Hominins in Lower-Middle Pleistocene Central Asia

A Landscape-Based Approach to Assessing the Earliest Possible Dispersal and Occupation

Patrick Cuthbertson

Acknowledgements

The proposal, planning, and execution of this thesis project over the past few years has been achieved with the help and support of a large number of people whose contribution requires acknowledgement here.

I want to thank Nick Barton (University of Oxford), who initially judged my Transfer of Status and gave feedback and encouragement in the early years of the project, and then later for his help and guidance in supervising me to the end of the project, even when difficulties arose that lengthened this process considerably.

I also want to thank John Pouncett (University of Oxford), who taught me to use Geographic Information Systems (GIS) during my MSt at the University of Oxford. John helped me extensively throughout the entirety of the project, and helped assess and give feedback for both my Transfer of Status and Confirmation of Status. This project would have been impossible without John's help and support.

Likewise, I want to thank Chris Green (University of Oxford), who regularly helped troubleshoot GIS problems and provided very necessary insight and critique on the spatial aspects of this project. His input was also essential to the completion of this project.

I want to thank Mike Petraglia (Max Planck, Jena), who was my supervisor at the start of the project, and encouraged me and provided feedback during the initial proposal of the project.

This project has also benefitted greatly from the encouragement of Mica Glantz (Colorado State University), data which she collected with the help of Tyler Beeton (Colorado State University), and Sayat Temirbekov (Colorado State University), and also comments and feedback she made as an examiner in the second viva.

I also want to thank Dan Hicks (University of Oxford) for comments, feedback, and help he gave as my internal examiner for the second viva.

Tom Higham (University of Oxford) provided extensive feedback as an assessor during my Confirmation of Status, and provided much needed support during the transition between my supervisors.

Robin Dennell (University of Exeter) provided useful discussion and suggestions on several occasions during the course of this project, and provided tough and detailed feedback as an examiner for the first submission. Similarly, I thank Rick Schulting (University of Oxford) for his feedback as an examiner on the first submission.

Bence Viola (University of Toronto) provided clarification on the coordinates and interpretation of the site of Sel'ungur.

I thank Radu Ioviţă (New York University, University of Tübingen) for his patience and understanding during the process of writing up, as well as for giving me the opportunity to see some of the regions in my study area during that time.

This project has been vastly improved by regular conversations, debates, and exchanges of information with my peers, but in particular in this regard I have to thank Andreas Nymark (Birkbeck University of London, University of Cambridge), Peny Tsakanikou (University of Southampton), Becka o'Sullivan (University of Oxford), Felix Henselowsky (University of Heidelberg), Michaela Ecker (University of Toronto), and Raija Heikkilä (University of Tübingen).

I want to thank Will Snyder (University of Tübingen) for the excellent interpretive illustrations he produced to accompany my discussion.

I have to thank the School of Archaeology, University of Oxford, for providing funding for the first 3 years.

The Oxford University Museum of Natural History also provided me with access to their rock collections, which was a great resource for improving my understanding of geology.

I also want to thank my parents, whose level of support in matters academic, emotional, and financial, has been beyond reckoning for all of my study in higher education.

All people and institutions listed above have contributed to the success of this project, and all errors remain my own.

Finally, I would like to dedicate this thesis to the memory of Terry Hardaker, who was always very friendly, very encouraging, and will be sorely missed.

Table of Contents

Acknowledgements 2

Chapter 1. Introduction 11

Chapter 2. The Lower Palaeolithic of Central Asia 18

2.1 Early Finds 23

2.2 Systematic Study 26

2.3 Major Themes in the Lower Palaeolithic of Central Asia 31

2.3.1 Dated Sites 31

2.3.2 Surface Sites 39

2.4 Discussion and Summary 41

2.5 Archaeology in the Soviet Union 44

Chapter 3. The Lower Palaeolithic of Neighbouring Regions 48

3.1 Georgia 50

3.1.1 Dmanisi 50

3.1.2 Early Pleistocene Caucasus 57

3.1.3 Summary 58

3.2 Iran 59

3.2.1 Shiwatoo 60

3.2.2 Khaleseh 61

3.2.3 Pal Barik 62

3.2.4 Kuran Buzan Valley 63

3.2.5 Amar Merdeg and the Mehran Plain 64

3.2.6 Ganj Par 67
3.2.7 Darband 70
3.2.8 Geleh 71
3.2.9 Kashafrud 71
3.2.10 Ladiz and the 'Ladizian' Sites 73
3.2.11 Isolated Handaxe Finds 74
3.2.12 Summary 75
3.3 Pakistan 77
3.3.1 Riwat 78
3.3.2 Pabbi Hills 78
3.3.3 Dina & Jalalpur 79
3.3.4 Summary 79
3.4 China 80
3.4.1 The Nihewan Basin 81
3.4.2 Lower Pleistocene Sites 96
3.4.3 Middle Pleistocene Sites 101
3.4.4 Large Cutting Tools in China 108
3.4.5 Summary 116
3.5 Mongolia 118
3.5.1 Dno Gobi 119
3.5.2 Flint Valley 120
3.5.3 Summary 120

3.6 Siberia 121

3.6.1 Summary 122

3.7 Summary & Conclusions on Neighbouring Regions 123

Chapter 4. Hominin Dispersal and Occupation in the Lower Pleistocene 131

4.1 The Nature of Dispersal & Hominin Competency 131

4.1.1 The Language and Logic of Dispersal 131

4.1.2 Hominin Competency 135

4.1.3 Hominin Ranging 141

4.2 The Role of Environments and Resources 142

4.2.1 Savannah Hypothesis challenged 145

4.2.2 Variability Selection Hypothesis 147

4.2.3 Mosaic Environments 148

4.3 Resources – A 'Variety of Elements' Approach 150

4.3.1 Drinkable Water 150

4.3.2 The 'Tectonic Landscape Model' 152

4.5 Summary 155

Chapter 5. Physical Geography and Climate of Present Day and Historical Central Asia 158

5.1 Physical Geography of Central Asia 160

5.1.1 Mountains, Tectonics, and Orogenesis 160

5.1.2 Glaciers and their Hydrological Effect 163

5.1.3 Intra-montane and Inter-montane Depressions 165

5.1.4 Peri-Mountainous Foothills and Piedmont Areas 166

5.1.5 Deserts and Dust Storms 167
5.1.6 Rivers & Waterbodies 171
5.1.7 Land Cover 175
5.2 Temperature and Precipitation in Central Asia 176
5.2.1 Temperature 176
5.2.2 Precipitation 177
5.3 Human Intervention and Climate Change 179
5.4 Summary and Conclusions on the Present Day Physical Geography and Climate of Central Asia 181
Chapter 6. Pleistocene Climate and Environmental Record of Central Asia 185
6.1 The Pedocomplex-Loess Sequence 186
6.1.1 The Role of Weather Systems and Gross Landscape Morphology in Long-Term Aridification and the Glacial-Interglacial Succession 188
6.1.2 Timing and Intensity of Loess Accumulation in Central Asia 190
6.1.3 Regional Geomorphology of Loess in Central Asia 192
6.1.4 Climate Reconstruction from Central Asian Loess 193
6.2 Correlation with the Chinese Loess Sequence, Global Oxygen Isotope Stages, & Lake Baikal 209
6.2.1 Forcing Mechanisms and Geomorphology of The Chinese Loess Plateau 209
6.2.2 Dating and Correlations with The Chinese Loess Plateau & global Oxygen Isotope Stages 210
6.2.3 Pleistocene Environment in the Chinese Loess Plateau: Similarities and Contrasts with Central Asia 213

6.2.4 The Lake Baikal Environmental Record: Correlation with Orbital Forcing Mechanisms 214

6.3 Summary: The Pleistocene Environment of Central Asia, a Zone of Increased Evolutionary Pressures? 219

Chapter 7. Modelling Methods & Results 222

7.1 Phase 1: Modelling Resources and Amenability to Occupation 222

7.1.1 Resources and Amenability Methodology 222

7.1.2 Resources and Amenability Results 251

7.2 Phase 2: Accessibility Analysis 267

7.2.1 Accessibility Analysis Methodology 267

7.2.2 Accessibility Analysis Results 271

7.3 Phase 3: Entry-Point Analysis 277

7.3.1 Entry-Point Analysis Methodology 277

7.3.2 Entry-Point Analysis Results 278

7.4 Rejected Modelling Methods: Least-Cost and Visibility 281

Chapter 8. Discussion: Technology, Dispersal, and Occupation in the Lower-Middle Pleistocene of Central Asia 284

8.1 Stone Tool Technology in Central Asia 284

8.1.1 Mode 1 Technology and The Karatau Pebble Culture 284

8.1.2 Mode 2 in Central Asia and the Movius Line 287

8.2 Occupation & Dispersal: Northern Routes, Tectonic Mountain Corridors, and Savannahstan 290

8.2.2 Occupation in Lower-Middle Pleistocene Central Asia 291

8.2.1 Dispersal: Northern Routes, Tectonic Mountain Corridors, and Savannahstan ... 296

Chapter 9. Conclusion ... 299

9.1 Future Directions ... 303

Appendix 1. Gazetteer of Central Asian Sites ... 305

Ak-Koshkar (Kazakhstan) ... 306

Batpak Valley (Kazakhstan) ... 307

Esen 2 (Uzbekistan) ... 310

Jaman Aibat 4 (Kazakhstan) ... 311

Karakuduk (Uzbekistan) ... 312

Karatau I (Tajikistan) ... 313

Karatau Range Surface Sites (Kazakhstan) ... 317

Khonako (Tajikistan) ... 319

Koshkurgan (Kazakhstan) ... 320

Kul'bulak (Uzbekistan) ... 322

Kuldara (Tajikistan) ... 325

Kumuktepe (Kazakhstan) ... 329

Kyzyltau (Kazakhstan) ... 330

Lakhuti I (Tajikistan) ... 332

Mugodjari (Kazakhstan) ... 336

Muzbel I (Kazakhstan) ... 338

Bolshoy Narym (Kazakhstan) ... 339

Obi-Mazar (Tajikistan) ... 340

Sel’ungur (Kyrgyzstan) 342

Semizbugu (Kazakhstan) 346

Shakhbagata (Kazakhstan) 347

Shoktas (Kazakhstan) 348

Vishnëvka (Kazakhstan) 349

Yangdja (Turkmenistan) 350

Appendix 2. Spatial Data Sources 352

Bibliography 353

Chapter 1. Introduction

This project takes a landscape-based approach to assessing the earliest possible dispersal and occupation of hominins during the Lower-Middle Pleistocene in Central Asia. This time period of the study region is only sporadically covered in the English-language literature, and the more extensive research of the region in the Russian-language literature is available to English-language scholars only in the form of occasional summaries and syntheses. Despite this, Central Asia has a potentially major role to play in developing our understanding of Pleistocene hominin dispersal in Asia.

The major orography of Asia suggests two potential routes eastwards from Southwest Asia; a 'Northern Route' through Central Asia and north-western China, and a 'Southern Route' through South Asia. While the southern route has been studied and mapped to some extent (Field & Lahr, 2005, Field, et al., 2007), the northern route has yet to be comprehensively studied in this way, and it is not clear if this 'route' provides a viable connection between what might be broadly thought of as western and eastern Asian populations of hominins. While surrounding regions in Asia have all provided dated assemblages and fossils in excess of 1.5mya (Garcia, et al., 2010, Pappu, et al., 2011, Zhu, et al., 2004), the securely-dated sites of the Central Asian record are notable in not exceeding an age of 1mya. This is especially surprising, in light of the fact that the foothills and piedmonts of Central Asia have specifically been highlighted as a rich, sheltered area, dubbed the Inner Asian Mountain Corridor (IAMC), which could potentially be enabling later Prehistoric dispersal (Frachetti, 2012), and seem likely to have functioned as a series of *refugia* during the Late Pleistocene (Beeton, et al., 2014, Glantz, et al., in press). This project examines whether the late dates in Central Asia are a reflection of an environment that is inhospitable for earlier hominin occupation, or a reflection of the scarcity of securely-dated sites (which may result from a lack of appropriate material for dating, the remodelling of the landscape leading to a loss of

earlier sites, or as a result of investigation bias), and also seeks to develop our understanding of hominin occupation in Central Asia during this time. This has involved assessing the habitability of Central Asia for hominins during the Lower-Middle Pleistocene, and its accessibility for hominins from nearby areas already known to be occupied during this time.

Traditionally, the definition of Central Asia has sometimes not included Kazakhstan, especially in the Russian-speaking world. For the purposes of this study, the definition of Central Asia follows the geographical regions devised by the United Nations Statistics Division (region code 143), including the modern political boundaries of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan (United Nations, 2013).

Three key questions structured the approach taken in this study:

1. Was Central Asia habitable during the Lower-Middle Pleistocene?
2. What were the most probable routes for hominins through Central Asia?
3. What was the most likely entry point for Lower-Middle Pleistocene hominins into Central Asia?

None of these three questions have been comprehensively addressed in the current literature, and they provided a structure of three phases of analysis for the project, and have formed the core of the methods employed.

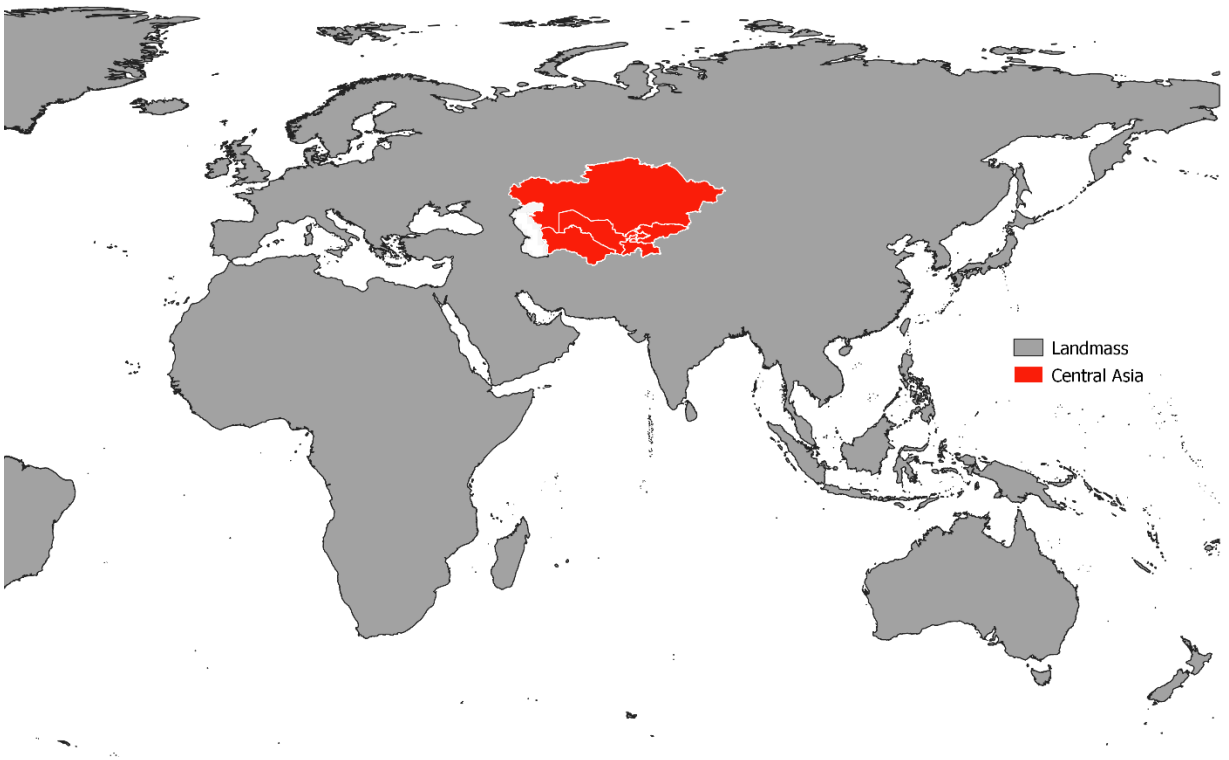

Figure 1 - Central Asia in a global context. Situated far into the interior of the Eurasian landmass, Central Asia is defined here to include the modern political territories of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan.

To answer question 1, several different types of data including archaeological, geological, and hydrological data, were used to assess the different elements important for hominin occupation in the study region using a Geographic Information System (GIS). The end goal for phase 1 was the combination of these elements to produce a map of the study region representing spatially its amenability to hominin occupation via what will be defined in future chapters as a 'taskscape' of affordances. The second phase of the analysis, addressing question 2, used the amenability surface resulting from phase 1 as a cost surface to characterise the nature and direction of possible dispersal into the region, or 'accessibility'. The third phase used the accessibility results to assess the most likely entry-point into the study region based on current site distribution, comparing the cost of reaching all of the sites in the study region. This project aims to draw on an extensive and in-depth review of the literature, both of Central Asia and neighbouring regions, to challenge and develop some existing concepts of hominin dispersal, to use that depth of research and those developed concepts to structure novel analytical approaches, and ultimately to use the results of those analyses to examine the relationship of the Central Asian sites to each other and their Lower-Middle Pleistocene landscape, as well as to develop a greater understanding of the regional and global factors affecting hominin occupation and dispersal globally.

The present project is valuable in achieving a number of secondary goals in the execution of the analysis. One of these goals, for instance, is synthesising the literature on the Lower-Middle Pleistocene record of Central Asia, and to situate it in relation to the contemporary archaeology of neighbouring regions. This thesis also challenges techno-typological arguments for dispersal in Central Asia, and compares them to the existing environmental evidence and the models produced here for the first time. Techno-typological arguments are prevalent in the literature, largely due to a lack of well-dated sites, but this thesis aims to

show that a spatial approach focused on environmental affordances rather than lithic technology in isolation can challenge and test them. Ultimately, it will be argued, neither environment nor lithic technology alone can be implicated as the sole determinant of hominin dispersal and occupation patterns, and any approach to these problems needs to provide an integrated approach that seeks to understand the 'affordances' that connect environmental factors and factors of hominin adaptation. The identification of these affordances or habitat elements in the course of this work has enabled a broad synthesis to be made and allowed an assessment of their relation to hominin occupation and dispersal in the region. This is a valuable addition to present studies by other researchers who are trying to define and understand similar topics (Finlayson, 2014, Gamble, 2013).

The methodological choice to map continuous resources in the landscape, rather than focus on discrete habitat patches, or defining environments immediately surrounding existing sites, is also a challenge to the strong site-based focus of Palaeolithic archaeology. Furthermore, the results of the three phases of the project described above work towards building a comprehensive framework for the region, which provides an invaluable addition in an area where there are so few securely-dated sites. Although this potentially includes the identification of new locations for investigation in the field, the current appraoch is fundamentally different to inductive predictive models used to predict site location from known features of existing sites. Such inductive predictive models tend to ignore the dynamics of human systems (Ebert, 2000), and are strongly site-oriented.

Despite the fact that GIS has been readily adopted as a tool by Palaeolithic archaeologists, this type of applied research is still in its infancy. This project functions as a demonstration that questions of relevance to Palaeolithic archaeologists can be reframed in the logic of spatial analysis, and answered with spatial methods, to develop a greater understanding of the existing archaeological record. To this end, this project applies a hominin-centred spatial

approach to further develop understanding of the current Lower-Middle Pleistocene record of Central Asia, to produce new data, and to place Central Asia within the context of wider hominin dispersal within Asia as a whole. GIS models are a lens through which to view constructed versions of the landscape, and as archaeologists we have to be selective what lens we use depending on what relationships we wish to investigate in the record. This also includes explicit explanation of why we have chosen specific lenses, and rejected others. The models presented here are not simply representations of the physical landscape, but have attempted to focus on aspects of hominin-landscape interaction that are routinely ignored my Palaeolithic archaeologists and spatial analysts alike. These approaches are also unusual in Palaeolithic GIS, in that they do not rely on any topographical data, even in a derived form. There are sound methodological reasons why topographical least-cost models are rejected here (see section '7.4 Rejected Modelling Methods: Least-Cost and Visibility').

In summary, the mountain chains of interior Asia broadly suggest two major routes through the continent for Pleistocene hominins, including a northern route and a southern route. Central Asia occupies the area of this possible northern route, suggesting that it may have an important role to play in understanding hominin dispersal through Asia as a whole. Dates from neighbouring regions imply that the earliest dispersal into and occupation of Central Asia is likely to have been during the Lower Pleistocene, in spite of the relatively late age of the dated sites known from the region at this time. It is currently unclear whether these late dates are a reflection of late occupation of the region, or represent simply a lack of well-dated sites. To address this, the current project will use a landscape-based approach to assess the habitability and accessibility of Central Asia for hominins during the Lower-Middle Pleistocene. This approach explicitly challenges techno-typological approaches and models of hominin dispersal that focus on broad, discrete habitats or eco-zones. Three questions have been proposed, which structure three phases of analysis. Absolute answers to these questions may not be feasible, especially considering the spatio-temporal scale of the

project. However, the project will use spatial models as a lens to provide a hominin-centred assessment of the landscape and environment of Lower-Middle Pleistocene Central Asia. Hominin-centred is intended to highlight hominin-landscape interactions, and especially to address the fact that hominins are unique in the degree to which their combined extrasomatic adaptations contribute to the construction of their own niche and occupation tolerances within the landscape. This project will also develop an understanding of the physical geography of the region and how environmental conditions change throughout the Lower-Middle Pleistocene, and also compare this with evidence from neighbouring regions.

