overview of the development of archaeological research in Mongolia, reviewed previous archaeological research in the Gobi Desert and the local Ulaan Nuur region, and reviewed the major applicable periods of study to the dissertation. Chapter 3 reviewed environmental Holocene changes globally, regionally and locally, introduced a new interpretation of the Ulaan Nuur lifecycle using a new PADM chart, and compared this to a detailed synthesis of environmental changes occurring across the Gobi Desert.

Chapter 4 introduced two of the major methodologies used in the dissertation, satellite imagery and GIS, and discussed their theoretical and technical aspects. Chapter 5 presented the results of the satellite imagery analysis, including visual analysis and ISODATA. This chapter also introduced the concepts of corridors and the identification of the spring belt corridors and palaeochannel corridors. Chapter 6 presented the results of the GIS based hydrology model, as well as a hypothesis of the location of the Holocene lake shoreline and the lakeshore corridor. The spatio-temporal evolution of Ulaan Nuur was demonstrated using historical data, satellite imagery, and a DEM model.

Chapter 7 introduced the field survey, including the key concepts behind the development of the survey methodology, and how the satellite imagery, hydrology model, geomorphological processes, and the corridors and hypothesised shoreline were integrated into the field survey design. Chapter 8 presented the results of the field survey. The field survey identified major areas of archaeological activity and noted the major geomorphological processes of each area.

Chapter 9 evaluated the strengths and weaknesses of satellite imagery analysis and GIS analysis combined with field survey in evaluating the study region, and discussed problems with scale,
visibility, and chronology. The spatial patterning of site location in relation to water, intervisibility, and raw resources was discussed, and a preliminary coarse local chronology of the Ulaan Nuur area was introduced, which integrated both archaeological and environmental data. A model of movement along corridors was presented, with wetlands as a major ecosystem of importance to hunter-gatherers in this area, and the implications of movement towards the spring belt corridor as a response of risk minimisation to aridification.

10.2 Research Question & Sub-questions Review

A major research question and several sub-questions were posed in Chapter 1 as the major issues to be examined in the dissertation. This section will review how well the dissertation answered these questions, and what further work is needed to better address these questions in the future.

To reiterate, the major research question is:

*What economic and adaptive strategies did local Holocene Gobi Desert groups utilise around the Ulaan Nuur region and what role did climate play in these adaptations, particularly the changing hydrological landscape, as aridification increased?*

To begin to evaluate this question, it was first necessary to establish to what extent the landscape was actually marginal (Chapter 3), and how a past hydrological network may have appeared (modelled in Chapter 6). To do this, three sub-questions related to the major research question were posed:

1. *How, from a geomorphological perspective, may the micro hydrology of the Ulaan Nuur area be examined, including less accessible areas such as pools, wetlands, ephemerals lakes, and springs, as well as transitional and boundary areas, and how may this be integrated with archaeological survey?*

   This sub-question was successfully addressed in the methodologies (Chapter 4) and their results (Chapters 5 and 6). The evaluation of local mosaics using satellite imagery, including ISODATA (Chapter 5) identified currently hydrologically active, as well as potentially active areas, and integrated these results into the formation of the field survey (Chapter 7). The field survey also identified several areas not visible on the satellite imagery, and successfully integrated this with the archaeological evaluation (Chapter 8).

2. *How may the archaeological evidence be linked to the hydrological and geomorphological evidence, through: 1. the influence of the modern landscape morphology and surface artefact*
distribution, and 2. the relationship between the spatial distribution of artefacts and the contemporary landscape morphology (the past landscape)?

In Chapter 8, all identified areas of archaeological activity were discussed and mapped within their landscape context. The influence of the modern landscape was successfully identified and how they affected surface artefact distribution (for example fluvial activities and the Right Palaeo Riverbank in Section 8.5) was also discussed. Additionally, the spatial distribution of artefacts and the contemporary landscape was successfully identified at many areas (for example the potential Neolithic surface level and artefact level at Zulegtiin Khud in Section 8.4).

3. After examining the micro hydrological landscapes, how is it possible to create a deeper historical understanding in which to evaluate the long-term hydro-social dynamics occurring in this area, and how may this understanding help to reassess ideas about macro hydrological landscapes occurring across the Gobi Desert?

This sub-question was successfully addressed through the discussion (Chapter 9). After the creation of a mosaic of ecosystems and hydrological corridors, including wetlands, and mapping sites in relations to these, results showed that sites are concentrated in ecosystems favouring wetland areas and small satellite lakes, where habitats would have been rich with resources. This suggests these ecosystems played a significant role in hunter-gatherer landscape movement.