Chapter 2. The Lower Palaeolithic of Central Asia

This chapter outlines the history of Lower Palaeolithic research in Central Asia, and also identifies several major themes that will structure the analysis and discussion. Numerous issues surround the study of this region and its archaeology, and its record is not well-known to English-language scholars. Understanding the history of study and the nature of the current record is crucial to any broad analysis of the region. The few comprehensive summaries that have appeared in English represent a fraction of the work and literature in this area, but provide an invaluable resource. Where possible within the constraints of this project, I have endeavoured to include some literature available in other languages; however, this account is not exhaustive but aims to provide enough information for the goals of the analysis. I have chosen to use the term 'Lower Palaeolithic' here to refer to the technologies that may have been present in Central Asia during the Lower-Middle Pleistocene. These technologies, by my assessment, are identified also as Mode 1 or Mode 2 technologies, with the latter more tentative for the study region due to problems of dating and context that will be examined shortly. Specifically because of the difficulty of dating many of these sites, the technological terms Lower Palaeolithic or Mode 1-2 are used to highlight the technological similarities but are not meant to presuppose a concrete chronological association. For the purposes of the present study, Mode 1 is understood to refer to core and flake technologies, sometimes including choppers, but without any Mode 2 technology. Mode 2 is understood to refer to technologies that include large cutting tools (LCTs) with a bifacial edge that have been made by bifacial façonnage and/or bifacial thinning, including so-called 'bifaces', 'handaxes', and 'cleavers'. Mode 2 assemblages may also include core and flake and chopper elements that may otherwise be thought of as Mode 1 technologies, and 'Lower Palaeolithic' is meant as an umbrella term to cover both Mode 1 and 2 technologies. It is understood that this means assemblages containing even a single LCT will be designated as a Mode 2 assemblage, which is particularly relevant for

surface assemblages that are likely to conflate material from multiple periods. We should therefore expect Mode 2 sites to be 'over-identified' in the surface record especially, but it is interesting to note (see '2.3.2 Surface Sites') that, nonetheless, many surface sites in Central Asia exhibit only a Mode 1 technology. Central Asian sites can be judged to contain Mode 1 or Mode 2 technologies, and tentatively suggested to be Lower Palaeolithic on this basis (or at least, not to contradict such a designation), but their dating as Lower-Middle Pleistocene sites can only be provisionally suggested unless secure dating has been undertaken (as it has in some cases). The central purpose of this chapter is in providing an overview of the Central Asian sites that may be considered as Lower Palaeolithic, while also teasing apart the major themes and problems of this record. This chapter concludes with a discussion of the conditions and quality of archaeological work conducted under the Union of Soviet Socialist Republics (USSR), which arrives at several key considerations for the use of data collected and published during this era. It is relatively common in the English-speaking world to denigrate and doubt the quality of the work of our colleagues who worked under the USSR and/or publish in Russian, and I hope I can challenge this attitude.

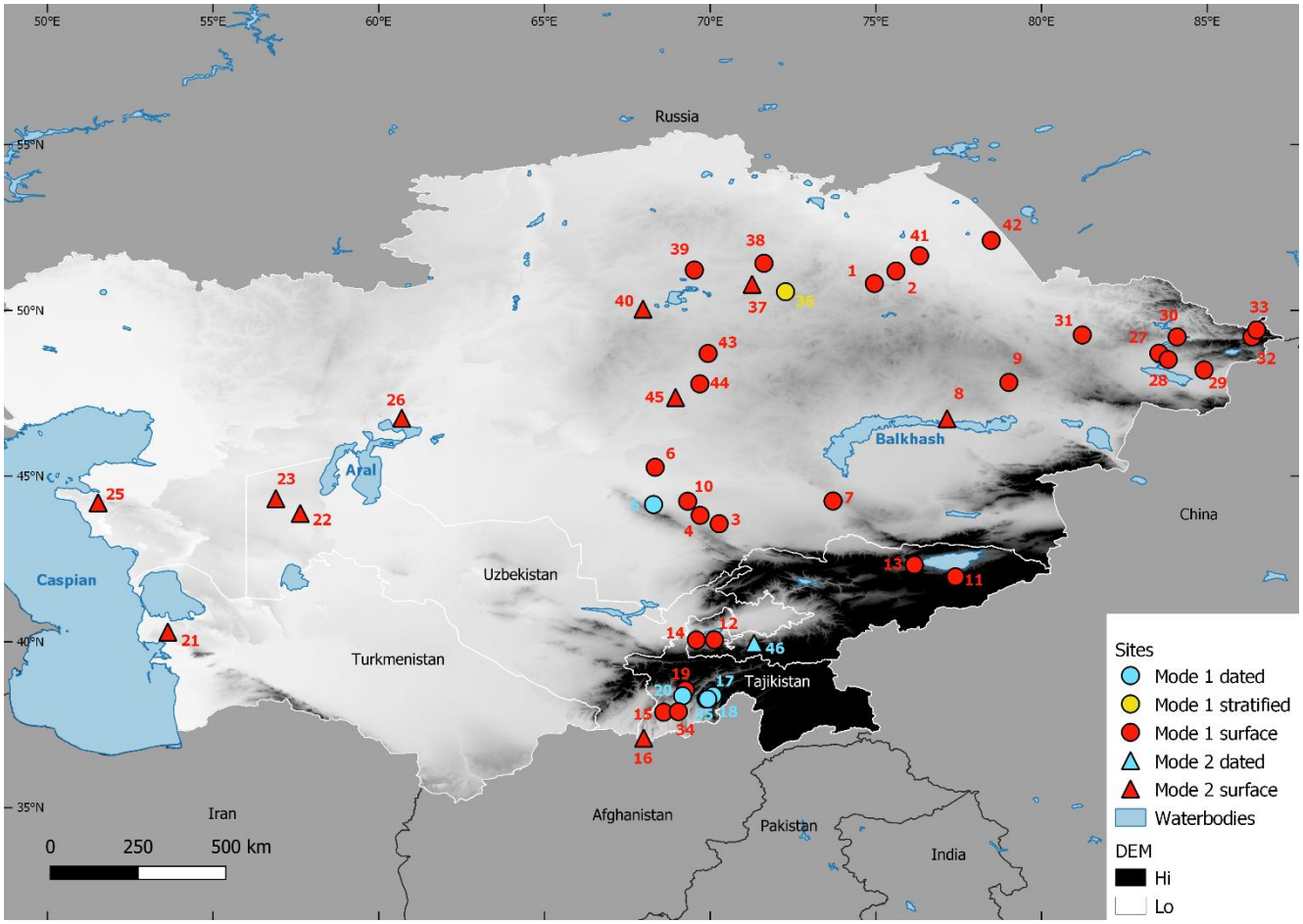

Figure 2 – Sites of a 'Lower Palaeolithic' technology in Central Asia, displayed by archaeological context and technological 'mode' see table on next page for the master list of site numbering – Some sites have a well-established claim to antiquity, such as the Tajik Loess sites, whereas others, such as the early finds at On-Archa are more speculative. The SRTM digital elevation model (DEM) shows the substantial mountains of the southeast in black, and lower-lying areas in lighter colours. This map includes co-ordinates reverse-engineered from maps in the literature, and co-ordinates supplied by several colleagues, items from the Global Administrative Areas (GADM) dataset, and the 1:10m modern lake & ocean datasets from naturalearth.com (see 'Appendix 2. Spatial Data Sources' items 1, 2, 3, and 5 for full details).

1. Angrensor
2. Taskuduk
3. Kemer
4. Karatau range sites
5. Koshkurgan1-3; Shoktas1-3
6. Kazangap
7. Khantau
8. Semizbugu
9. Chingiz
10. Tokaly1-3; Zhanatas etc.
11. On-Archa
12. Kajragach
13. Bech-Barmak
14. Khodzha-Bakirgan
15. Kizyl-Kala
16. Koyki-Tau
17. Khonako
18. Lakhuti; Obi-Mazar
19. Karamaidan
20. Karatau
21. Yangadja
22. Esen 2
23. Karakuduk
24. Shakhbagata
25. Kumaktepe
26. Aralsk
27. Zaisan Basin 1
28. Zaisan Basin 2
29. Zaisan Basin 3
30. Bolshoy Narym
31. Camp Lake Site
32. Dzambul
33. Berel'
34. Kuhi-Pioz
35. Kuldara
36. Batpak, Mizar
37. Vishnëvka
38. Volgolonovka
39. Kamenka
40. Ak-Koshkar
41. Kudaikol
42. Maraldi
43. Muzbel; Obalisan
44. Aidarli
45. Zhaman Aibat
46. Sel'ungur

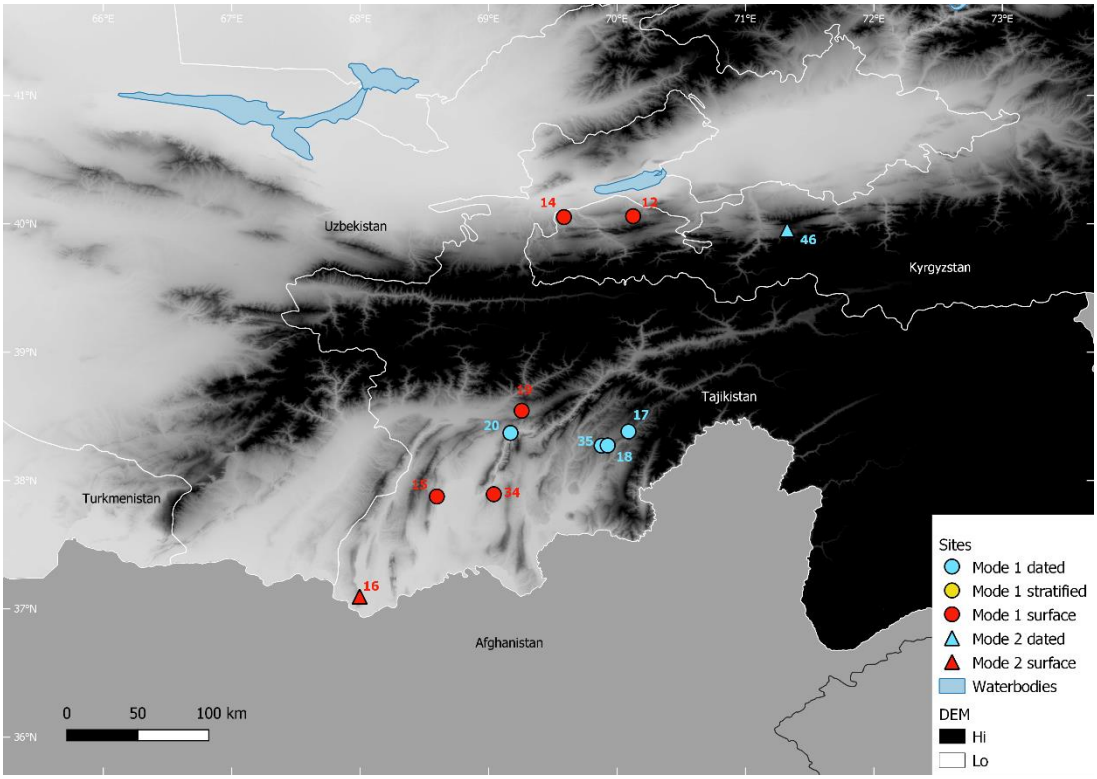

Figure 3 -Detail of sites in western Tajikistan and the Fergana Depression – This includes the oldest dated site at Kuldara (Tajikistan), and the youngest dated site considered in this analysis at Sel'ungur (Kyrgyzstan). See Figure 2 for data used in this map.

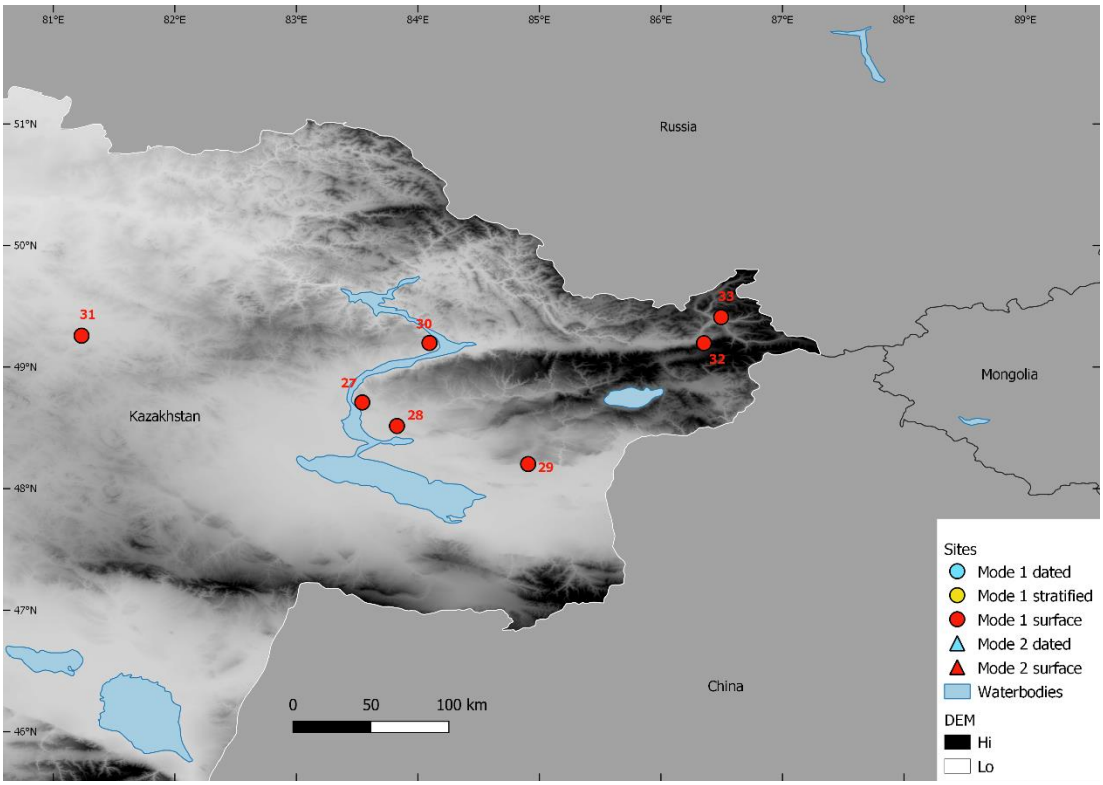

Figure 4 - Detail of sites in the eastern Kazakhstan/Kazakh Altai-Tarbagatai area – These sites are undated and without a firm context, but are located in an area crucial to the question of northernmost hominin dispersal. Proposed early dates for sites in Siberia and Mongolia remain controversial, see 'Chapter 3. The Lower Palaeolithic of Neighbouring Regions' . See Figure 2 for data used in this map.

2.1 Early Finds

Prior to the late 1930s, there were no indisputable Palaeolithic or Mesolithic finds in Central Asia (Movius, 1953, p. 383). Archaeological expeditions, operating in a colonial fashion and backed by several different colonial powers failed to identify any real possibilities for a Lower Palaeolithic record. More intensive expeditions and studies began post-WWII (Kohl, 1984), but these were slow to produce any Lower Palaeolithic finds. This pattern is part of a trend of the relatively slow growth of European understanding of the region, which has often caused European scholars to ignore the role of Central Asia in the human past. Codrington notes that European knowledge of Central Asia was slow to accumulate from the Classical era onward, and that it was long considered a "…hinterland, from which the terrible flood of men and horses erupted…" (Codrington, 1944, p. 29). The period 1943-56 saw the top-down establishment of national academies of sciences in the Soviet Socialist Republics (SSRs) of Central Asia by the Academy of Sciences of the USSR. This would have provided resources and infrastructure for investigating the archaeology in the region, even as it bolstered the control of the USSR on Central Asian countries under their dominion.

The first possible Lower Palaeolithic finds in Central Asia were made in 1953, in Kyrgyzstan, by the archaeologist A. P. Okladnikov from a road-cutting through an ancient river terrace alongside the On-Archa river (Klein, 1966, p. 36, Ranov, 1991, p. 210). These are reported as being a large pebble tool or chopper with affinities to the pebble traditions of South and Southeast Asia, alongside a few other possible tools included a possible side-scraper (Klein, 1966, p. 36). The finds were attributed to a tentative early Middle Pleistocene date; however, this is unreliable due to the lack of a firm context or date for the finds (Ranov, et al., 1995, p. 338). This was also the case with other finds located between 1950-70, all of which provided circumstantial evidence for a Lower Palaeolithic occupation, but no definitive proof in a firm, datable context. In the same year, Okladnikov began a systematic exploration of Palaeolithic Tajikistan with Vadim Ranov, who was a key figure in developing

and communicating the Lower Palaeolithic record of this region. Throughout the 1950s, Okladnikov travelled around Soviet Asia, and he was responsible for the discovery and publication of many of these early finds from Kyrgyzstan, Tajikistan, and Turkmenistan. In the late 1950s, K. A. Alpysbaev published several surface finds found by an expedition in the Karatau mountain range (Kazakhstan), which were reported as a Lower Palaeolithic technology (Frumkin, 1970, p. 13, see Figure 5).

Much of this early work was published in Russian, which limited its impact in the English-speaking world. Klein (1966) summarised some of these finds in English, although he seems to have been unaware of some of Okladnikov's earlier finds and of all the finds reported by Alpysbaev. Despite this, Klein's conclusion that "…the presence of Chellean/Acheulean man has not yet been demonstrated for Soviet Asia", was a fair assessment considering what was then known of the archaeological record in this region.

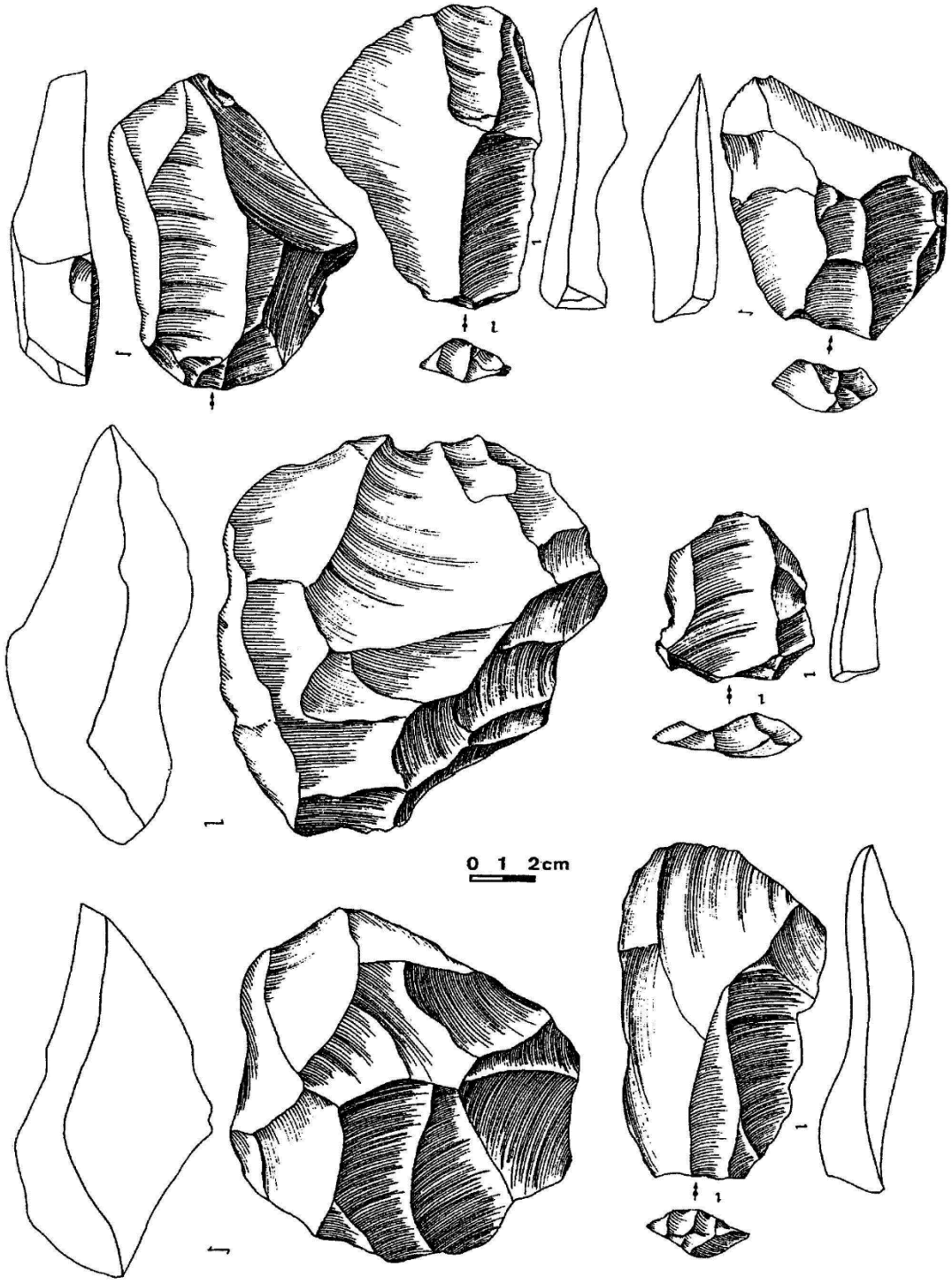

Figure 5 - Artefacts from the surface site of Borykazgan (Kazakhstan). One of Alpysbaev's surface sites from the Karatau mountain range in southern Kazakhstan. It is likely that the assemblage of artefacts collected from sites like Borykazgan represent a range of Palaeolithic periods mixed together. These sites have been interpreted as possible workshops (Taimagambetov, et al., 2013, p. 689, Vishnyatsky, 1999, p. 101). Figure from Otte (2000, p. Fig. 70), modified.

2.2 Systematic Study

Between 1953 and 1973, Ranov & Davis (1979, p. 252) noted the identification of nine additional surface sites containing a combined total of only 14 tools. As with earlier finds, these suffered from a lack of secure context and were therefore of limited value for developing chronological understanding of the region. However, in 1972, the geologist A. A. Lazarenko discovered *in situ* lithics when investigating a loess sequence in Tajikistan (Ranov & Davis, 1979, p. 252). This locality became known as Karatau I (unrelated to the Karatau range surface sites in Kazakhstan, Karatau means 'Black Mountain' and is a relatively common place name in Central Asia), and was published in 1977 by Lazarenko and Ranov (see Figure 6 and Figure 7). This discovery stimulated further investigation of the Tajik loess sequences, with Lakhuti I and Khonako both excavated in 1976 (Ranov, 1984, p. 6). Ranov spent the next two decades collaborating with researchers from several countries to study the loess sites, publishing the results in several languages. The Quaternary loess accumulations of Central Asia represent an exceptional record in a unique environmental setting. The geological sequences in these areas alternate layers of humid palaeosols with arid loess horizons, and their formation and significance for archaeology and environment will be examined in greater detail in 'Chapter 6. Pleistocene Climate and Environmental Record of Central Asia'.

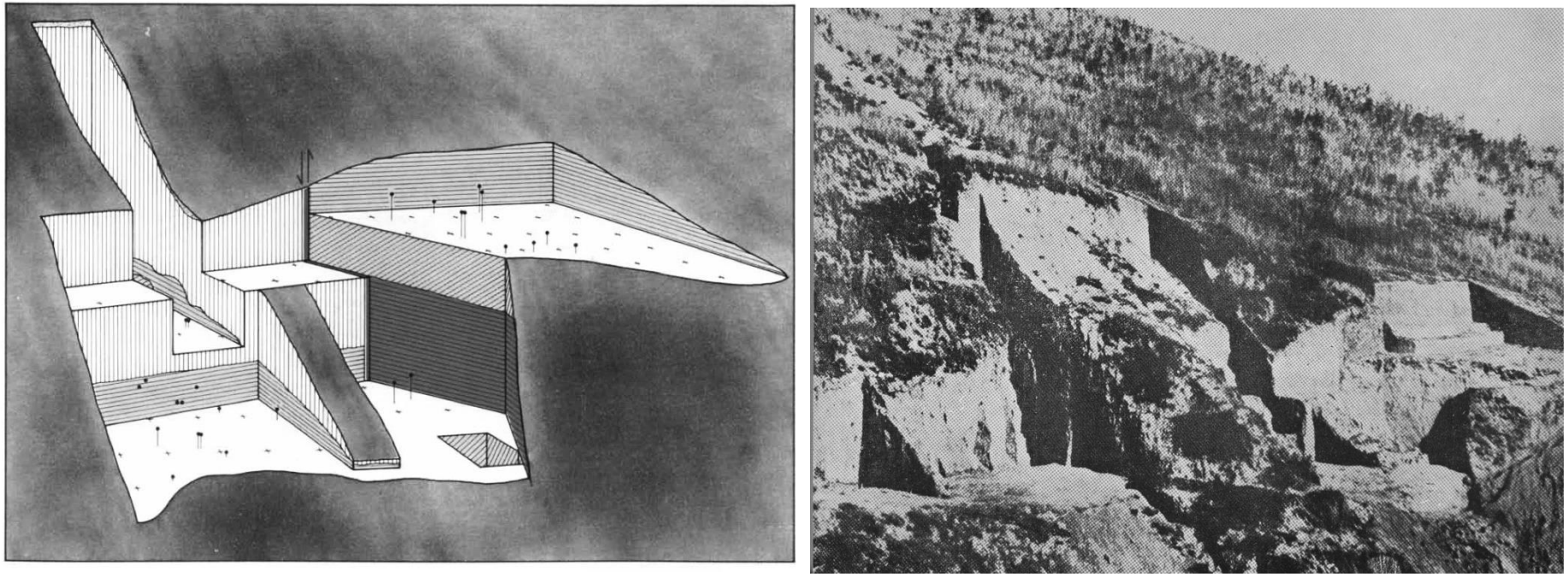

Figure 6 - The excavation at Karatau I, as represented schematically by Davis et al. (1980, p. 136, left), and a photograph of the same excavation from Gupta (1979, p. Plate 2), both modified. Karatau I was the first locality with *in situ* Lower Palaeolithic archaeology to be discovered in Central Asia, and became the technological type site for the Karatau Pebble Culture. The curvature of the loess hillside visible in these figures highlights some of the difficulties of locating and excavating Lower Palaeolithic archaeology in these areas, where Quaternary loess overburden can be substantial. It follows that surveys in these regions are most successful when they target exposed sections, as when Lazarenko (unintentionally) discovered Karatau I. Unlike surface sites, which disproportionately represent the horizontal relationship in the archaeology, such sections represent the other extreme by being skewed towards vertical representation of the archaeological record. A corollary of this is the difficulty of exposing the horizontal spatial relationship in such a context. It is notable that all of the major sites from this area of Tajikistan are located in areas where major rivers have cut down into the loess and exposed loess sections to erosion.

Kuldara (Tajikistan) was excavated from 1981 to 1984 (Ranov, 1984, p. 9, Ranov, et al., 1995, p. 339). The excavation recovered only 40 definite artefacts, but it was identified early on as significantly older than the previous loess sites investigated in the region. Kuldara was initially dated to 850-750kya via palaeomagnetism and an experimental thermoluminescence (TL) technique (Ranov, 1984, p. 9, Ranov, 1995, p. 735). A series of TL dates on Tajik palaeosols were also provided for the other loess sites by the Ukrainian scientist V. I. Shelkoplyas (Ranov, 1995, p. 732). Support for these dates was not unanimous, as even Ranov's collaborator Davis (1987, p. 127) was unwilling to accept dating of the Lower Palaeolithic in Central Asia to before 250kya, although he did concede that the TL dates probably underestimated the age of the loess sites (Davis, 1988, p. 299).

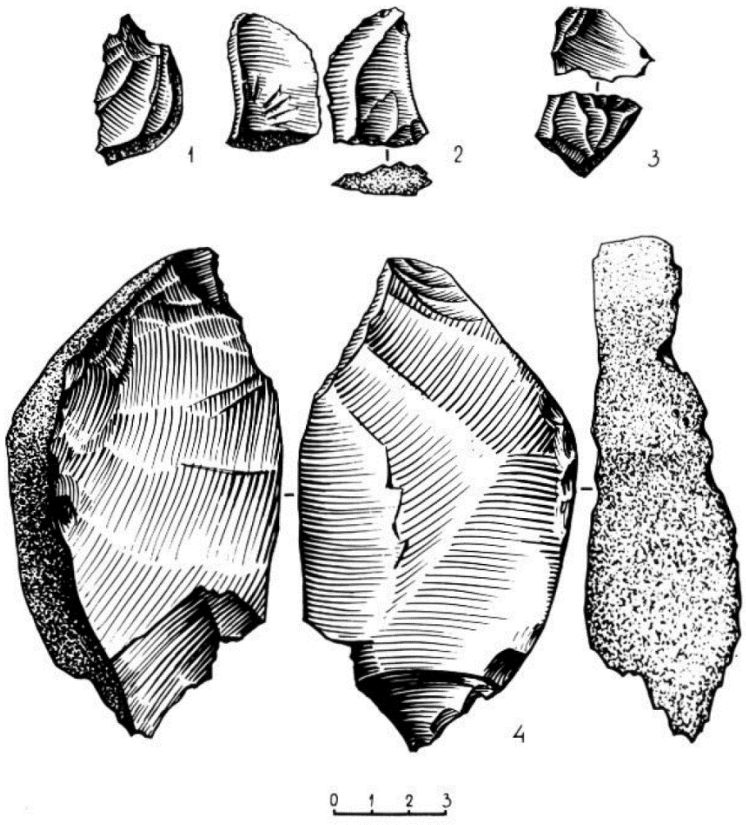

Figure 7 - Artefacts excavated from the Tajik loess site of Karatau I. Items 1 and 2 are flakes, item 3 has been interpreted as a core, and item 4 is a *quartier d'orange* or '*zitron*' flake, diagnostic of bipolar core reduction techniques on an anvil. Figure from Ranov (1984, p. Fig 5).

As of 1988, Davis noted that no comprehensive site report had been published for Kuldara (Davis, 1988, p. 300). A series of articles in the 1990s dealt with specific aspects of chronology and technology at the Tajik loess Palaeolithic sites (Davis & Ranov, 1999, Ranov, 1991, Ranov, 1995, Ranov, et al., 1995), and a summary of the context and technology of Kuldara (Ranov & Dodonov, 2003) references a comprehensive site report in the Russian literature. The same situation prevailed for the other Tajik loess sites, and access to these site reports would provide valuable information for assessing the security of their contexts and dating. Correlation between the Tajik loess deposits and the better-dated Chinese loess deposits subsequently demonstrated the underestimation of the TL dates, as well as providing secure dates of greater antiquity than the earlier dates claimed for the Tajik sites (Ding, et al., 2002, Dodonov & Baiguzina, 1995, Dodonov, et al., 1999, Frenchen & Dodonov, 1998, also see '6.2 Correlation with the Chinese Loess Sequence, Global Oxygen Isotope Stages, & Lake Baikal').

The site of Sel'ungur, originally test-pitted by Okladnikov in 1955 (Davis & Ranov, 1999, p. 189), was also excavated in 1980 by Y. I. Islamov (1990). Initial dates for Sel'ungur appear to have vastly overestimated its age at around 500-700 kya, or more conservatively 200-250 kya (Ranov, 1991, p. 215). The occupation at the site has been dated to 126 ± 5 kya via uranium-thorium dating on overlying travertine by Leningrad State University laboratory (Markova, 1992, p. 217), although this date is not universally accepted (M. Glantz pers. com.). The site continues to be excavated and reassessed, and new TL samples have returned a spread of dates with a mean result of 112 ± 19 kya. While Krivoshapkin et al. (2020, p. 91) acknowledge that this date is extremely unreliable due to high dosage variation, giving it a large error range, they also suggest that the results require that the probable age of the site should be revised younger than previously supposed. However, as the enormous age range of the new date overlaps fully with the smaller age range of the more reliable earlier U-series date, it would not be unreasonable to consider the occupation

at the site still to lie at the boundary of the Middle-Late Pleistocene. The artefacts also seem to originate from a redeposited colluvium within the cave, indicating that they may, in fact, be at least a little older than the dated deposits (Krivoshapkin, et al., 2020, p. 91).

A further development around this time comes from the publication of several surface finds of handaxes in Turkmenistan and Kazakhstan (Vishnyatsky, 1989, Vishnyatsky, 1999, pp. 71-3, 103). These represented an interesting development at the time, but as surface sites alone they provide little additional chronological information, and may as easily be considered Middle Palaeolithic as Lower Palaeolithic (Davis & Ranov, 1999, p. 189). The difficulty of applying techno-chronological terms such as Middle or Lower Palaeolithic, as well as the high likelihood that surface assemblages represent conflations of material from different periods, is the reason why I have preferred to use 'mode 2' for these kinds of artefacts in my analyses. Derevianko (2008) has also added to these finds, reporting handaxes from surface localities in the Mugodjari mountains (Kazakhstan).

More recently, a joint Kazakh-Russian expedition in south Kazakhstan has been studying and publishing on the two localities at Kyzyltau (Kazakhstan), which were originally identified in 1997 (Alipova, 2012, Taimagambetov & Alipova, 2013, Taimagambetov, et al., 2013). Although the artefacts identified number more than 15,000, no handaxes have been recovered, where in a surface context they should be expected to be even more easily found and identified than other technologies. These localities are close to Alpysbaev's Karatau surface sites (Baigunakov & Sabdenova, 2014, p. 308), but are also currently undatable. These sites are therefore of limited value for building the regional chronology, even as they provide a tantalising glimpse of what might be Pleistocene hominin occupation.

The recent re-dating of Kul'bulak is also interesting. The site has a long sequence, with some of the lowest layers (16 and 23) providing possible early Pleistocene occupation (Kolobova, et al., 2012, p. 15). The designation of these lower layers to the early Pleistocene is open to

challenge without secure dates (Vishnyatsky, 1999, p. 96), and recent Optically Stimulated Luminescence (OSL) dates bracketing layers 2-10 are 39 ± 4 kya and 82 ± 9 kya respectively (Vandenberghe, et al., 2014). Dating of the lower layers still remains uncertain, so the possibility that they may extend back into the Middle Pleistocene or any earlier is yet to be resolved.

2.3 Major Themes in the Lower Palaeolithic of Central Asia

In the Lower Palaeolithic of Central Asia, a rough division can be made between two of the major categories of evidence. The first is the dated sites, of which Ranov's 'Tajik loess Palaeolithic' sites form a core in the south-east of the study region (see Figure 3). The second category covers the surface sites, which are numerous and varied. There are some sites in the study region that do not fit well into either of these two categories. Some of the artefacts from the Batpak valley (Kazakhstan), for instance, are stratified, but are to all intents and purposes not dated. Similarly, some sites such as Koshkurgan I are considered dated (and included here as such), but the security of the date has been questioned. These sites form a valuable core of information for the region, and will be considered on a case by case basis.

2.3.1 Dated Sites

The Tajik 'Loess Palaeolithic' Sites

The Tajik loess sites include occupations in multiple localities at Karatau, Khonako, Kuldara, Lakhuti, and Obi-Mazar (A.K.A. Lakhuti III, and also including the Obi Mazar Opolsen locality). These currently represent the best preserved and best dated Lower Palaeolithic sites in Central Asia. As previously mentioned, the dates are derived from the correlation of the loess stratigraphy of Tajikistan with the related loess deposits in China. The distinction between arid loess and humid palaeosol (A.K.A. pedocomplexes, or 'PC') phases is pronounced in the loess stratigraphy, and has made this correlation possible, and has also

allowed some insight into the environment that might be contemporary with these occupations. It should be noted that the Tajik loess sites are from foothill and piedmont areas of the study region. During interglacials, these areas would have been lush and forested, and during glacials loess would have accumulated rapidly in these areas. The environmental evidence for conditions during the formation of individual palaeosols and loess horizons is considered in more depth in the section '6.1.4 Climate Reconstruction from Central Asian Loess', but small summaries are presented here in relation to the sites. The earlier TL dates for these sites have been widely rejected, and are not included here.

The oldest of the Tajik loess sites is Kuldara, which has been dated to *c.* 955-880 kya within the 11th and 12th palaeosols, and is represented by a minimum of 40 *in situ* lithic artefacts (Dennell, 2009, p. 326, Ranov, 1995, p. 735, Ranov & Dodonov, 2003, Ranov, et al., 1995, p. 339). The raw materials are very variable, but are predominantly quartzite pebbles (Glantz, 2010, p. 104). Technologically, the assemblage has been interpreted as a very simple core reduction on cortical or plain platforms, both by freehand knapping and simple bipolar percussion (Davis & Ranov, 1999, p. 188). The latter technique is evidenced by the presence of distinctive wedges and *zitron* or *quartier d'orange* flakes (see Figure 7 and Figure 8). Retouch is rare, and when present is inconsistent and *ad hoc* without standardisation of tool types, suggesting a strategy centred on the reduction of pebbles for usable flakes. This technology is typical of what Ranov has called the 'Karatau Pebble Culture' (Davis & Ranov, 1999, p. 187), although Kuldara does lack choppers, which are a feature of other Karatau Pebble Culture sites. Conditions at this time seem to be fairly humid with a varied forested environment in the foothills and piedmont. Continuity in the floral community across glacial periods of the Lower Pleistocene is a sign of how mild glacial periods seem to be during this time, in contrast to the increasing difference between glacial and interglacial periods during the Middle Pleistocene.

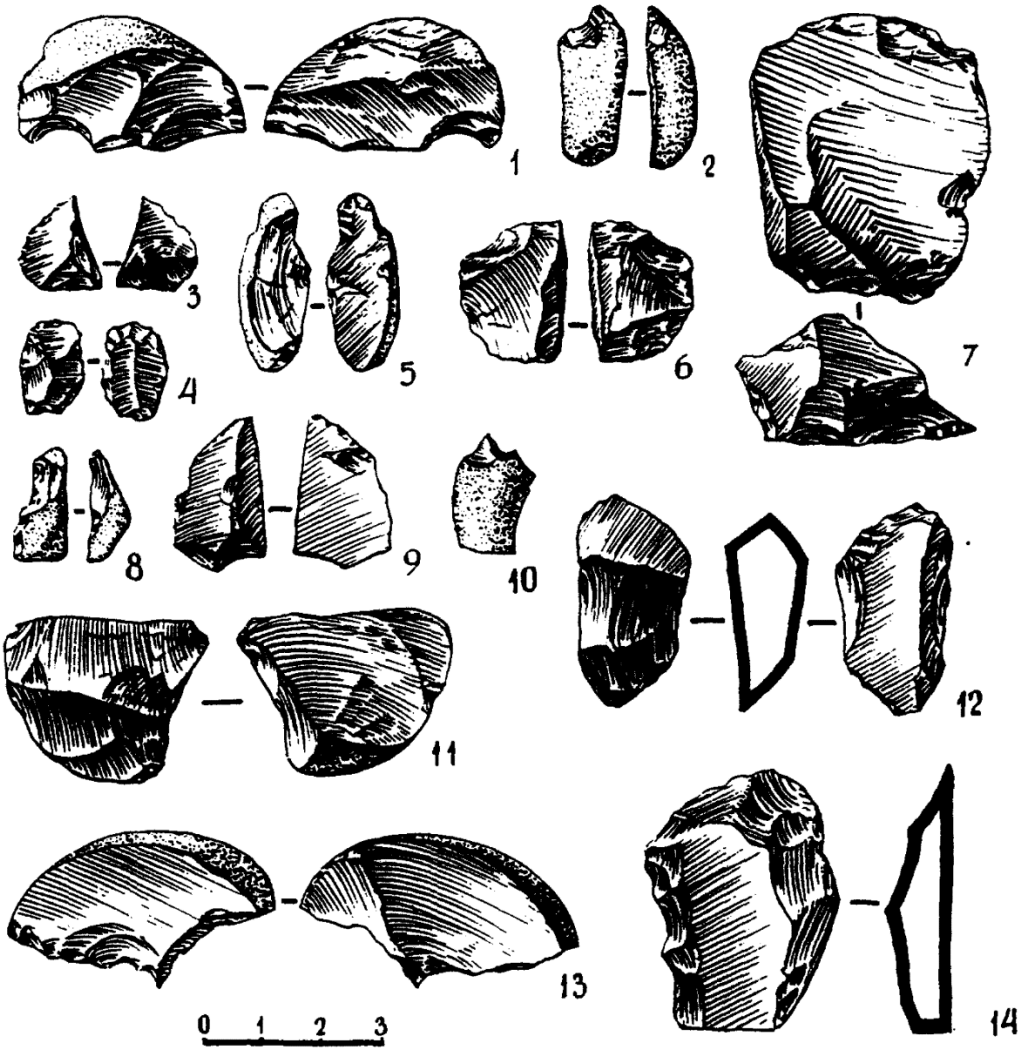

Figure 8 - Artefacts from Kuldara (Tajikistan) Artefact numbers 1 and 13 represent the distinctive quartier d'orange flakes that are diagnostic of bipolar percussion on pebbles. Figure from Ranov (1995, p. Fig 3).