The information gained from exploring each of these sub-questions may now be used to address the overarching research question examining to what extent climate, particularly aridification and the changing hydrological landscape, influenced economic and adaptive strategies. This dissertation has provided some clues to help to begin to answer this question. Based on the data so far, it is most likely that people moved along hydrological corridors, which became a necessity over time as aridification increased and shorelines changed, and thus an adaptive risk minimisation in response.

To examine how the environmental landscape may have influenced movement within the anthropogenic landscape, it was first necessary to create an environmental framework. In Chapter 3, this was successfully established by examining at what point aridification increased across the Gobi. To establish this with certainty in the Ulaan Nuur region, further palaeoenvironmental work is needed. This is entails OSL dating of dunes, small palaeolake deposits, and fluvial deposits at each archaeological site. Doing so would contribute valuable information about local environmental change, as well as occupational site chronology.
Hydrological corridors were used for local movement as well as larger regional movement. These corridors, which included the spring belt, the river channels and lakeshore, were detected using a combination of satellite imagery and GIS analysis, and further explored through field survey. After examining site locations in relation to these hydrological corridors, it is evident there is a network of sites. This suggests an extensive common local culture, stretching from Flint Valley to Bayanzag.

Each site is visible from one to the next, and important raw materials are conveniently located within range of each. Raw resource locations were identified during field survey. Based on field observations, local movement probably followed the spring belt and secondary tributaries, which connected all of these sites, indicating people had a deep understanding of their local landscape. In contrast, broader movement outside of the Ulaan Nuur region probably concentrated along the major palaeochannels and palaeolake shoreline.

Local sites are located in the lake basin (along small lakes and springs), but not next to the larger Ulaan Lake itself. Instead, sites are close to the river channels, but not directly next. Instead, they are situated in the valley of these channels (along smaller connecting tributaries), rather than directly next to them. The main sites around these small satellite lakes and wetland areas range between the Mesolithic and Eneolithic/Early Bronze Age.

The maximum site chronology at the detected areas corresponds to the Eneolithic/Bronze Age. This also corresponds to the local environmental changes in the area, including dune reactivation and shoreline contraction. Additionally, the larger Ulaan Lake experienced increased salinisation, which is directly tied to aridification.

At the beginning of this research, it was expected that more sites would be found following the shrinking coastline of Ulaan Nuur. However, field survey found this was not the case. People did not follow the shrinking lake shoreline, but instead they moved away from the area of the lake, leaving the small satellite lakes and wetlands areas. Instead it is likely that they moved towards the spring belt, which is the origin of the fresh water.

However, people did not abandon the area, as artefacts from later periods are found at some sites including Bayanzag and Khoyor Khairkhan. Today, current major areas of occupation are located along the modern spring belt. Where current occupation occurs outside of the modern spring belt, these are found where wells reach groundwater, which is connected to the larger underground river network.
Chapter 10: Conclusion

After the shift to herding sometime in the Bronze Age, the spring belt would have been more stable for domesticated animals, compared to ecosystems heavily connected to and influenced by Ulaan Nuur, including wetlands. For example, the current soum capital of Bulgan, the city of Bulgan, is in the modern local spring belt. The current province capital of Omnogovi, Dalanzadgad, lies in another spring belt connected to the Gurvan Saikhan mountain range. The spring belt has probably moved over time from its original position due to regressive erosion.

When considering how the environmental landscape affected the anthropogenic landscape, a multi-scalar approach can be used to interpret all proxies. By doing this, landscape evolution can be used to evaluate archaeological changes. At the largest scale, Ulaan Nuur influenced hunter-gatherer groups across all analytical scales from the fine to the coarse. Movement and interaction along distal regions of alluvial fans, as well as interfluvial zones and local water resources were central to societal transmission.

Local groups existed and operated in their own microenvironments, and these microenvironments are more important to landscape movement than the larger lake. Chief among these were small satellite lakes, with connecting wetland environments, and springs or seepages. However, the health of the larger lake influenced the health of these microenvironments. Salinisation, desiccation of the river/stream networks, and lake contraction all influence mobility. In the context of sustainability, regions are overall more stable than landscapes, and because of this, it is more difficult to detect small scale changes on the regional scale.

In an arid zone economy, economic change must be studied on the local scale. In the Ulaan Nuur region, this would be better examined with the addition of more data, with an emphasis on intensive study at household/site scales. The geomorphological and taphonomic processes present at all sites should be considered in this evaluation, as it is likely most sites are covered, have been destroyed, or have been inaccurately assigned a chronology, particularly when artefacts from many periods are mixed on the surface. A low chronological resolution obscures the true extent of occupation, especially where the boundaries between semi-arid and arid areas have moved through time (Veth et al., 2005: 295).