Information is sparse on the Khonako localities, making it difficult to assess them critically. Nonetheless, they bridge crucial gaps in the chronology of the loess Palaeolithic, and their position within the well-dated Tajik pedocomplexes allows us some confidence in their dating at least. Ranov (1995, pp. 733, 339) has attributed stone tools to the 3rd PC, and faunal remains to the 9th at the Khonako localities, and there are no other descriptions of finds available in the English-language literature. Ranov & Dodonov's (2003, p. 145) publication on Kuldara includes extensive diagrams and information on other Tajik sites (and the same figure with additions has been included in Dennell (2009, p. fig 8.33), and adapted for use here, see Figure 12), and notes Lower Palaeolithic artefacts in PCs 8 and 4 at Khonako

II (740-725 kya) and in the glacial period between PCs 5 and 6a at Khonako I (570-530kya). Khonako II potentially provides a date between the oldest site Kuldara and the younger Tajik sites, while Khonako I appears to indicate glacial period occupation in the Middle Pleistocene. However, without further information on their context, dating, and technology, these sites must be treated with caution. Artefacts in PC8 would coincide with the beginnings of the increase in aridity throughout the Middle Pleistocene, and an environment that sees the expansion of steppic and steppe-forest conditions. The loess horizon between PCs 5 and 6a is thinner than the loess horizons that precede and succeed it, and therefore conditions are likely to be milder during this glacial period. Artefacts in the 4th PC would coincide with humid conditions, and a mixed forest and meadow environment. As can be seen from Figure 12, Khonako III provides artefacts in every PC from the 4th onwards into the Late Pleistocene, with conditions becoming increasingly arid.

Karatau I is dated to *c.* 620-570kya in PC6, and is the type-site for the Karatau Pebble Culture. The nearby site of Lakhuti I dates to *c.* 530-475kya in PC5, and is also included in Ranov's Karatau Pebble Culture. Both contain artefact numbers in the hundreds (absolute figures differ between sources), and both include wedges, *quartier d'orange*, simple flakes with cortical or plain platforms, *ad hoc* retouched flakes, and pebble choppers (Davis & Ranov, 1999, pp. 187-8). All of these features are typical of (and define) the Karatau Pebble Culture sites, where core-working of pebbles produces simple flakes and choppers (see Figure 7, Figure 8, and Figure 9). The Lakhuti localities are also reported to have artefacts in the 6th PC. Obi-Mazar is a nearby exposure where over 200 artefacts were found in the 4th and 5th PCs during cleaning (Ranov, 1995, p. 741), and apparently also from the 6th and 3rd PCs. The correlated loess dates for PC3 is 335-300kya, and PC4 is 430-360kya. There may be some confusion over the exact identification of the PCs (Ranov, 1995, p. 743), but Ranov & Dodonov (2003, p. 145) report artefacts originating from the 6th, 5th, 4th, and 3rd palaeosols.

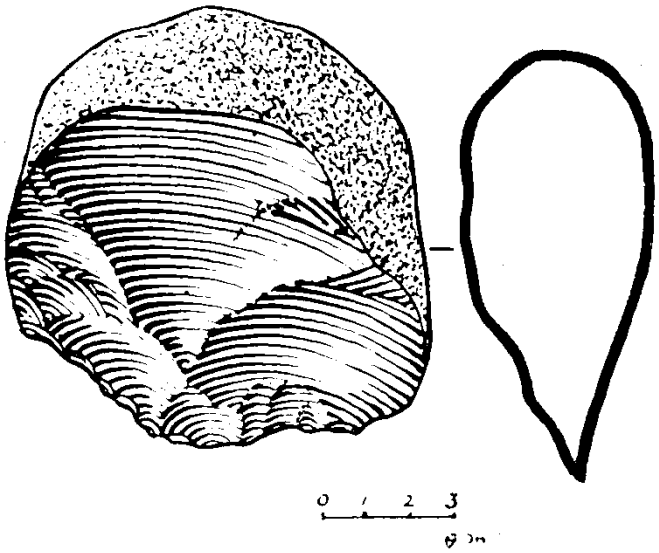

Figure 9 - An example of a pebble chopper from Karatau I. Figure from Gupta (1979, p. Fig 3.1)

Sel'ungur & Koshkurgan/Shoktas

Dated sites outside the region of the Tajik loess sites are Sel'ungur (Kyrgyzstan), Koshkurgan (Kazakhstan), and Shoktas (Kazakhstan).

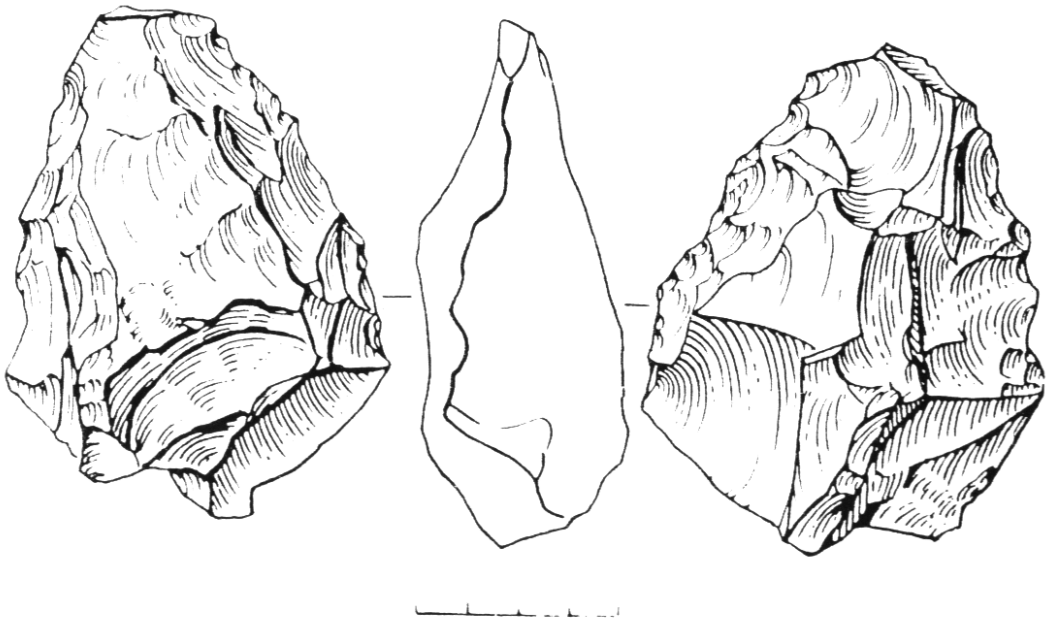

Figure 10 - The biface excavated from the cave site of Sel'ungur. Some authors reject its attribution as a handaxe or biface. From Islamov (1990, p. Fig 3) modified.

Sel'ungur represents the youngest dated site in Central Asia considered within the present study, but is relatively close to the Tajik loess sites that include the oldest Lower Palaeolithic site in the region. Prior to being absolutely dated, Ranov (1991, p. 215) had previously suggested an age of much greater antiquity for Sel'ungur, and an unpublished radiometric date of about 1.4mya is understood to be widely rejected (Krivoshapkin, et al., 2020, p. 99). Islamov (1990, p. 683) identifies one biface and two cleavers (*hachereaux*) at Sel'ungur, which are contested by other researchers on techno-typological grounds. Vishnyatsky (1999, p. 95) contends that the 'handaxe' is "morphologically vague", and rejects one of the cleavers. Davis & Ranov (1999, p. 189) similarly question the biface. Islamov's designation of a biface seems reasonable from the published illustrations (see Figure 10); however, only one of the proposed cleavers appears convincing. Ranov (2001) makes reference to a claim in a 1995 Russian-language report by Islamov & Krakhmal for thirteen cleavers from the site of Sel'ungur, but it has not been possible to assess this. Recent re-excavation and reanalysis of Sel'ungur has concluded that the technology is best described as Middle Palaeolithic (Krivoshapkin, et al., 2020, p. 99), meaning that the bifaces might be considered to be representative of an early Middle Palaeolithic technology in Central Asia. The new excavation also identified artefacts from all the stages of bifacial production, including eight bifacial thinning flakes, bifacial 'pre-forms', as well as finished bifaces. Interestingly, Krivoshapkin et al. (2020, p. 99) do not find technological parallels with either the western handaxes from surface contexts, nor with stratified Late Pleistocene assemblages such as those at Kulbulak. Whatever the exact techno-typological designation might be, the site can be said to contain the oldest stratified bifacial core tools or Large Cutting Tools (LCTs), in Central Asia, dated to the boundary of the Middle-Late Pleistocene. In is unclear from the present literature what raw materials the Sel'ungur LCTs are made from.

Koshkurgan and Shoktas are often discussed together as the 'travertine sites', because both are in similar preservation conditions and relatively close to each other within the landscape.

They both represent three localities each where stone tools have been found in association with fauna and spring-fed travertines. Along with very approximate faunal dating, Electron Spin Resonance (ESR) dating directly on the travertines has been used to date the sites, but the exact results of this dating are slightly confused in the literature. Otte et al. (2000, p. 106) report an age of *c.* 500kya from ESR dates at Koshkurgan I, supported by association with a Lower-Middle Pleistocene fauna, and correlates this sequence with the Shoktas localities. Zh. Taimagambetov participated in the excavations at the sites, and reports a date range of 500-300 kya for Koshkurgan I and Shoktas I (Taimagambetov, et al., 2013, p. 689), while Glantz (2010, pp. 104-5) notes a date range of 500-170 kya for all of the Koshkurgan localities (I, II, and III). The earliest occupations at these travertine sites is therefore likely to be broadly contemporary with the occupations at the Lakhuti, Obi Mazar, and Khonako localities, and the later occupations of the travertine sites seem to overlap with later occupations at the Obi Mazar and Khonako localities. Koshkurgan is sometimes designated as a Lower Palaeolithic 'microlithic' assemblage (Glantz, 2010, p. 104), but this does not necessarily signal a departure from technological behaviour at the Karatau Pebble Culture sites. Burdukiewicz (2009) has noted the existence of Lower Palaeolithic 'microlithic' assemblages in the northern latitudes of Eurasia (including sites such as Vértesszölös in Hungary, and Bilzingsleben in Germany). These assemblages "…are characterized by core/flake technology and by the very small size of the artifacts…" but are "quite unlike" typical definitions of Mode 1 and Mode 2 technologies (Burdukiewicz, 2009, p. 196). In agreement with Ranov & Dodonov (2003), he classes Kuldara as a microlithic assemblage in this definition, which could also apply to other assemblages in the Karatau Pebble Culture. The microlithic assemblage of Koshkurgan is not necessarily a divergence from the nearby Karatau Pebble Culture, but possibly could be viewed as a more 'derived' version of the local tendency towards 'small tool' working of pebbles. Size of unworked clasts is rarely reported for these sites in English, and without this it is difficult to assess whether this microlithic

aspect is conditioned by small clast size in the raw materials. At least for Kuldara, Vishnyatsky (1999, p. 89) has suggested that this may be the case, in which case the microlithic assemblages should be seen as broadly similar in terms of technology to the other Karatau Pebble Culture sites. Study of the Shoktas artefact illustrations published by Otte et al. (2000) allow identification of many of the features common to the Karatau Pebble Culture, including simple cores, flakes with plain platforms and cortical areas, and choppers. A biface was also found at Shoktas, but in a surface context, and is therefore not necessarily associated with the stratified assemblages (Otte, et al., 2000, p. 109, see Figure 11).

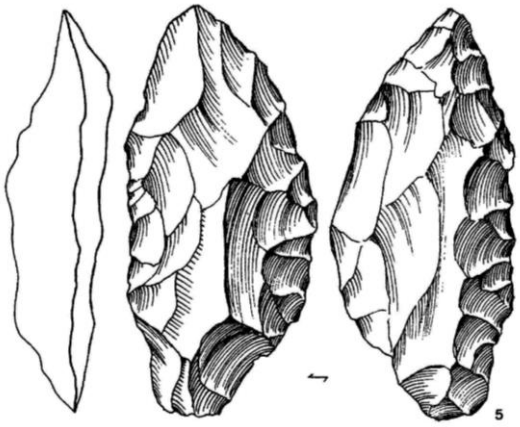

Figure 11 - The biface from a surface context at Shoktas. Figure from Otte et al. (2000, p. Fig 6.7), modified.

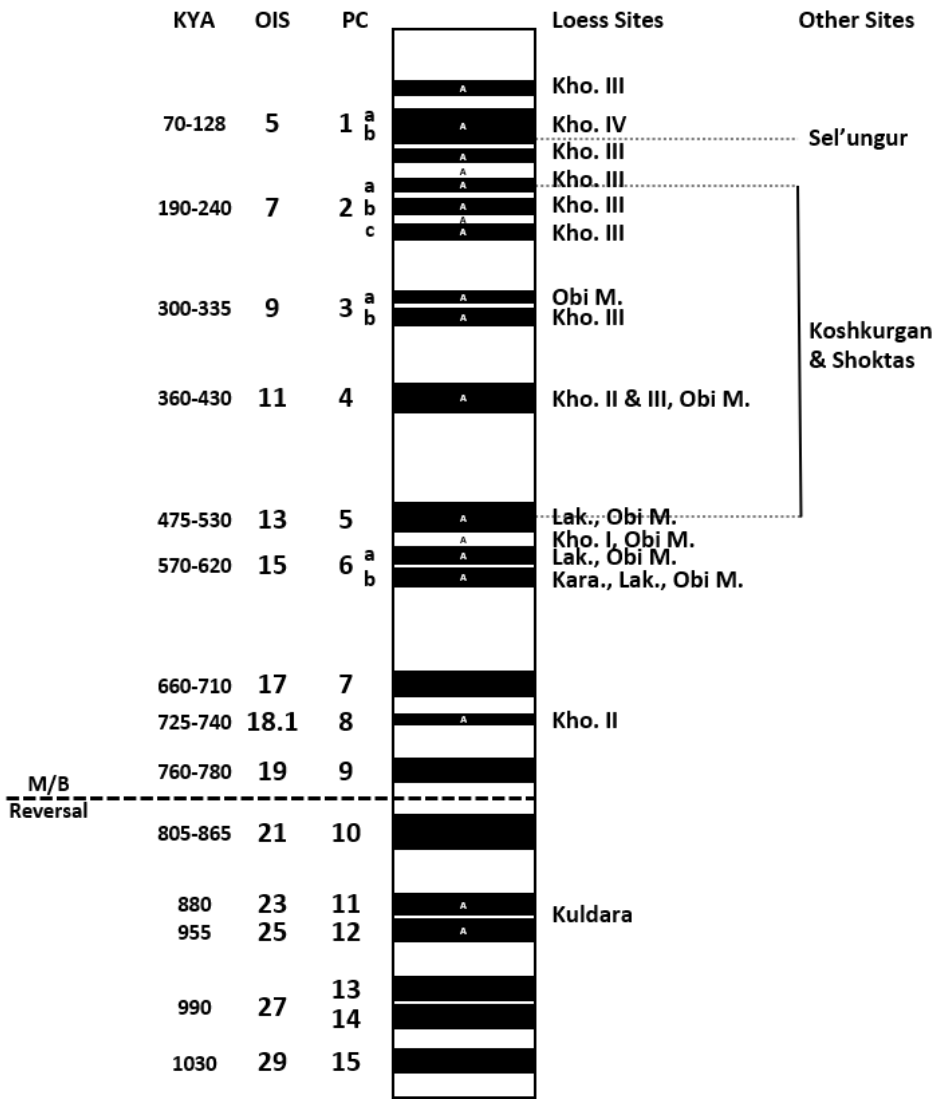

Figure 12 – A composite stratigraphy representing the Tajik pedocomplex sequence, where palaeosols representing humid interglacials (black) alternate with loess horizons representing arid interglacials (white). Units that contain archaeology are marked with an 'A'. The ages of the Koshkurgan/Shoktas localities, and the cave site of Sel'ungur are added to show their date in relation to the Tajik sites. Some site names abbreviated for clarity: Kho. = Khonako, Obi M. = Obi Mazar incl. Obi Mazar Opolosen, Lak. = Lakhuti, and Kara. = Karatau. Redrawn from Dennell 2009 figure 8.33, with additional information added.

2.3.2 Surface Sites

Surface sites comprise the majority of the potential Lower Palaeolithic record of Central Asia, and several sites with artefacts in a surface or derived context have already been mentioned. It will be noted from the map in Figure 2 that, aside from Sel'ungur, all Mode 2 assemblages in the study region are from a surface context. Partly this is related to the wider geomorphological processes at work in Central Asia. The areas in the north and west of the

study region are areas of net sediment erosion by aeolian processes. This is especially true in the former, larger extent of the Caspian Basin, to the north of the modern Caspian extent, where fine sediments laid down in previous transgressions of the Caspian are in active erosion. The areas where handaxe surface sites are found in large numbers, on the Ustyurt Plateau and in the Kazakh highlands, are similarly areas of net erosion where such artefacts are easily spotted during survey (see Figure 13). This leads to an increased chance of surface site detection, and especially an increased chance of identifying large artefacts such as LCTs. This situation is the opposite of that in the south and southeast of the study region, where a net deposition of sediment throughout the Quaternary causes lengthy loess sequences to build up over hundreds of thousands of years.

Also worth noting are the surface sites in the north-east of the study region, around the Zaisan Basin (see Figure 4). These sites were identified fairly recently by Chlachula (2010), and are identified by that author as being Pleistocene in age. The technological features of the assemblages do not contradict this suggestion, but lacking a firm geological context and independent dating means that the dating of these sites remains tentative. The sites of the Zaisan Basin are particularly interesting due to their geographical position in eastern Kazakhstan/Kazakh Altai, close to the border with both Russia and China. The proposed identification of these sites is therefore very interesting from a Pleistocene dispersal perspective, in that they may suggest hominin occupation of this region, and therefore access to this region, at this time. While early Pleistocene occupation is well-evidenced from China, it is not proven at such a northerly latitude, and proposed early Pleistocene sites from Siberia and Mongolia remain very tentative (see 'Chapter 3. The Lower Palaeolithic of Neighbouring Regions').

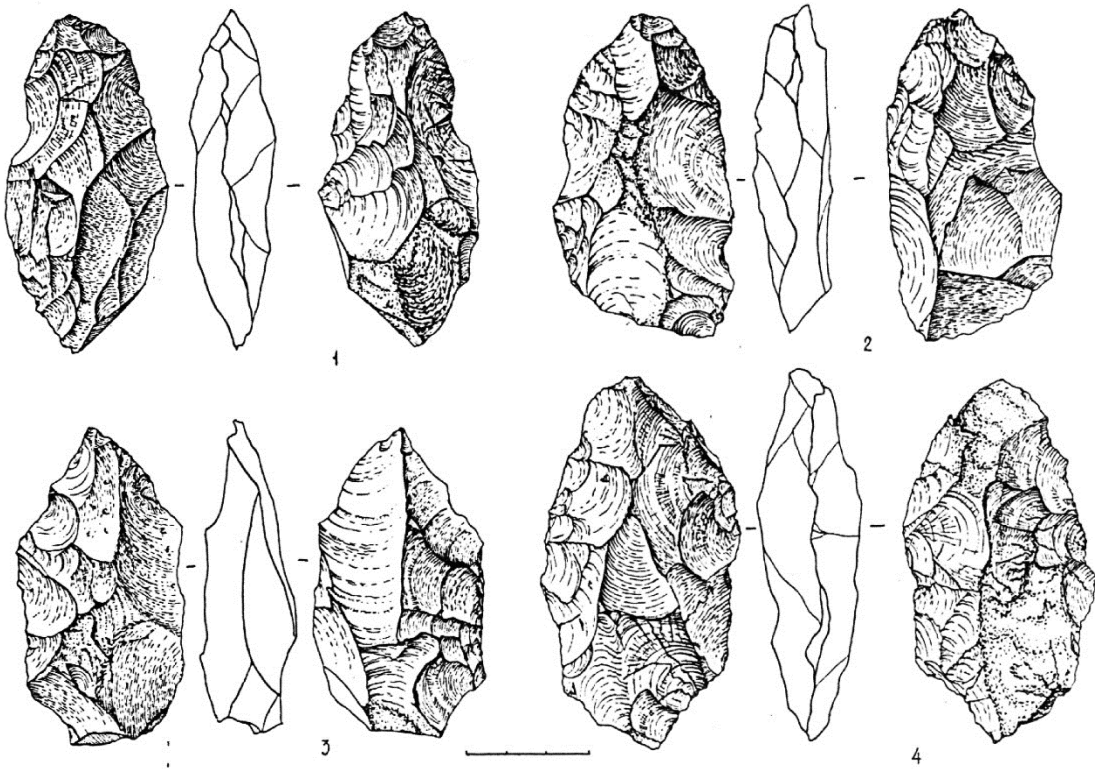

Figure 13 - Bifaces from Yangdja, Turkmenistan. This site on the Krasnovodsk Peninsula is a good example of the kinds of surface assemblages of bifaces found in the Ustyurt Plateau region between the Caspian and Aral seas. Figure from Vishnyatsky (1989, p. Fig 2)

2.4 Discussion and Summary

The Central Asian Lower-Middle Pleistocene record does contain several dated sites of Lower Palaeolithic technology. However, the highly concentrated distribution of these sites, and the questionable reliability of some of the dates attributed to them, complicate the possible conclusions that can be drawn about Lower-Middle Pleistocene hominin occupation in this region. Attempts to draw on the archaeology to elucidate issues, especially of timing, of hominin dispersal are similarly complicated. Prior to the discoveries at Dmanisi (Georgia), the closest technological comparisons for the stratified assemblages of Central Asia were the Soanian of Pakistan (Gupta, 1979, p. 123) and the Chinese loess sites (Ranov, 1984, p. 18, Ranov, et al., 1992, p. 49). With a limited record for occupation in Palaeolithic Asia, the Soanian was seen as a possible origin point for the younger 'pebble cultures' of Tajikistan. While early Pleistocene movement is still a possibility between Pakistan and Tajikistan via

Afghanistan, the demonstration of a simple Mode 1 core and flake technology of great antiquity at Dmanisi certainly reduces the need for an 'origin point' for the Central Asian sites. The archaic date proposed for Korolevo (Ukraine) foreshadowed this shift in approach, and the similarities between the Central Asian sites and those of the Chinese loess sites have received more attention from Central Asian and Russian researchers as a result. Based on the proposed antiquity of Korolevo and Kuldara, Gladilin (the excavator of Korolevo) and Ranov proposed a model that emphasised movement from the Near East, in north-westerly and north-easterly directions into Eurasia (Davis, 1988, p. 300). Ranov (1995) shows a map of loess distribution and Lower Palaeolithic sites that underlines this point (see Figure 14), emphasising the role of the westerly regions as origins for dispersal rather than South Asian areas such as Pakistan, while also hinting at possible dispersal eastwards into China.

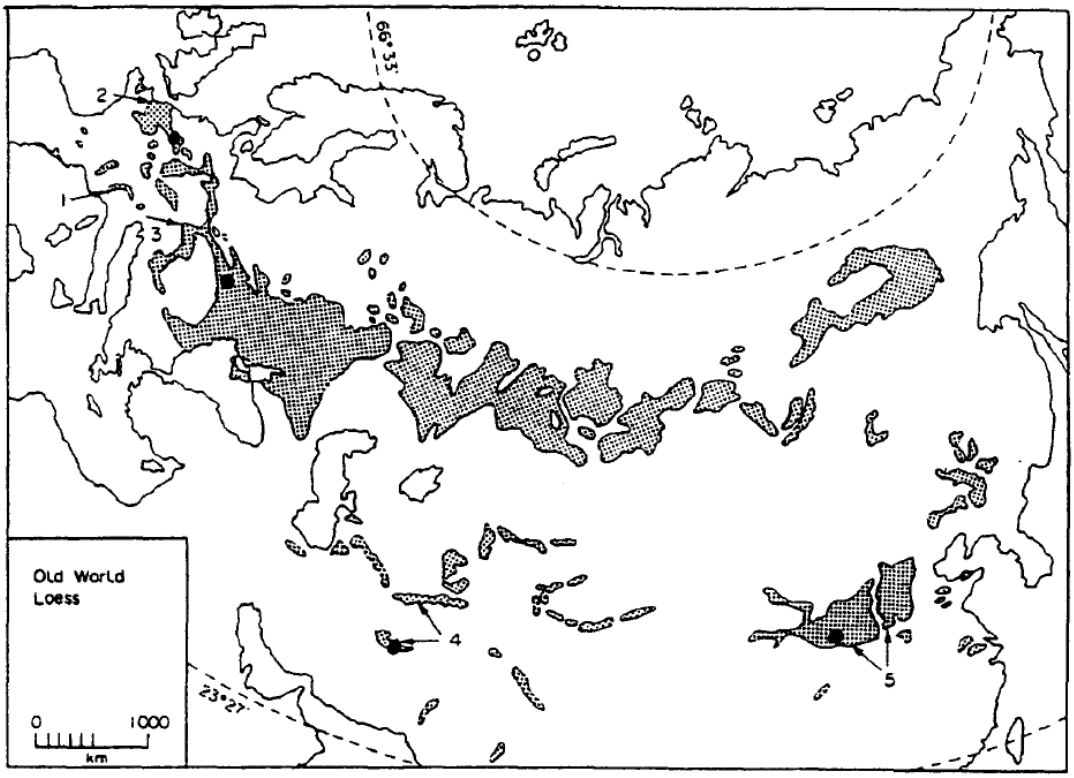

Figure 14 -Ranov's (1995: Fig.1) map of loess distribution (shaded grey) and Lower Palaeolithic sites (black dots). From east to west is: Lantian, the Tajik loess sites, Korolevo, and the Rhineland (Kärlish)

The reality is that these Mode 1 technologies are so simple that many of their 'diagnostic' features most likely stem simply from the emergent commonalities of limited intensity

pebble reduction itself. This excludes the possibility of techno-typological arguments for dispersal, but it does not exclude the possibility that such a dispersal happened. A string of surface sites appear to trace out Ranov's proposed route eastwards, but dating them is currently impossible. It seems likely that the apparent pattern of this eastward route could emerge simply from a bias of archaeological study, and these may represent just one route or occupational zone of many.

Many of the surface sites in Central Asia also contain LCTs, while the stratified sites on the whole do not. The opposition between the Karatau Pebble Culture and the virtually non-existent Mode 2, which is almost certainly derived from the 'Movius Line' model (Davis, 1988, p. 298, see also the section entitled 'The Movius Line' in '3.4.4 Large Cutting Tools in China'), is yet to be satisfactorily resolved. There have been suggestions that the juxtapositions of technologies might represent an upland/lowland distinction, or reflect raw material constraints. The arrival of diagnostically Mousterian technologies in Central Asia is also notably late. Whether this is connected in any way to the possibly late advent of Mode 2 technology in the region, or whether this is an artefact of the small number of sites investigated, is still an open question.

One of the major weaknesses of this record centres on the lack of reliably dated sites over such a vast region. Although this is something that should be kept in mind when considering the results of the analyses presented in later chapters. The analytical methods of this project have been specifically designed to avoid over-reliance on individual sites and their dating. The project addresses the sparse nature of the Central Asian record by producing complementary, but independent, data to contextualise and test some of the claims made regarding these sites. This will provide a valuable framework for the region, while also generating contextual information for the sites and their wider landscape, allowing new insights into the nature and timing of dispersal and occupation at this time.

2.5 Archaeology in the Soviet Union

A large number of the archaeological sites used in this analysis were discovered, investigated, and published during years when the study region was a part of the Union of Soviet Socialist Republics (USSR). It is clear from several sources that the relationship between 'Western' researchers and researchers working within the Soviet Union was at times tense and suspicious (Frumkin, 1970, p. 2, Kohl, 1984, p. 238). Although political relations with the Soviet Union were notoriously difficult, clearly the barriers could be surmounted by dedicated researchers, and numerous valuable collaborations are evident in the literature. Frumkin (1970, p. 2) has suggested that Western scholars questioned the quality of work conducted in the Soviet Union primarily because they could not read Russian, and were therefore unaware of their Soviet colleagues' achievements. Understanding the situation and conditions under which work was done is important for assessing the quality of that work, and in light of these suspicions, such an assessment appears necessary.

Kohl (1984, p. 238) provides a broad discussion of the structure and methods of Soviet archaeological work in Central Asia, based on his experiences during two three-month fieldtrips and attendance at an All-Union archaeology congress in Leningrad. As positives of Soviet work, he lists the large-scale excavations conducted by Soviet scholars, and the use of pioneering analytical techniques, such as use-wear analysis (Semenov, 1964). The negatives he lists, however, have especial relevance for the current project. Firstly, he notes that three major aspects of western archaeology appear to have been absent or underdeveloped in Soviet archaeological studies; provenance and raw-material characterisation, environmental recovery techniques, and appreciation for spatial units larger than individual sites (i.e. regional studies). Raw material sources and the distributions of specific geologies are a focus of the current project, and so, where possible, these will be constructed and studied without reliance on Soviet archaeological sources. The second criticism does not fundamentally

affect the current project, but will be kept in mind when interpreting ecological reconstructions and published fossil sites.

Kohl's third criticism is the most relevant, and centres on several related spatial and mapping issues, which can be summarised as 1) a strongly site-centred approach that neglects regional studies, 2) generally poor-quality maps lacking crucial information, and 3) political sensitivity and censorship responsible in some degree for the lack of reliable spatial information. It should be noted that all of these criticisms can be levelled at the present 'Western' discipline to a certain degree, so they are far from unique to archaeological work done under the USSR. The site-centred approach is still the focus of much Palaeolithic research, and is a criticism that the current project addresses and attempts to mitigate (see '7.1.1.1 Data Collection and Formatting'). It is certainly true that many of the maps available in the literature of Palaeolithic Central Asia are not precise, or lack some crucial piece of information for use in spatial analysis. Judicious use of only the most reliable maps, as well as cross-referencing with spatial data independent of these maps is used to ensure accuracy in this study. Political interests also still play a part in the data available in these areas. While the United States Geological Survey (USGS) provides only very basic geological data for Central Asia, the information on the geology of Afghanistan provided by the USGS is extensive (including, particularly, petroleum resource potential). It is beyond the scope of this project to concretely affirm or reject the criticisms raised by Kohl, but they will be used to maintain an awareness of possible issues in interpreting archaeological work published under the USSR.

Under the Soviet Union, scientific research was a highly centralised activity, falling under the responsibility of the Academy of Sciences of the USSR. National academies of science in the individual SSRs answered to the Academy of Sciences of the USSR, and included several specialised divisions within their structure. Archaeology was considered an historical

discipline, and was included in the history division of the Academy of Sciences and the national academies of the SSRs. Kohl (1984) estimates that more than 90% of the archaeological work done in the USSR around the time of his publication was supported and funded by the Academy of Sciences and the national academies.

The Academy of Sciences of the USSR underwent two major reorganisations in 1961 and 1963 (Swanson, 1965). The former created the State Committee for the Coordination of Scientific Research, with the apparent aim of improvings coordination and direction of research in the USSR. The latter reorganisation in 1963 reassigned several of these new responsibilities back to the Academy of Sciences. While the Academy of Sciences itself was directly responsible to the USSR Council of Ministers, the Committee for the Coordination of Scientific Research (and its SSR sub-divisions) were deeply embedded within the hierarchy of the Supreme Council of the National Economy. This structuring may have proven too cumbersome, and prompted the 1963 reorganisation. Maintaining an appropriate balance in such a centralised and structured system was clearly an on-going challenge, with advantages as well as disadvantages.

Frumkin (1970, p. 3) suggests that archaeologists in the USSR were well paid and had more financial and technical resources than their western colleagues. Kohl (1984, p. 245) argues that the financial disparity was less pronounced, and instead emphasises only the structural advantages of the system. Fieldwork and prompt publication were encouraged and rewarded in a system that ensured continuity of support and rapid internal dissemination of reports. But what archaeology in the SSRs gained in infrastructure, resources, and stability from the establishment of national academies of science needs to be set against the administrative rivalry and academic dogmatism that may also have been a result of this security and investment (Kohl, 1984, pp. 246-8).

Overall, it would appear that the archaeological work done under the USSR was of a very high standard, especially as far as reports of excavation and analysis and description of artefacts are concerned. Caveats specifically relevant to the current project focus on the use of geological or spatial information, and this issue will be discussed in more depth in the methodology (See 'Reliability of Soviet Mapping' in section '7.1.1.1 Data Collection and Formatting'). Although researchers using these data should be aware that some analytical techniques were absent or under-developed, these need only be highlighted alongside similar critical concerns for using any kind of published research. Especially, concerns regarding the role of ideology in archaeological interpretation are less salient for Lower Palaeolithic research, and probably unwarranted. The only area in which this may have an impact is a tendency to interpret long sequences as unbroken, autochthonous development (Davis, 1987, p. 130, Davis, 1988, p. 297).

Chapter 3. The Lower Palaeolithic of Neighbouring Regions

This chapter will consider the Lower Palaeolithic record of the areas that border the current study region of Central Asia. In order to keep the focus concise and relevant, only areas with an extant modern border with one of the present day countries that define the study region have been considered, with the exception of Georgia, which provides an exceptional insight into early Pleistocene Asian hominins. The neighbouring regions of Iran, Pakistan, and China have been subject to particularly close examination, primarily because they surround the 'Northern Route' through Central Asia, providing relatively older dates than those found in Central Asia itself. The Chinese record in particular is uniquely rich in evidence, but as can be seen from the map in Figure 15, the Chinese sites are far from the border with Central Asia. This is no doubt in part due to the large expanse of mountains and desert that comprise much of the western half of the Chinese landmass. Descriptions of the individual Chinese provinces as 'northern', 'southwestern', etc., as used in the current chapter, tend to mean relative to the more populous eastern half of the country, rather than the landmass of the country as a whole. Afghanistan cannot provide detailed analysis, as the record is so sparse as to be non-existent, containing only one possible Lower Palaeolithic site at Dasht-i-Nawur (Davis & Dupree, 1977, Dupree, 2006, p. 76, Dupree & Davis, 1976). Many of the issues that affect the Central Asian Lower-Middle Pleistocene record also affect the regions that neighbour it, and a broad understanding of these dispersal issues is especially only possible with reference to these records, which will be considered in aggregate at the end of the chapter. The implications for the Central Asian record of the Lower and Middle Pleistocene records of these neighbouring regions will also be considered, and an especial focus will be the faunal and floral remains from Dmanisi (Georgia) and the Nihewan Basin (China), and what resources might be available to hominins in those regions in the Lower Pleistocene. Throughout this chapter, *H. erectus* is used in the *sensu lato*, to include not only East Asian fossils, but also the broader definition encompassing other Asian and African specimens.

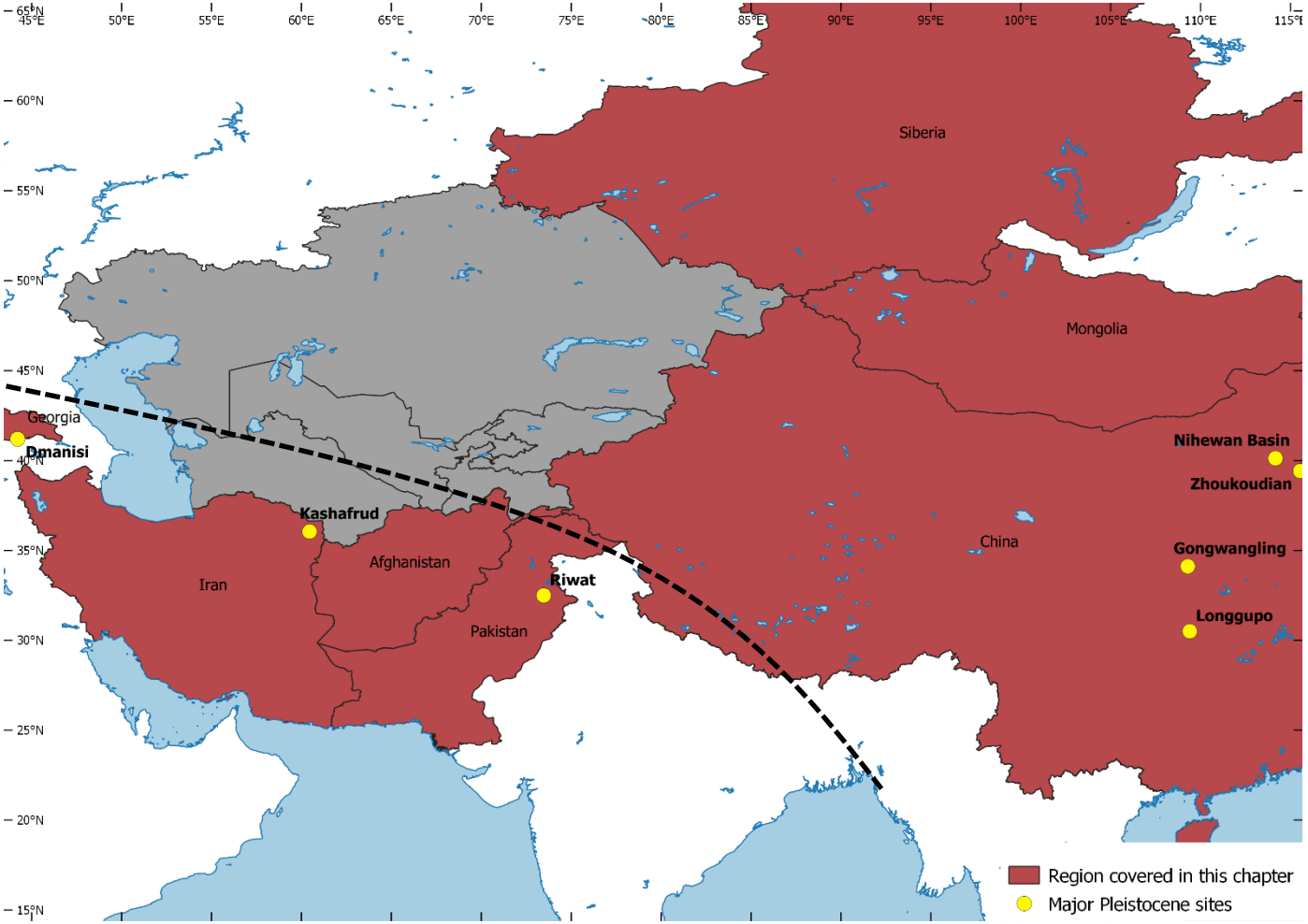

Figure 15 – Neighbouring regions covered in the present chapter. Major Pleistocene sites discussed in the text are included. The dotted line that cuts across the regions represents a rough approximation of the Movius Line, although exact rendering of this very poorly-defined boundary inevitably varies between authors.

3.1 Georgia

Georgia lies on the opposite coast from the current study region of Central Asia, but provides several crucial points for considering early Pleistocene dispersal into that region. Firstly, it provides a very early date for Asian colonisation that is today widely accepted. The geographical position of this site in combination with the early date is a key constituent in the framework for the Pleistocene colonisation of Asia. It also raises the issue of whether dispersal into Central Asia was most likely to occur through a route south of the Caspian, via Iran, or a route north of the Caspian, which has been suggested by the only early Pleistocene GIS study so far to cover Central Asia (Holmes, 2007). The combined association of hominin fossils, lithic technology, and environmental evidence at Dmanisi provides some insight into hominin lifeways and adaptive behaviours at this time. This may help to elucidate what the realistic capabilities and requirements of hominin occupation are during the Lower Pleistocene, and what might be expected of a hominin ancestor hypothesised to be capable of occupying Central Asia during this timeframe.

3.1.1 Dmanisi

The site of Dmanisi was discovered during restoration work on a church in south Georgia. The site itself lies 85km south-west of Tbilisi (Gabunia, et al., 2001, p. 159), and approximately 360km west of the modern extent of the Caspian Sea. Dmanisi has several hominin fossil individuals represented, faunal remains, and a substantial assemblage of lithics. The fossil and artefact bearing layers have been dated to around 1.78-1.85mya on the basis of palaeomagnetic, faunal, ESR, and argon-argon dating (Calvo-Rathert, et al., 2008, Ferring, et al., 2011, p. 10433, Gabunia & Vekua, 1995, p. 509, Gabunia, et al., 2001, p. 162, Mgeladze, et al., 2010, p. 422).

The hominin fossils from the site have been variously attributed to *H. erectus* or *H. ergaster (Gabunia & Vekua, 1995, p. 509,* Gabunia, et al., 2000a), and have even been proposed as the type fossil for a new species or local sub-species, either *H. georgicus* or *H. erectus georgicus* (Gabounia, et al., 2002). An area of particular controversy is the relatively primitive dentition of the fossils, which has been likened to Plio-Pleistocene African hominin specimens (Margvelashvili, 2008). Although the original excavators have tried to denote the local sub-species, *H. georgicus,* most researchers accept the identification of these fossil hominins as *H. erectus (sensu lato)*.

The fossils of *H. erectus* at Dmanisi are associated with a simple Mode 1 technology that includes choppers, simple cores, and flakes (de Lumley, et al., 2005). More than 8000 artefacts have been recovered from the site (Mgeladze, et al., 2010, p. 424). Most of these artefacts have been recovered stratigraphically higher up the sequence than the hominin remains have been found (Gabunia, et al., 2001, p. 164). However, the lithics higher and lower in the sequence are seen to be technologically comparable.

The majority of artefacts are flakes, some with discontinuous retouch, but overall retouch is very rare in the assemblage (Gabunia, et al., 2001, p. 164, Mgeladze, et al., 2011). The type and nature of the artefacts present are indicative of all stages of the manufacture process, suggesting that the full process of lithic tool production took place at the site, at least in some instances. However, an overall lack of cortex along with small average flake size has been taken to indicate that the majority of the flakes in the assemblage are representative of later stages of manufacture. Other

authors have noted that several of the cores suggest rather short reduction sequences, maybe around three to four strikes on average, and the exploitation of natural angles (Baena, et al., 2010, de Lumley, et al., 2005).

Several authors have noted a possible movement towards a discoidal or centripetal pattern of organised flaking in the latter half of the assemblage (Baena, et al., 2010, Mgeladze, et al., 2010, Mgeladze, et al., 2011). These kinds of intensive reduction are most commonly applied to the rarer, finer-grained raw materials, suggesting that the hominins at Dmanisi factored in raw material quality in their reduction strategies (Mgeladze, et al., 2010, p. 424). Some blocks of stone appear to have been used as anvils, and a few angular cores have been identified as exhibiting the technique of bipolar reduction on an anvil (de Lumley, et al., 2005, p. 78). There has also been a suggestion from experimental studies and lithic analysis that evidence for soft hammer percussion is visible in the lithic assemblage from lower down in the sequence (Baena, et al., 2010).