Even in current conditions today, people choose to live near these sites. These current occupied areas correspond to areas where groundwater is still present. Areas with no current occupation are areas within the vicinity of the volcanic fields and in the interior of the lake, which currently has salty wetlands, as well as dune fields. These areas also show no evidence of ancient occupation. Continuity of groundwater resources where ancient fresh water resources were,
supports the current occupation, or not too far from. This demonstrates how closely anthropogenic and environmental landscapes are both complementary and interrelated, and the necessity to examine both across several scales.

10.3 Directions for future research

A better understanding of hunter-gatherer and early herder adaptations in the Ulaan Nuur region is needed to better evaluate the complex interactions between anthropogenic and environmental landscapes. An interdisciplinary approach is necessary to reconstruct this. Geomorphological and environmental processes and landscape change must be considered in interpretations of archaeological site use and artefact distribution, particularly as all sites in this area are exposed on the surface and most have mixed artefacts from many periods. By doing this, a comparison of the distribution of materials across the local Ulaan Nuur landscape may be compared, indicating whether hunting strategies changed before or after the Early Bronze Age, concurrent with changes in the hydrological landscape.

This dissertation represents a contribution in beginning to understand these dynamics in the Ulaan Nuur region. The methodologies integrating satellite imagery analysis and GIS analysis with field survey were successful, and demonstrate they may be used reliably for future survey in this area, while also identifying potential avenues of additional methodological research. The field survey demonstrated there are several areas of archaeological activity around the region, with new identified areas. With extended survey, there is the potential for the identification of many more new areas. Further survey of the spring belt corridor and other areas of the Ulaan Nuur palaeoshoreline may reveal others areas of archaeological activity. Using the methodologies described here, this may become more manageable, and further demonstrates the need for multi-scalar methodological approaches. Further, dating these sites and studying them intensively in the future will contribute to the growing chronology of the Gobi Desert archaeological record.

In Chapter 1, the hydro-social relationship was introduced. Water exists and functions as a resource, but also as a natural agent in the facilitation and conduit of movement, interaction, communication, and trade (Linton, 2008, 2010). Environment and society are closely interrelated and local hunter-gatherer groups in the Ulaan Nuur region responded to theirs by utilising and moving between specific ecozones. Water is linked to the sustainability of a region, where it functions as a dynamic entity that is connected to all landscape processes. Not only can it disrupt or structure societies (Linton and Budd, 2014), but it also shapes landscape and social classifications (Mosse, 2008).
This survey demonstrated that not only macro-hydrological regimes, such as river systems and alluvial environments, are important, but equally significant are micro-hydrological resources to understand movement on local scales. This is particularly applicable to arid and semi-arid environments where movement, exchange, communication, and socio-economic development are directly tied to water and ecosystem dynamics. Climate change directly affects the hydrological landscape, and by examining subtle spatio-temporal and multi-scalar changes in this landscape, it is possible to use these as proxy variables in which to measure human-environment interactions.

In desertscape like the Gobi, a better understanding of this provides an opportunity to reassess our understanding of these macro and micro processes, where movement can be traced through investigation of smaller and often overlooked resources. By doing this, additional questions related to the sustainability of desert regions and the evolution of desert societies, including technological and economic responses to aridification, population change, and social organisation, may be continued to be studied and expanded.
Appendix

1. Geomorphological Processes at Khoyor Khairkhan

Erosion and deflation are predominant in this area and typical of arid environments. Artefacts from several archaeological periods are mixed on the surface as the stratigraphy erodes. Deflation image modified from: http://images.slideplayer.com/8/2379634/slides/slide_6.jpg.
2. Archaeological Materials

All archaeological materials from all periods recorded at each identified area of archaeological activity are organised by site:

1. Khoyor Khairkhan (see Section 8.2; p. 169)

2. Bayanzag (see Section 8.3; p. 192)

3. Zulegtiin Khud (see Section 8.4; p. 200)

4. Right Palaeo Riverbank (see Section 8.5; p. 208)

5. Southern Lakeshore Corridor (see Section 8.6; p. 212)
1. Khoyor Khairkhan

There are diverse materials around this site. Jasper is the most abundant, but also basalt, chalcedony, and agate.
KHOYOR KHAIRKHAN - SUBSITE 1.A.
Appendix

KHOYOR KHAIRKHAN– SUBSITE 1.A.
Appendix

KHOYOR KHAIRKHAN- SUBSITE 1.A.