Core tools are relatively rare in the assemblage as a whole (de Lumley, et al., 2005). The majority of the core tools are unifacial and not heavily reduced, although some of them are bifacial (Gabunia, et al., 2001, p. 164, Mgeladze, et al., 2011, see Figure 16). None of the flakes in the assemblage would suggest biface or handaxe production, and no LCTs are represented. The industry has been compared to industries in the African Oldowan record (Mgeladze, et al., 2010, p. 424).

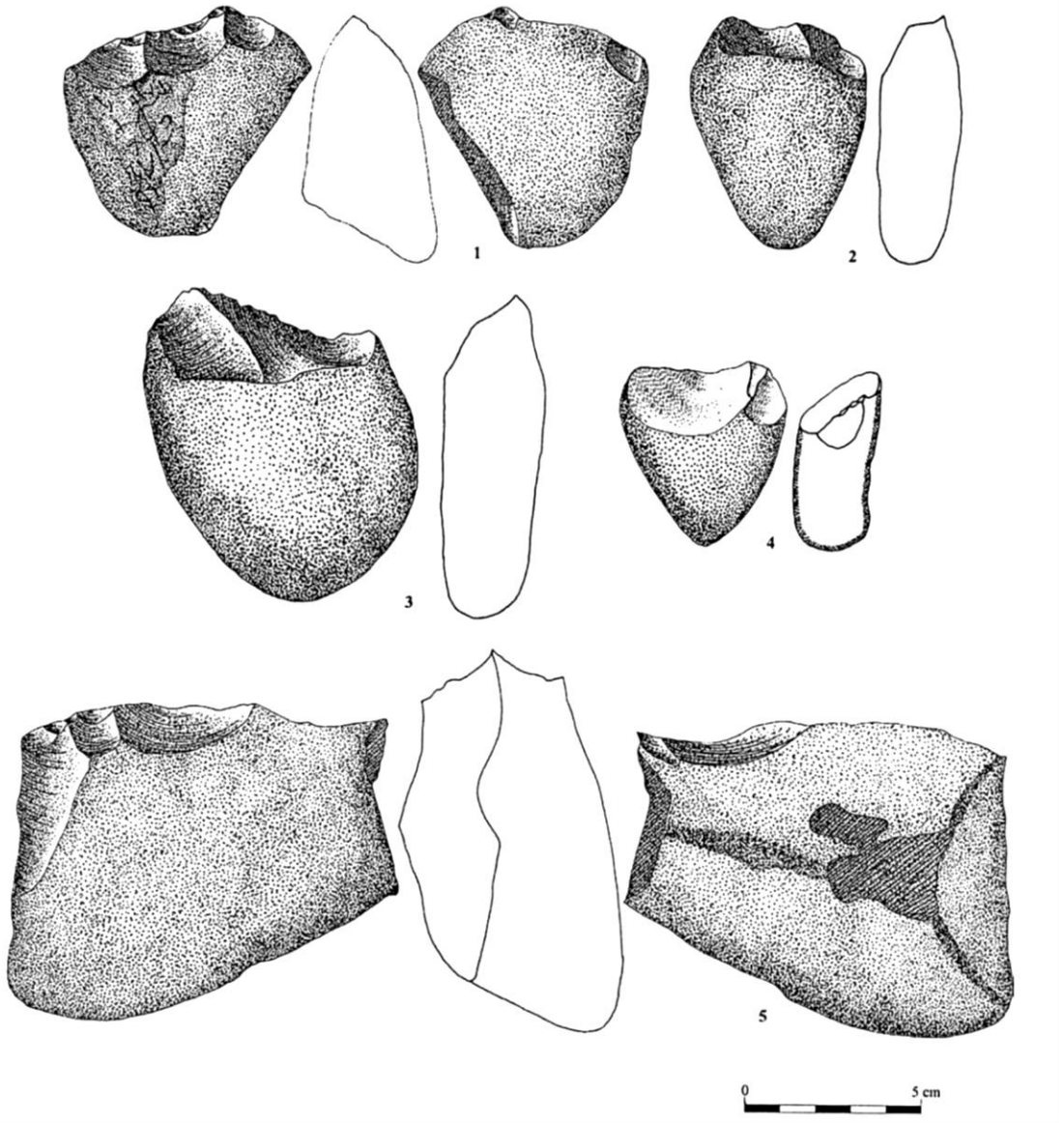

Figure 16 - Several choppers from layer 2 at Dmanisi. Figure from de Lumley et al. (2005, p. Plate 2)

There is a wide variety of raw materials utilised at the site, and the majority of them are in the form of rounded pebbles, but some are in the form of blocks (Mgeladze, et al., 2010, p. 424, Mgeladze, et al., 2011). All of the raw materials represented at the site are locally available (Gabunia, et al., 2001, p. 164), either in outcrops or secondary deposits (Ferring, et al., 2011, p. 10433). The range of distance for procurement of raw materials is estimated as being somewhere between hundreds to thousands of metres, possibly up to 15 km. Both unworked raw material and

finished tools may have been curated and brought to the site, indicating a fairly complex mix of acquisition and tool use behaviours. The emphasis of the raw material selection appears to have been on several varieties of basalt, although a variety of other flakeable materials are represented including andesite, granite, quartz, rhyolite, and rhyodacite (Baena, et al., 2010, Mgeladze, et al., 2010, p. 424, de Lumley, et al., 2005, Ferring, et al., 2011, p. 10433). Metamorphic rocks such as quartzite, as well as sedimentary rocks, are present but rare.

Although this technology might be considered to be 'simple', some of the knapping strategies do appear to suggest some important aspects of behavioural complexity. For example, there is evidence that more complex reduction strategies were applied to the higher quality raw materials in the assemblage, and that this strategy may change over time at the site (Baena, et al., 2010). The selection of better raw material seems to increase further up the sequence, and may be responsible for the more successful production of longer flakes in the later assemblage.

The Dmanisi site provides a rare glimpse into the environment of early *Homo* in Asia. Environmental studies have suggested that the climate was a little warmer and drier than the present day, with the area around Dmanisi characterised by a temperate, mixed woodland biome (Gabunia, et al., 2001, p. 163, Messager, et al., 2010b). Although pollen preservation is quite poor at the site (Messager, et al., 2010b, p. 25), phytolith and archaeobotanical studies of the Dmanisi sequence have suggested that grasses were a significant component of this mixed environment (Messager, et al., 2010a). The drying of the climate represented in the phytolith record is most pronounced in the middle of the sequence, which would have made it contemporary

with the hominin occupation at Dmanisi. This signal of aridity coinciding with the hominin occupation is further reinforced by analysis of the reptilian and amphibian fossils from the site (Blain, et al., 2014). Although similar in many ways to an African savannah environment, Dmanisi differs at this time in terms of having mostly temperate vegetation. Rather, the environment of Dmanisi has been compared to a modern-day Mediterranean one, with mostly arid steppe, semi-desert, and rocky areas, including open forest and shrubs and some permanent waterbodies. Lordkipanidze et al. (2007, p. 305) have suggested that the topographic complexity, variety of conditions of humidity including permanent water, and varied floral environment in the immediate vicinity of Dmanisi all contribute towards making the area attractive to hominins (an aspect that will be revisited in the discussion of early hominin environments in the section '4.2 The Role of Environments and Resources')

In terms of edible flora that hominins may have been able to exploit, grasses may have provided seeds, hackberry trees may have provided edible berries, and chestnuts, hazelnuts, pine nuts, beechnuts, hornbeam nutlets, and wingnuts may also have been available (Gabunia, et al., 2001, p. 163, Messager, et al., 2010b, p. 25). More difficult to exploit would have been the sweet sap of birch and sycamore trees, and tannin-rich acorns, both of which require some level of technology and processing in order to be a productive food source.

According to Gabunia et al. (2001), a lack of cutmarks on the faunal remains from Dmanisi means that hominins were unlikely to be the accumulators of the assemblage. However, subsequent taphonomic work has been used to suggest that hominins were acquiring meat, either through scavenging or hunting, and to suggest

that they had priority access to animal carcasses (Lordkipanidze, et al., 2007, p. 305). The small-bodied hominins at Dmanisi seem unlikely to have been accomplished hunters. It is perhaps possible to imagine that they could have caught small game such as pikas, rabbits, tortoises, lizards, amphibians, snakes, and a wide variety of rodents (including marmots), all of which were present (Blain, et al., 2014, p. 138, Gabunia, et al., 2000a, p. 1024). Larger-bodied vertebrates that hominins could have targeted if they were able include deer, horses, gazelle, bison, muskoxen, and giraffes. Mammoths and rhino were also present, but both seem unlikely targets for the Dmanisi hominins. Ostriches, also, may have been too dangerous to hunt directly, but an entrepreneurial hominin might have stolen their eggs (as well as the eggs of other birds and reptiles).

More likely, is the possibility that the Dmanisi hominins may have been prey to larger animals in the landscape, such as the sabre-toothed and scimitar-toothed cats (Arribas & Palmqvist, 1999, p. 579), jaguars (Hemmer, et al., 2010, Gabunia, et al., 2000a, p. 1024), and cheetahs (Hemmer, et al., 2011). Although these felids would have presented a very real danger to the hominins, they are likely to have left substantial amounts of meat on the carcasses of their kills, and perhaps even cached carcasses in trees, both of which may have provided scavenging opportunities. Bears and several varieties of canid were also in the landscape at this time, and likely to present a substantial threat to hominins if encountered.

The occupation at Dmanisi follows just after a major transgression event that results in a much larger extent of the Caspian and Black Seas, when the two were joined through a substantial waterway into the Azov Sea (Gabunia, et al., 2000b, p. 793, van

Baak, et al., 2013, p. 130). This flooding, known as the Apsheronian extent of the Caspian, or even just as the Apsheronian Sea, also had substantial ramifications for hominin dispersal in the present study region of Central Asia. The Caspian-Azov waterway would have been active and substantial, providing a barrier for dispersal northwards and periodically turning Georgia into a peninsular (see Figure 17). This would seem to eliminate the possibility of hominin dispersal into Central Asia north of the Caspian at some crucial times of the Pleistocene when considering Mode 1 and Mode 2 dispersals.

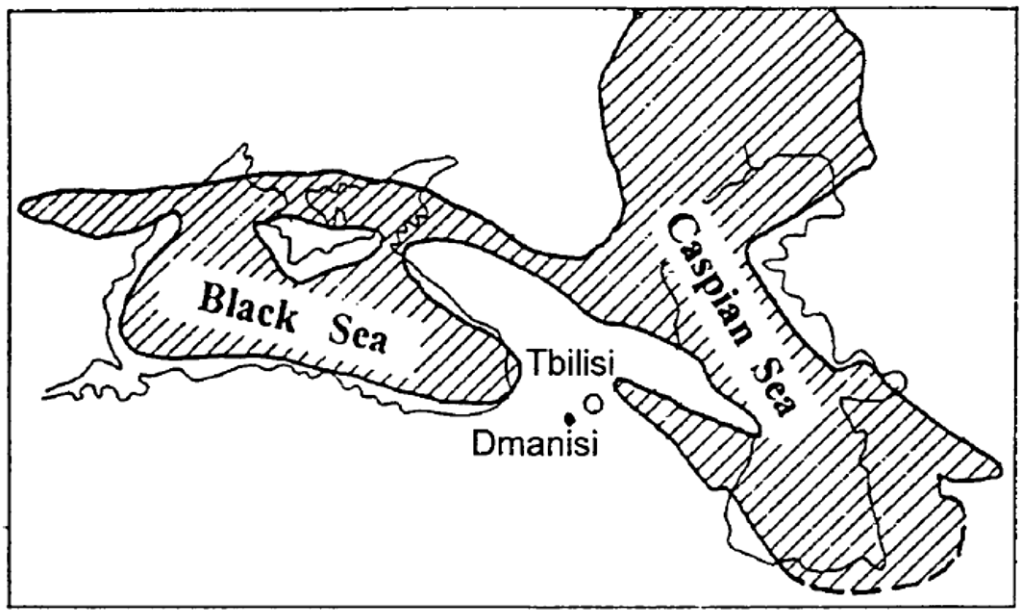

Figure 17 - Map showing the position of the archaeological site of Dmanisi in relation to a reconstructed extent of the Caspian and Black seas near the end of the Pliocene. Figure from Gabunia et al. (2000b, p. Fig 7)

3.1.2 Early Pleistocene Caucasus

Dmanisi has been focused on here in spite of the fact that it does not strictly 'neighbour' the study region, because of the extremely detailed evidence it provides for hominins in this area of Asia during the early Pleistocene. Elsewhere in the Caucasus, other early Pleistocene sites indicate the extent of occupation on this side of the Caspian at this time. Murkhai 2 is thought to be the oldest, with a core and flake assemblage dated with a slightly suspect

dating via palaeomagnetism and faunal stratigraphic techniques to around 2.4-1.95mya (Vasilyev & Amirkhanov, 2018, p. 106). The dating of the first Mode 2 industries in this region is a subject of controversy, but relatively well-worked bifaces have been found in a marine terrace at Darvagchai 1, with a reported age range of 800-600kya, and this is the more widely accepted date for the earliest Mode 2 occurrence (Vasilyev & Amirkhanov, 2018, p. 107). Interestingly, this coincides roughly with the Middle Pleistocene Transition (MPT), and the early Baku transgression of the Caspian, where the Caspian would also have been joined to the Black Sea through an active waterway, as in the Apsheronian.

3.1.3 Summary

Dmanisi is particularly interesting as it provides a very detailed insight into the physiology, behaviour, ecology, and therefore also the lifeways of hominins during the Lower Pleistocene in southwest Asia. Although not directly bordering the study region, Dmanisi is very close at the continental scale of global hominin dispersal discussions.

The site shows the presence of hominins, quite possibly a local subspecies of *H. erectus*, using a core and flake technology in the Lower Pleistocene. The repeated occupations of this slightly arid mixed woodland and grass environment suggest a sustained occupation by an established mobile population (Ferring, et al., 2011, p. 10433), although possibly a population still tethered to some extent to permanent waterbodies. This area provided an extremely varied environment with lots of floral and faunal resources. Hominins are likely to have exploited the fat-rich and protein-rich floral resources, to have caught small game where they could, and perhaps even scavenged the kills of larger predators. It would also have been a dangerous environment for hominins at risk of predation, especially out in open environments.

The Dmanisi technology is quite simple overall, with freehand direct percussion, bipolar anvil core reduction, and the *ad hoc* retouching of informal flake tools. Some of the core reduction strategies seem to develop through the sequence, and the change in raw material selection at the site is purported to show generational changes in hominin technological adaptation to the changing environment.

Dmanisi is useful in coming to terms with ideas of hominin dispersal and adaptation. Although Mode 1 core and flake technologies are traditionally seen as quite simplistic, the discussion around the Dmanisi assemblage highlights the adaptability of core and flake technologies in terms of features such as raw material management and core reduction strategies, all of which might be manipulated and developed by hominins to adapt to new environments. The emergence of Large Cutting Tools (LCTs) or Mode 2 technologies may represent a significant change in hominin adaptation that may have coincided with, and impacted upon, a complex constellation of hominin features, including, physiognomy, diet, and ranging behaviours (see '4.1 The Nature of Dispersal & Hominin Competency'), but the example of Dmanisi can be used to suggest that similarly dramatic niche development and adaptation is possible also within a core and flake technology (Gabunia, et al., 2001, p. 169).

3.2 Iran

Biglari & Shidrang (2006, p. 160) have observed that Iran determines access from southwest Asia into South Asia and Central Asia, and is therefore a key region for understanding hominin dispersal eastwards through the continent. To the northeast it borders Turkmenistan, and on its east it borders both Afghanistan and Pakistan, making it highly

relevant in considering hominin dispersal into Central Asia. However, despite systematic field survey of Palaeolithic remains since the late 1950s, the Iranian Pleistocene record remains sparse. Although a number of sites have been identified, none of these are securely dated, and nearly all are surface finds, varying in size. There are no hominin fossils, only a few contentious links between artefacts and faunal remains of Lower-Middle Pleistocene age, and no sites unequivocally dated to the Lower-Middle Pleistocene.

The sites that do exist tend to fall into one of three categories; core-chopper assemblages, assemblages with bifaces, and isolated biface finds. The most notable of these will be considered on a case by case basis. The comparison of assemblages from a number of sites in the south-east of Iran have been used to define the 'Ladizian' industry, which has been defined as a non-handaxe industry based on core-choppers and flake tools (Bar-Yosef, 1994, p. 252), but it appears essentially to be comparable with the other Mode 1 industries of Asia. Some typological confusion exists between what might be termed 'Acheulean' (Mode 2) bifaces, and what are invariably later bifacial products of a Mousterian industry associated with Levallois technological components. Such confusion is inevitable in a record where the secure dating of stratified assemblages is so rare, and this situation closely parallels that of Central Asia. It seems likely that the Ladizian contains some mixing of artefacts from different periods.

3.2.1 Shiwatoo

The site of Shiwatoo was discovered by a survey team in 2004 in the Mahabad area of north-western Iran (Biglari & Shidrang, 2006, p. 165, Jaubert, et al., 2006, p. 2). Almost a hundred lithics were collected from surface scatters at the site, and the assemblage consists mostly of cores, tested clasts, and 'core-choppers'. It also includes a cleaver made on a large side-struck flake, which is described as having been made on a dark volcanic material, possibly andesite. The lithics are reported as having been made primarily with hard hammer flaking,

and there is also evidence for the technique of bipolar reduction on an anvil using raw materials in cobble and pebble form. The assemblage is interesting in that it contains both large flake components and pebble tool components.

Raw material is plentiful at the site in the form of fluvially deposited cobbles and pebbles of andesite, basalt, and quartzite, as well as local outcrops of limestone and basalt (Biglari & Shidrang, 2006, p. 165). All of these different raw material types are represented as worked artefacts in the assemblage.

The lithics have been classified as representing an Acheulean industry (Jaubert, et al., 2006, p. 2), but leaving aside a few cores that have been suggested to resemble partial bifaces (Biglari & Shidrang, 2006, p. 165), the cleaver appears to be the only diagnostically Acheulean component reported. Very possibly the association of the different components of this surface assemblage has been created by subsequent conflation. A lack of small artefacts might also indicate some taphonomic disturbance of the exposed assemblage.

3.2.2 Khaleseh

In Zanjan Province, also in north-western Iran, rescue excavations targeted at the Late Neolithic remains at Tepe Khaleseh also recovered 23 lithics that the excavators classified as possibly Lower Palaeolithic (Alibaigi & Khosravi, 2009, Gręzak, et al., 2010, Alibaigi, et al., 2010, Nasab, 2011, p. 73). These heavily patinated artefacts were discovered in disturbed contexts near looter trenches, and are described as cores, choppers, a percussor, and flakes with and without retouch. Further investigations of the site between 2003-2008, probably using surface survey, located an additional 36 artefacts in a similar condition (Alibaigi, et al., 2010, p. 11). These artefacts include more choppers, flakes, cores, flake tools, and a percussor, but also a sandstone core tool provisionally identified as a cleaver.

The reported raw materials include limestone, chert, tuff, quartz, and unidentified igneous rocks, all of which are available in the immediate vicinity of the site. Limestone as a raw

material is particularly notable in that it constitutes around 45% of the assemblage, with igneous rocks constituting a further 25%. The use of river cobbles or pebbles for knapping is evidenced by the presence of fluvially worked cortical surfaces on the pieces. The raw materials are described as grading from high to low quality, with most falling somewhere in the middle.

Technologically, the original investigators have defined this as an industry centred on core and flake production and choppers (Alibaigi, et al., 2010, p. 12), in spite of the possible cleaver. Davoudi et al. (2015, p. 9) do interpret this assemblage as "showing some Acheulean features". These finds have been related typologically to other proposed Lower Palaeolithic finds in Iran, such as Pal Barik (Alibaigi & Khosravi, 2009, Alibaigi, et al., 2010, p. 12), but the disturbed context, lack of dating, and absence of diagnostic tool forms mean it is impossible to establish a genuine antiquity for these finds.

3.2.3 Pal Barik

Bifaces have been found in a surface scatter at Pal Barik, in the west of central Iran. Originally discovered in 1974, these lithics have been attributed to the Last Interglacial or earlier on the basis of typology and inferred association with geomorphological units of this age (Davoudi, et al., 2015, p. 9). Around 89 artefacts, described as being heavily patinated, were recovered from an area around 50m by 80m. One small, subtriangular biface was identified in this initial scatter, along with a large number of core-choppers, retouched flake tools identified as scrapers, notches, and denticulates. Cores are described as representing "unipolar, discoid, multiple and irregular cores" (Biglari & Shidrang, 2006, p. 165). An additional core-like biface was discovered to the south-west of Pal Barik.

Biglari & Shidrang (2006, p. 165) have noted that in the assemblage from Pal Barik choppers dominate the core tool component, and they describe the Acheulean component as "poor". The lithics found at the site of Khaleseh have been likened to those from Pal Barik, and Pal

Barik has been likened to the assemblages from Amar Merdeg and Gakia. One small Levallois core is also reported from Pal Barik, which would suggest either that this assemblage represents a Mousterian industry, or that it is a conflated assemblage of multiple industries. There is even some doubt over whether the bifaces from Pal Barik represent true core tools or whether they might actually represent Levallois cores. Based on the descriptions of the assemblage that are available in the literature, it might be most parsimonious to regard Pal Barik as representing a Mousterian surface assemblage, if it does indeed represent a homogenous assemblage at all.

3.2.4 Kuran Buzan Valley

The Kuran Buzan valley lies in the Central Zagros region, in western Iran. A survey in 2010 identified a number of Palaeolithic artefacts in scatters interpreted as open-air sites (Alibaigi, et al., 2011). Three of these scatters were classified as Lower Palaeolithic. At one of these scatters at Gashor, 420 Lower Palaeolithic artefacts were identified within a large multi-period mixed assemblage of around 50,000 artefacts. The criteria for classifying these artefacts has not been elaborated upon in the literature, and must be considered as provisional.

One of the finds from another scatter at Koreh Dasht-e Sofla is cautiously identified as an Acheulean handaxe (see Figure 18). However, the depiction presented in (Alibaigi, et al., 2011, p. Fig 7) does not show fine working around the proposed cutting edge, and it might be considered as morphologically indistinguishable from Levallois core techniques or early stage bifaces (ESBs). Caution is warranted here, as Levallois cores are known from many of the other surface scatters in Iran.

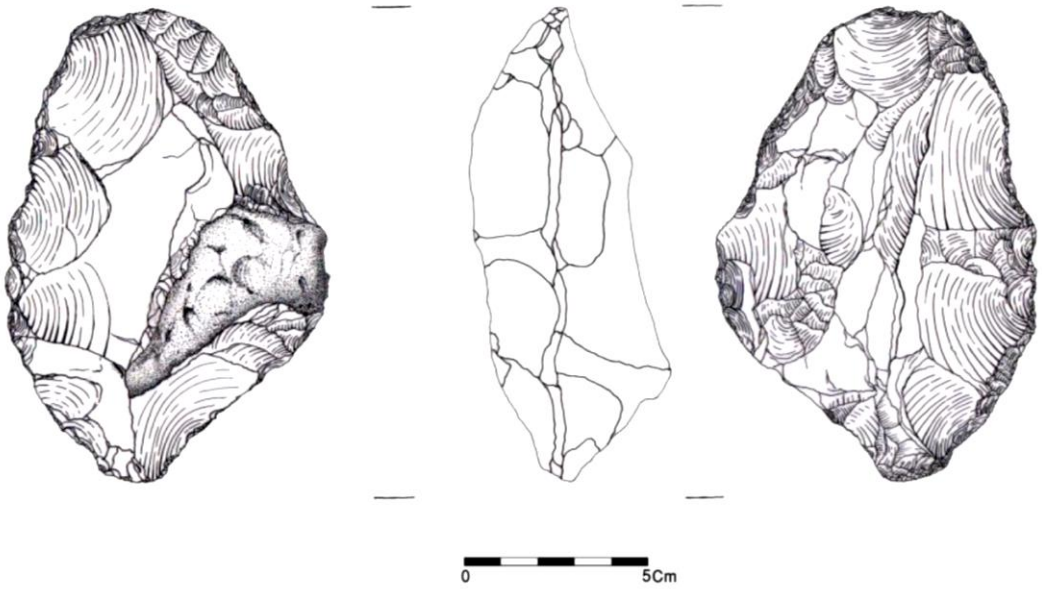

Figure 18 - The possible Acheulean handaxe from a surface context at Koreh Dasht-e Sofla. The lack of fine edge trimming and the thickness of the piece (which may be a result of hierarchical volume management) mean that this artefact could be an LCT, an ESB, or equally a Levallois core. Figure from Alibaigi et al. (2011, p. Fig 7)

The area is rich in raw material for lithics in the form of chert outcrops, with the chert ranging from medium to high in terms of quality. However, small clast size may have provided an upper limit on the tools produced at these sites (Alibaigi, et al., 2011). The original investigators have also suggested that this area may have been a rich area for hunting game in the past. Due to the lack of dating and indeterminate technological classification, the remains from Kuran Buzan valley can only provisionally be included as possible evidence for a Lower Palaeolithic record in the region.

3.2.5 Amar Merdeg and the Mehran Plain

A series of surface localities with lithics were discovered during an archaeological survey in 1997 on the Mehran Plain in south-western Iran (Biglari, et al., 2000, p. 749). These localities were reinvestigated and mapped in 1999, and three of them were identified as containing possible Palaeolithic artefacts. The most substantial of these was Amar Merdeg, which comprised several individual scatters on a series of alluvial hills, interpreted as having been

laid down during the Pleistocene. The site was subsequently reinvestigated in 2001 and 2004, and again in 2010 (Darabi, et al., 2012).



Figure 19 - Artefact identified as a 'core-chopper' in the Amar Merdeg assemblage. Figure from Biglari et al. (2000, p. Fig 3).

The assemblage from the original Amar Merdeg localities is dominated by tested cobbles of raw material, along with cores, core-choppers, and cortical débitage (Biglari, et al., 2000, p. 749, Biglari & Shidrang, 2006, p. 164, see Figure 19). A small number of flake tools made on fine grained chert were also reported from the site, including notches, denticulates, and scrapers. Artefacts made on the coarse grained raw materials such as sandstone tended to be core-choppers, which were predominantly made on large, rounded, cobbles. On a typological basis, the site was assigned a possible Pleistocene date due to its Lower Palaeolithic technological affinities.

Initially, no bifaces were located at Amar Merdeg, leading to its preliminary classification as a Mode 1 site. However, the subsequent investigations in 2001 and 2004 located four complete and partial bifaces, as well as Levallois cores (Biglari & Shidrang, 2006, p. 164), opening up the possibility of a Mousterian interpretation for the assemblage. One of the bifaces was made on a large, rounded cobble, of the type used commonly for the core-

choppers. Darabi et al.'s (2012, p. 446) reinvestigation of the four localities that comprise Amar Merdeg found additional artefacts of a similar technology to the original survey, including bifacial and unifacial choppers, and one handaxe described as being atypical, although this atypical morphology may have resulted from unidentified taphonomic processes.

When the area was subsequently investigated in 2010, Darabi et al. (2012, p. 445) also identified five additional surface scatters that they classified as Lower Palaeolithic. One of these scatters was represented by two polyhedrons made on chert pebbles in a larger assemblage of a possible later date, another by an assemblage of flakes and unipolar cores with a small number of choppers. The remaining three all contained bifaces, including one chert handaxe associated with choppers and bifacial tools, an isolated heavily patinated chert bifacial tool, and a heavily reduced mudstone handaxe found alongside other tools described as Palaeolithic. Biglari & Shidrang (2006, p. 165) have noted the absence of many artefacts commonly associated with Acheulean industries in south-west and south Asia, such as cleavers, polyhedrons, and spheroids. It should be noted that the subsequent investigations in 2010 identified at least one artefact classified as a polyhedron at one of the surface localities on the Mehran Plain. The high amount of early manufacture stage lithic artefact types versus the low amount of finished tools has led to this being interpreted as a manufacture site (Biglari, et al., 2000, p. 749).

A variety of raw material sources are reported as being densely clustered and plentiful around Amar Merdeg and the other Mehran Plain sites (Biglari, et al., 2000, p. 749, Biglari & Shidrang, 2006, p. 164, Darabi, et al., 2012, p. 445). Chert and sandstone are reported as being available in the immediate vicinity of Amar Merdeg in the form of cobbles, pebbles, and nodules, and a small amount of quartzite available for raw material is also mentioned . These raw materials are described as being both high quality and fine grained, and may have

provided an attractive resource for hominins. This reinforces the interpretation of the series of scatters at Amar Merdeg as a lithic manufacture site. Cobbles, pebbles, and nodules of chert are reported as numerous at the other surface sites that have been identified as Lower Palaeolithic in the Mehran Plain. The handaxe made on mudstone that Darabi et al. (2012, p. 446) report from one of the scatters they identified in the 2010 survey is heavily reduced, and was probably introduced to the locality as a finished tool.

The original investigators designated the Amar Merdeg site as typologically Lower Palaeolithic on the basis of its technological affinities (Biglari, et al., 2000, p. 749). In the absence of any secure dating, and in light of the subsequent discovery of Levallois cores and bifaces at the site, this technological designation must be considered provisional at best. The artefacts are described as mostly being heavily patinated, and it is also suggested that some may exhibit different phases of patination consistent with working in multiple periods. If this is true, then it is possible that these artefacts have been exposed on a deflated land surface in an area used repeatedly over several periods as a manufacture or raw material sourcing locality (Darabi, et al., 2012, p. 447). This adds another layer of complexity to its interpretation, which acts to obscure any possible behavioural interpretation for any potential Lower Palaeolithic component of the assemblage.

It remains a very real possibility that the assemblage from Amar Merdeg is a deflated assemblage composed of artefacts from different periods. A Mode 1 or Mode 2 component may exist independently of the Levalloisian or Mousterian elements of the assemblage, as suggested by Darabi et al. (2012, p. 447), but this is really impossible to assess at present.

3.2.6 Ganj Par

The surface scatter at Ganj Par was discovered during a survey in 2002 (Biglari, et al., 2004). The site is located in northern Iran, approximately 75km from the southern coast of the Caspian Sea. Over the course of three visits, around 140 artefacts identified as representing

a Lower Palaeolithic technology were collected from the locality (Biglari & Shidrang, 2006, p. 166). The presence of small flakes coupled with the lack of evidence for heavy abrasion or wear on the artefacts has been interpreted as indicating a relatively undisturbed assemblage, despite the surface exposure.

The assemblage contains a number of cores, flakes, scrapers, core-choppers, and percussors but also contains several large cutting tools in the form of handaxes, cleavers, and a trihedral pick (see Figure 20). The bifaces are reported as being very crude in terms of their refinement, some being described as intermediate between bifacial choppers and bifaces (Biglari, et al., 2004), and around half of the bifacial tools utilised large flakes as primary blanks (Biglari & Shidrang, 2006, p. 166). There are a wide variety of core types represented in the assemblage, included some cores that exhibit use of a bipolar anvil knapping technique.

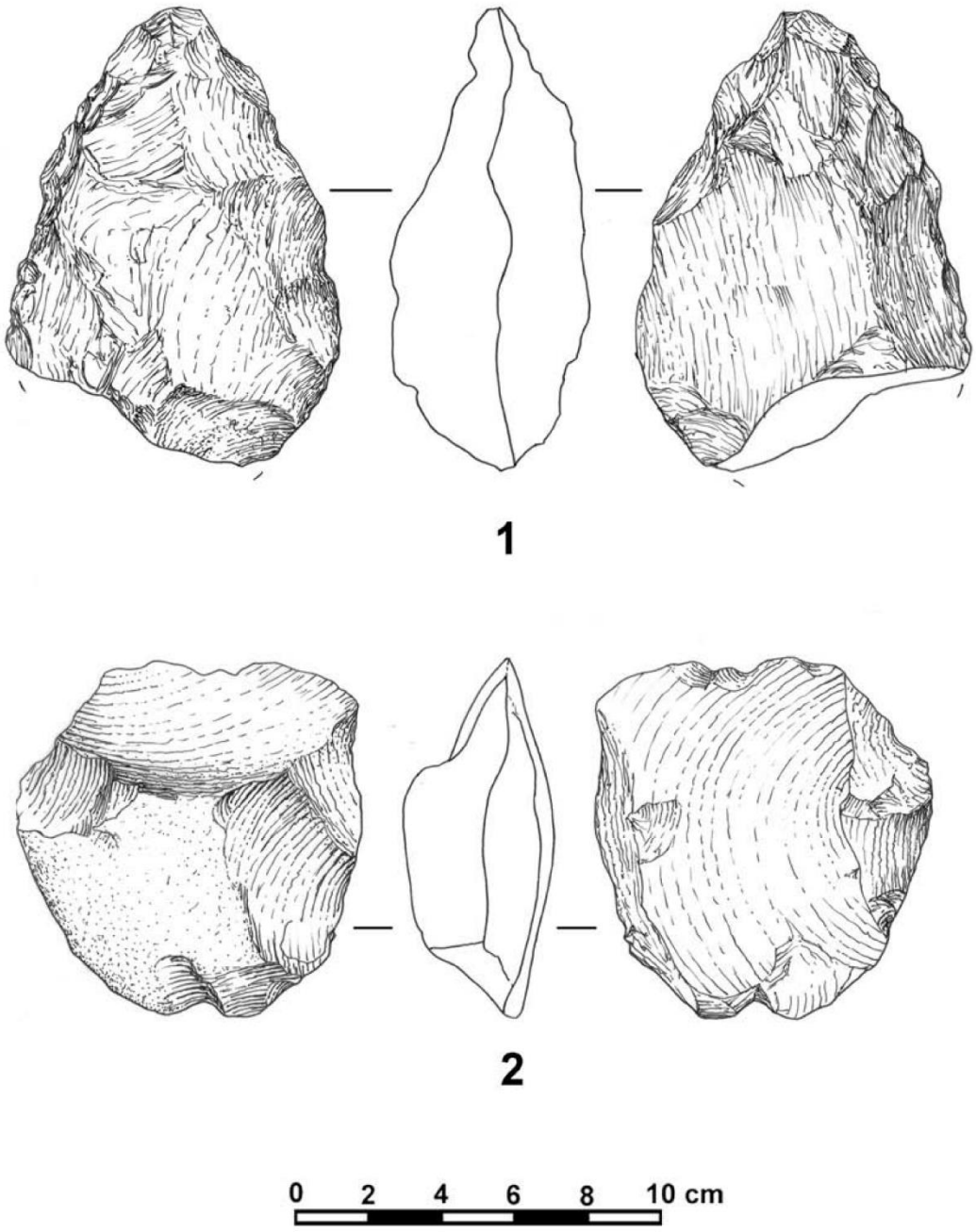

Figure 20 - A proposed handaxe (1) and cleaver (2) from Ganj Par. Figure from Biglari & Jahani (2011, p. Fig 7)

This is a very varied assemblage in terms of raw material usage (Biglari, et al., 2004). Unusually, close to half of the artefacts recovered from Ganj Par have been made on limestone clasts sourced from the limestone bedrock of the locality. The remaining artefacts including flakes, are made on a wide range of raw materials including silicified sandstone, quartzite, andesite, basalt, volcanic tuff, chert, and others, probably sourced from nearby gravel deposits (Biglari & Shidrang, 2006, p. 166). The Ganj Par assemblage has been

described as having affinities with early and Middle Acheulean assemblages from the Levant and East Africa (Biglari, et al., 2004, Biglari & Shidrang, 2006, p. 166), although this must be qualified with the acknowledgment that this is a surface assemblage, and for that reason is likely to be time-averaged.

3.2.7 Darband

Close to the south-east of Ganj Par, lies the south-facing cave site of Darband (Biglari & Shidrang, 2006, p. 166, Biglari & Jahani, 2011, p. 9). In 2006, a visit to Darband cave resulted in the discovery of 25 lithics in a disturbed context, associated with numerous faunal remains. The context is reported as having been disturbed by looters, presumably attracted by the later prehistoric remains in the cave.

The heavily patinated lithic artefacts are mostly retouched flake tools, with a few unmodified flakes, a core, and a core-chopper (Biglari & Shidrang, 2006, p. 167, Biglari & Jahani, 2011, p. 9). One flake is identified as a possible thinning flake from a biface (Biglari & Shidrang, 2006, p. 166). Chert is the most common raw material, along with silicified volcanic tuff, and the rest of the lithics are on other forms of volcanics. The small chert clast size is proposed to limit the size of the artefacts produced on this material. The Darband assemblage represents the only artefacts attributed to the Iranian Lower Palaeolithic record from a cave site.

The mixed faunal remains recovered from the same context were predominantly cave bear with some ungulates (Biglari & Shidrang, 2006, p. 167), and these were proposed as suggesting a Middle Pleistocene date (Biglari & Jahani, 2011, p. 9). Two of the specimens of bear teeth were sent for U-series dating, and this is reported as confirming a late Middle Pleistocene date (Biglari & Jahani, 2011, p. 13). However, this date must be considered provisional for the lithic assemblage due to the uncertain association between the faunal and lithic remains in a disturbed context.

3.2.8 Geleh

Located in Isfahan Province, central Iran, the Geleh locality was surveyed in 2003 and 2006 (Biglari & Shidrang, 2006, p. 164, Davoudi, et al., 2015). The assemblage includes several large flakes and cores, as well as unifacial core tools described as “unifacial handaxes” and a fragment of a broken biface.

The industry is described as being focused on the production of large side and end struck flake (Biglari & Shidrang, 2006, p. 164). Some of these large flakes are partially retouched, but the overall impression is that this assemblage represents only the early stages of reduction, and is therefore interpreted as a workshop. It might very cautiously be suggested that the large flakes produced at this locality could represent the production of blanks for biface manufacture, which would then be curated away from the site for further reduction and use. Indeed, some of the large flakes are described as resembling cleavers, and the assemblage has been classified as Acheulean in character.

In terms of raw material sourcing, trachyandesite outcrops are known to be nearby in the region, and all of the artefacts found so far are made on this material (Biglari & Shidrang, 2006, p. 164). The presence of springs in the local area is cited as a possible resource attracting hominins to this location, but it is unclear whether these would have existed in the past. Absence of small artefacts such as flakes has been interpreted as winnowing of the assemblage while exposed.

3.2.9 Kashafrud

The Kashafrud locality was discovered in the early 1970s in north-eastern Iran close to the border with Afghanistan (Dennell, 2009, p. 116, Biglari & Shidrang, 2006, p. 161). The locality is represented by a series of 80 lithics recovered from seven identified sites on an eroding alluvial basin that has been interpreted as once containing a large and shallow lake . Some of these lithics were subsequently discovered to be fluvially worked geofacts, but the

remaining lithics were identified as pebble tools made on quartz, and included core-choppers, flakes, cores, a few flake tools, and percussors (Dennell, 2009, p. 117). The cores mostly demonstrate limited reduction with very few removals, primarily exploiting natural, cortical flaking platforms. The few retouched flakes that have been recovered are described as "casual" and are presumably unstandardized (Biglari & Shidrang, 2006, p. 161). Biglari & Shidrang (2006, p. 161) also identify bipolar percussion as a method of core reduction on several cores in the assemblages. An additional survey along the Kashafrud river in 2007 recovered artefacts from additional surface scatter sites identified as Lower Palaeolithic, including flakes, flake tools, and a chopper (Jamialahmadi, et al., 2008).

In terms of raw material, cobbles of quartz and andesite are described as plentiful in the local gravels; however, the quartz is seen to be the only raw material selected for working into lithics in the assemblages (Biglari & Shidrang, 2006, p. 161). Biglari & Shidrang (2006, p. 161) have suggested that the evidence for preferential flaking of the slightly friable quartz at Kashafrud is indicative of a good understanding of the fracture mechanics of a difficult raw material, and suggests a certain level of skill on the part of the knappers. This site remains undated, and its attribution to the Pleistocene is based on broad, typological comparisons by the original excavators and subsequent authors to Oldowan assemblages in East Africa, but also to the lithic assemblages at Dmanisi (Biglari & Shidrang, 2006, p. 162).

Kashafrud is considered to be the likeliest candidate for the oldest evidence for hominin activity in Iran; however, this site remains problematic in terms of dating, although Dennell (2009, p. 118) appears to accept the provisional early Pleistocene date suggested for this site on the basis that several artefacts from the assemblage are comparable to other assemblages from lake deposits in Saudi Arabia and Israel (the other artefacts he rejects as geofacts). Although very little can be said about a typologically dated site, the artefacts that have been found at the Kashafrud locality are, by definition of their typological classification,

unproblematic to an early Pleistocene Asian context. The simple chopping tools, flakes, and cores made on quartz pebble raw materials are all within the evidenced skillset of early Pleistocene hominins. There are also no traces of a Mode 2 technology, but the assemblage is seen to be broadly 'Oldowan' in appearance. The reduction of cobbles and pebbles of quartz via bipolar percussion for predominantly plain, usable flakes, bears a striking resemblance to the Karatau Pebble Culture defined for Central Asia, as well as to similar products in evidence at other Iranian sites and Dmanisi. The comparison is made even more attractive due to the geographical position of this site close to the border with Turkmenistan, but because the attribution of the technology is purely typological, Kashafrud provides, at best, circumstantial evidence for dispersal in the region.