Appendix
KHOYOR KHAIRKHAN - SUBSITE 1.A.
KHOYOR KHAIRKHAN - SUBSITE 1.B.

Humid area - Palaeolake?
Sub-site 1.B.

GPS point: 179
1064-1066

Sites

1

GPS point: 180
1069-1077

1155
1153
260
Appendix

KHOYOR KHAIRKHAN - SUBSITE 1.B.

[Images of artifacts with scale bars indicating measurements of 1 cm and 2 cm]

GPS point: 181  1084-1126

GPS point: 182  1031-1061

262
KHOYOR KHAIRKHAN - SUBSITE 1.B.
Possible wind-blown saddle decorations found together in close proximity. Because the left decoration is bi-metallic (bronze and iron), these are most likely post-Xiongnu to a later historical period (Bill Honeychurch via Lisa Janz, personal communication).
KHOYOR KHAIRKHAN- SUBSITE 1.C.

Khoyor Khairkhan

Humid area - Palaeolake?

1

GPS point 73
W65°49'
416'40"N

2

GPS point 75
W65°49'
413'44"N

3

Appendix
KHOYOR KHAIRKHAN - SUBSITE 1.D

Khoyor Khairkhan

GPS point = 72
9796-9805
KHOYOR KHAIRKHAN - SUBSITE 1.E.
KHOYOR KHAIRKHAN- SUBSITE 1.F.

Burial 1
KHOYOR KHAIRKHAN - SUBSITE 1.F.

Burial 2

Burial 3

Burial 4
KHOYOR KHAIRKHAN - SUBSITE 1.F.

Burial 5

Burial 6

Burials 7-8-9

GPS area 172
947-948

GPS area 172
949-950

GPS point: 173
952-954
KHOYOR KHAIRKHAN - SUBSITE 1.G.

Advanced eroded inselberg or burial?
Appendix

AREA 2

2cm

AREA 2
Appendix

AREA 2

280
Appendix

AREA 2
2. Bayanzag

Lake

Dunefield

Deflated area

Intermittent river
Bayanzag

6
7
8

GPS point: 4

9
10
11

GPS point: 25

12
13
14

15

GPS point: 30

16
Bayanzag

GPS point: 14

GPS point: 15

GPS point: 16

GPS point: 19

GPS point: 18

GPS point: 19

GPS point: 20
Bayanzag

Appendix

289
3. Zulegtiin Khud

ZULEGTIIN KHUD - AREA 1.A.

Blade on the stratigraphy of the central yardang

Material scattered around the central yardang

HILLS AROUND ZULEGTIIN KHUD - AREA 1.B.
SOUTH-WEST OF ZULEGTIIN KHUD - AREA 1.C.
SOUTH-WEST OF ZULEGTIIN KHUD - AREA 1.C.
SOUTH-EASTERN EDGE OF ZULEGTIIN KHUD - AREA 1.D.
Pottery sherds were exclusively found exposed on top of several deflated areas like the one above. Other pottery were observed partially buried in the stratigraphy of these areas. These are potentially hearths or living spaces and would benefit from excavation and further intensive study.
Another deflated area with pottery sherds exclusively found on top of it. Pottery sherds were also observed partially buried in the edges of the stratigraphy. The yellow jasper arrowhead (#43) was found next to this deflated area.
EASTERN EDGE OF ZULEGTIN KHUD - AREA 1.E.
### EASTERN EDGE OF ZULEGTIIN KHUD - AREA 1.E.

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NORTH-EAST OF ZULEGTIIN KHUD - AREA 1.F.
4. Right Palaeo Riverbank

Hills Adjoining Palaeo Riverbank Scatters

[Images of artifacts with 2cm scale bars]

GPS point: 149 712-716
Right Palaeo Riverbank
Right Palaeo Riverbank

GPS point: 41

GPS point: 44

GPS point: 46
Right Palaeo Riverbank

GPS point: 36

GPS point: 37

GPS point: 38

GPS point: 39

GPS point: 40
Right Palaeo Riverbank

GPS point: 47

GPS point: 54

GPS point: 48

GPS point: 56

GPS point: 55
5. Southern Lakeshore Corridor

MANDAL BAGA

This ovoo and religious monument has several pieces of debitage around them. The ovoo had pieces of debitage inside of it. This means people picked up pieces from the surrounding area and placed them inside.
VOLCANO FIELD BURIALS

Burial

GPS point: 138  620

Burial

GPS point: 139  621
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A


B


D


E


F


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