3.2.10 Ladiz and the 'Ladizian' Sites

In the mid-1960s, 17 different lithic scatters were found on eroded gravel terraces within the Ladiz, Mashkid, and Simish river valleys in the south-east of Iran (Biglari & Shidrang, 2006, p. 162). These artefacts included cores, chopper-cores, flakes, and retouched flake tools. Some of the cores were identified as being diagnostic of a bipolar percussion technique. The 'Ladizian' industry was defined on the basis of two of the scatters from the Ladiz river valley (Biglari & Shidrang, 2006, p. 164). These particular scatters are thought to be relatively undisturbed as they include substantial numbers of refits.

Quartzite, chert, and jasper are represented as raw materials in cobble form at the Ladizian sites, with the former being the most common, and all reported as being available locally. Although originally identified as representative of Lower Palaeolithic technologies, Biglari & Shidrang (2006, p. 162) classify the Ladizian assemblage as Middle Palaeolithic. With a lack of diagnostic tool types in the assemblage, and no dating evidence, it remains impossible to distinguish either way.

3.2.11 Isolated Handaxe Finds

A number of sites in Iran are represented only by isolated finds of bifaces or handaxes, especially in the north and west of the region. Some have limited information available on them, reducing their utility in the present examination of the evidence. We can add to this list a "probable Acheulean occurrence" at Kavir, in central Iran (Biglari & Shidrang, 2006, p. 163), and a possible fragment of a trihedral pick in the north-west around the Sahand Massif (Biglari & Shidrang, 2006, p. 165). Also the surface scatter at Minab in the south-east or Iran. The partial biface at Minab is associated with around fifty other artefacts identified as Lower Palaeolithic, including flakes, flake tools, and cores (Biglari & Shidrang, 2006, p. 163). It is identified as being made on a grey-green volcanic material, and is suggested to resemble a cleaver.

Gakia

Gakia, sometimes known as Tepe Gakia, is in the Kermanshah region of western Iran in the western-central Zagros region (Biglari, et al., 2004, Biglari & Shidrang, 2006, p. 164). At this site a surface scatter was found on a terrace of the Qara Su river during a survey in 1959-60, making it the first evidence of a possible Lower Palaeolithic reported from Iran at the time of its discovery (Davoudi, et al., 2015, p. 9). The scatter included flakes and cores assigned to later periods, but also included a biface classified as an amygdaloid type Acheulean handaxe. The area is reported as containing numerous radiolarian chert outcrops interpreted as workshops, with which the scatters were spatially associated (Biglari & Shidrang, 2006, p. 164, Heydari, 2004, p. 126). Two subsequent surveys around the region have located numerous further surface scatters of lithics associated with the chert outcrops, but nothing diagnostic of Lower Palaeolithic industries.

The assemblage from Gakia has been noted as lacking other artefacts usually associated with Acheulean industries such as cleavers, polyhedrons, and spheroids (Biglari & Shidrang, 2006,

p. 164). It should also be noted that amygdaloid handaxes are sometimes a component of Mousterian industries, which are numerous in the surrounding area as surface scatters. As a result, it cannot be said for certain whether this isolated find represents evidence for Lower Palaeolithic handaxe industries in the region.

Harsin

North-west of the Gakia surface finds is the site of Harsin, where a survey in 2006 located two heavily patinated chert bifaces in a surface context (Biglari & Shidrang, 2006, p. 164). These bifaces were found in association with lithic scatters that were classified as Middle Palaeolithic, casting substantial doubt on their possible antiquity.

Lake Quri Gol

Usually named in the literature as 'Quri Gol', the lake in the Eastern Azerbaijan Province of Iran is more usually transliterated as 'Gurigöl'. In 1970, a survey team located an isolated surface find of a quartzitic sandstone handaxe to the south-east of Lake Gurigöl (Biglari, et al., 2004, Biglari & Shidrang, 2006, p. 165). The handaxe is described as worn and heavily patinated, and was classified as a subcordate type.

Biglari et al. (2004) report two bifaces, Biglari & Shidrang (2006, p. 165) report one handaxe.

3.2.12 Summary

The lack of well dated sites and the probable conflation of the known surface assemblages in Iran makes it very difficult to separate these sites and their technologies chronologically, or make any interpretations specific to the Lower-Middle Pleistocene record. Antiquity is primarily deduced on the basis the 'primitive' or simple appearance of artefacts, which is very problematic. In many ways, this situation mirrors a similar problem with the identification of handaxe technologies in Central Asia. Problematically, large tools such as choppers and bifaces tend to characterise surface assemblages, and only in their absence are core and flake assemblages such as that at Kashafrud identified. The distribution of sites

in Iran is probably skewed by a lack of investigation (Biglari & Shidrang, 2006, p. 167), which may account for some of the lack of sites in the south and around the central Iranian desert.

From a Central Asian perspective, Kashafrud is the most interesting site due to its probable antiquity and its close proximity to the border with Turkmenistan and Afghanistan. Ganj Par is also very interesting, in particular because it implies a possible association of Mode 2 technology with bipolar percussion technique on very varied raw material. The use of bipolar percussion on cores, known as a key technique for defining the Central Asian pebble culture sites, is well-evidenced at several Iranian sites. At Shiwatoo, Kashafrud, and the Ladizian sites in particular the bipolar percussion technique is applied to raw material in the form of cobbles and pebbles. There is also a very large variety of raw materials exploited throughout the Iranian record, of which chert and flint are not always the most prevalent. Many igneous and metamorphics are represented at these sites, and even sandstone and limestone, the latter of which is the primary raw material at several sites. This has some parallels with the varied raw material usage at Central Asian pebble culture sites, although flint and chert tend to be dominant even in the most varied assemblages within Central Asia.

There is a reasonable likelihood that handaxe technologies were present in Iran during the Lower-Middle Pleistocene due to the existence of other dated sites in southwest Asia and south Asia. There are some hints of a large flake Acheulean industry in the form of handaxes and cleavers distributed across the country, but especially in the north-west around Lake Urmia. Being positioned as it is between the Levant and South Asia, this is unsurprising. Sharing as it does a border with Central Asia, it would be interesting to know more about the possible spread of this technology into Afghanistan or southern Central Asia. However, even possible surface finds of Mode 2 technologies are so far absent from the north-east close to the border with Central Asia, and the known record of Afghanistan is practically non-existent. It might be possible that the north-east of the study region provides some kind of a

barrier to dispersal of these technologies, perhaps as a result of the Central Iranian desert, although this is impossible to know for certain. The lack of handaxe finds in the north-east of Iran is interesting from a Central Asia perspective, because it somewhat mirrors the scarcity of handaxes at the southern Central Asian sites. The hints at several Iranian sites of a possible coexistence of Mode 2 technologies and pebble-based technologies is particularly intriguing. However, the poor dating of these sites, and the very real possibility that these assemblages are mixed through deflation rules out any certainty in this regard.

Kashafrud is the most interesting site in the region for the present study due to its technology and its proximity to the border with Central Asia. The assemblage is represented by a core and flake technology with pebble tools such as choppers, and the use of bipolar core percussion. Limited reduction sequences and informal retouch of flake tools are also key aspects of this assemblage. This reflects features of both the Dmanisi assemblages and the Karatau Pebble Culture sites, but caution is required in any parallels drawn between these records. All of the elements required for the Karatau Pebble Culture industries are identifiable in the surface assemblages in Iran, but the lack of chronology limits the observations that are possible on this basis. An uncertain chronology for Mode 2 technologies in Iran compounds this issue, but it is probably safe to assume a fairly early arrival for these technologies, as is implied by the south Asian record.

3.3 Pakistan

Much like Iran and Afghanistan, the early Pleistocene record of Pakistan is very limited. A couple of notable localities with artefacts were reported in the 1980s, but remained very contentious initially. One of the major reasons for this was probably because the proposed dates for these sites came in advance of some of the earliest dates now known for Asia in Georgia and China. With the current chronological framework for the Asian continent, these dates seem less isolated and more acceptable now than previously.

3.3.1 Riwat

At the site of Riwat in northern Pakistan, a small number of quartzite artefacts that had been flaked prior to their incorporation into a conglomerate gritstone unit were found during a survey (Dennell, 2009, p. 137, see Figure 21). The age of the formation of the gritstone unit gives the artefacts a minimum age of 1.9 mya (Dennell, 2009, p. 137). The artefacts are convincing as intentional flaking products, and Dennell et al. (1988a, 1988b) went to great lengths to demonstrate this. Despite this effort, the artefacts have been the subject of controversy (Hemingway, et al., 1989), in part because their discovery came years before many of the older dates now reported in Georgia and China.

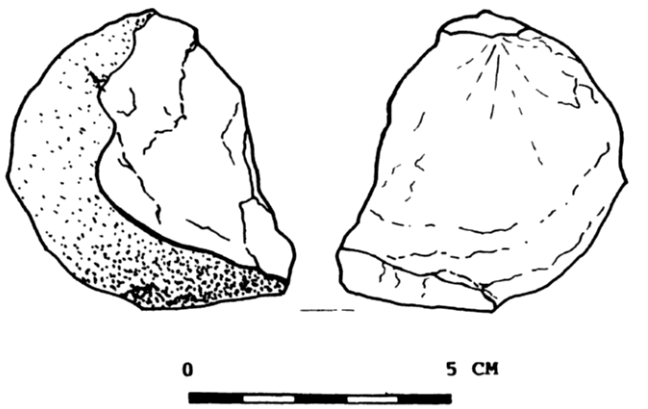

Figure 21 - Quartzite flake from Riwat. Figure from R. W. Dennell's 'Reply' to Hemingway (1989, p. Fig 1)

Dennell et al. (1988a, p. 498) originally proposed three possible scenarios on the basis of the Riwat finds; "(a) *Homo habilis* was distributed as far east as Pakistan, (b) *H. erectus* is an Asian lineage at least as old as *H. habilis*, or (c) another, as yet unidentified tool maker was responsible." As a result of the finds at Dmanisi, it would now appear that *H. erectus* could indeed be responsible for the stone tools at Riwat, although the south Asian record lacks any contemporary hominin fossils to confirm this.

3.3.2 Pabbi Hills

607 artefacts collected around the Pabbi Hills, northern Pakistan, from a rapidly eroding deposit with associated fossils, and consists of simple cores and flakes predominantly on

quartzite (Dennell, 2007, p. 58, Dennell, 2009, p. 140), although a small collection of 12 flint artefacts are interpreted typologically as Neolithic or later. These artefact scatters were extremely low density with 211 separate locations, and around 45% being found as isolated finds. The proposed Lower Palaeolithic artefacts themselves are described as being simple cores and flakes on quartzite. Technologically, these were reported as being comparable to Oldowan assemblages; however a lack of secure context or dating mean that this interpretation must be provisional. A rough dating bracket of 0.9-2.2mya has been proposed for the deposit (R. Dennell, pers. com.).

3.3.3 Dina & Jalalpur

The sites of both Dina and Jalalpur lie in Northern Pakistan (Dennell, 2009, p. 339). Both sites have furnished handaxes, with one from Dina and two from Jalalpur (see Figure 22). Both are dated roughly with only palaeomagnetism to around 600 kya.

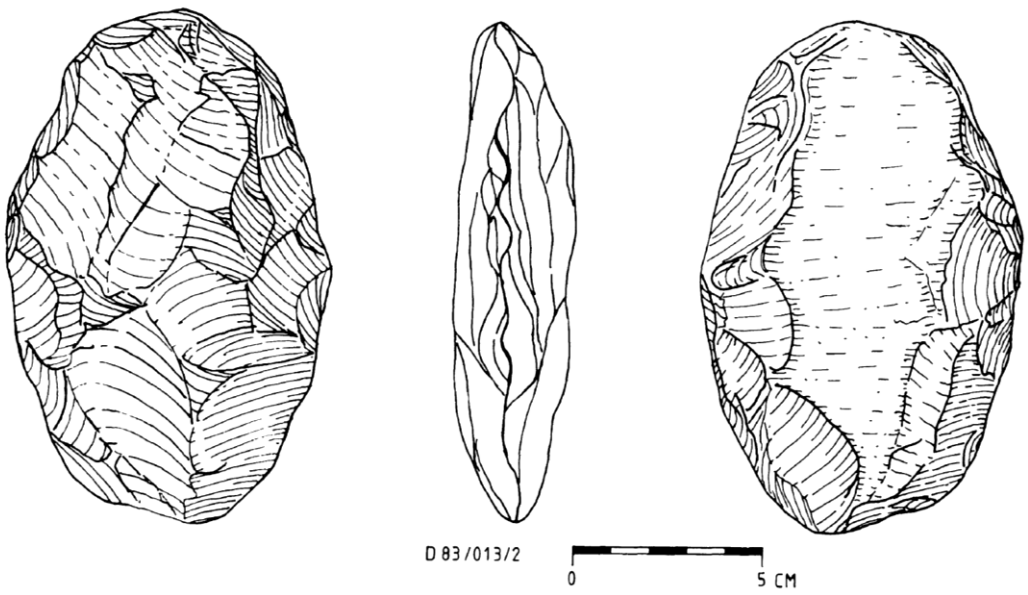

Figure 22 - The handaxe from Dina. Figure from Ganjoo & Dennell (1986, p. Fig 1), modified by current author.

3.3.4 Summary

As with Iran and Afghanistan, the scarcity of finds, and the lack of crucial dated sites in particular, contribute to the difficulty of producing a meaningful contextual framework for

understanding this area of Asia. However, there are several themes that do emerge from a consideration of the Lower-Middle Pleistocene record of Pakistan. The earlier sites, if accepted, suggest a simple Mode 1 technology on quartzite pebbles is the dominant form of technology during the Lower Pleistocene.

Dennell (2007) has suggested that the floodplains of Pakistan may have provided an obstacle to hominin occupation, thereby accounting to some extent for the lack of Lower Pleistocene sites. The periodic hazard provided by the sudden inundation of the south Asian Monsoon cycle, exposure to predation in an open landscape, and substantial fluvial deposition limiting access to raw materials are all suggested as reasons why hominins would struggle in such an environment (Dennell, 2007, pp. 45-8). Also, that geological events near the end of the Lower Pleistocene increased access to raw material across the region, enabling a more stable occupation in the Middle Pleistocene. However, it should also be noted that these factors that may have provided obstacles to hominin occupation are also factors that could have acted to erase possible earlier records of hominin presence.

Current evidence suggests that Pakistan might have represented a transient region, difficult for hominins to occupy. It might therefore have represented a possible access point into Central Asia, but remains an unlikely region for providing a source population to occupy Central Asia.

3.4 China

The Lower-Middle Pleistocene archaeological record in China is incredibly rich, and no attempt to cover it comprehensively will be possible within the confines of the present study. The emphasis in this limited review of the Chinese material will focus firstly on the early Pleistocene finds around the Nihewan Basin, as well as a selection of other Pleistocene sites from across China.

A lot of the dates from the early Pleistocene Chinese record rely on magnetostratigraphic methods combining palaeomagnetism and estimates of sedimentation rates. These are commonly the only dating methods, and are sometimes combined with faunal evidence using biostratigraphy. These are not ideal methods for dating, but reflect a better situation than that in many of the other neighbouring regions examined here. Some absolute methods such as ESR, OSL, and U-series dating are sometimes applied, but often provide conflicting results. The Chinese record can boast a good relative chronology in dense areas, and some areas are almost certainly occupied throughout the Pleistocene, but the very earliest dates proposed by the investigators must be viewed as very tentative in some cases.

3.4.1 The Nihewan Basin

West of modern Beijing, the Nihewan Basin is a large basin covering areas of Hebei and Shannxi Provinces, as well as some of the Inner Mongolian Autonomous Region (Shen, et al., 2010, p. 169). The area is rich in Pleistocene hominin sites. Many of the sites cluster around the remains of a palaeolake (Gao, et al., 2005, p. S118). The area was studied most intensively from the late 1970s onwards (Shen, et al., 2010, p. 169). Several Mode 1 core and flake assemblages at different localities in the basin provide a fairly complete sequence of this technology throughout the Pleistocene, and some of these assemblages include choppers (Bar-Yosef & Wang, 2012, p. 322). Several localities demonstrate evidence for bipolar percussion on an anvil as well as direct percussion techniques.

There is a varied use of local raw materials in the Nihewan Basin, such as volcanics, flint and chert, limestone, and quartz (Bar-Yosef & Wang, 2012, p. 322). But in particular, the exposed quartzitic bedrock has, in some places, a ‘chert-like’ quality, and this is very commonly the primary raw material at many of the Nihewan localities (Schick, et al., 1991, p. 17). Sometimes this raw material is simply referred to as chert in the literature.

Majuangou

Several Lower Pleistocene localities have been found at Majuangou in the Nihewan Basin. Majuangou I has been dated with magnetostratigraphy to 1.55 mya (Zhu, et al., 2004, p. 561), and this is supported by an ESR dating of *c.*1.4 mya (Liu, et al., 2014). Majuangou II has been dated with magnetostratigraphy to *c.* 1.64 mya (Zhu, et al., 2004, p. 561), and ESR dating has also supported this with a date of *c.* 1.7 mya (Liu, et al., 2014). However, the most interesting of these sites is at Majuangou III, which has been also previously published under the name 'Goudi'.

Majuangou III (Goudi)

Several layers with artefacts and faunal remains have been found at Majuangou III (Gao, et al., 2005). The site does not actually have a direct stratigraphic relationship to the other Majuangou sites, hence the confusion over the site name (Keates, 2010, p. 409). 493 artefacts were excavated in total from several trenches at the site, including flakes, cores, and hammerstones, and some of the flakes provide refits with the cores (Shen, et al., 2010, pp. 174-5, Keates, 2010, p. 410, see Figure 23). The assemblage is made on locally sourced low quality raw materials, mostly the local chert-like quartzite similar to those from the nearby site of Xiaochangliang (Gao, et al., 2005, p. S117), or sometimes identified simply as 'chert' (Shen, et al., 2010, p. 175).

The artefacts and faunal specimens are interpreted as being deposited in a warm, moist, lake shore environment, where the starchy edible water caltrop would have been available (Keates, 2010, p. 409, Zhu, et al., 2004, p. 559). Furthermore, the faunal remains seem to indicate that the wider local environment primarily comprised grasslands with some mixed woodland (Ao, et al., 2013b, p. 4), perhaps provided access to edible grass seeds and tree resources such as seeds, nuts, and fruits. Deer, horses, and gazelles were present, if hominins could have hunted them. Even if they weren't able to hunt them, they may have

been able to scavenge the kills of *canids* or *hyaenids* who were also present. Some of the faunal specimens exhibit damage that has been interpreted as being indicative of marrow extraction by hominins (Deng, et al., 2007), perhaps after a successful scavenging event, as suggested by Dennell (2013b, p. 226). However, as well as being potentially dangerous to small-bodied hominins, hyaenas are also accomplished bone-crunchers, perhaps suggesting that these scavenging opportunities might be sporadic and dangerous for the hominins involved. Ostriches were likely to be too dangerous for hominins to tackle, but they may have stolen their eggs if the opportunity arose.

The artefactual layers have been dated to *c.* 1.66 mya with magnetostratigraphy (Zhu, et al., 2004, p. 561), and this has been reinforced by a subsequent ESR date of *c.* 1.7 mya (Liu, et al., 2014).

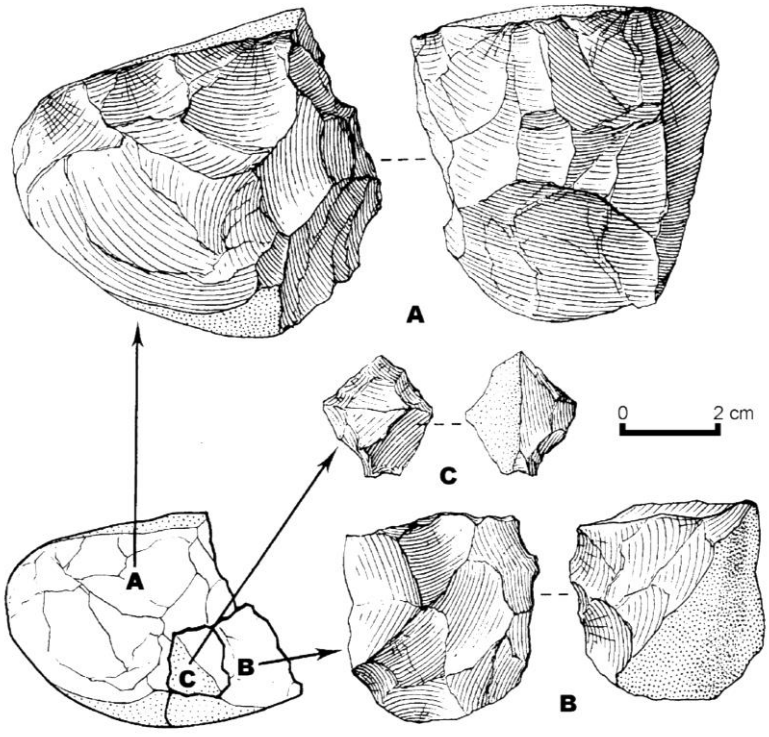

Figure 23 - Several refitting artefacts from the Majuangou III locality (Goudi). Figure from Shen et al. (2010, p. Fig 3.4)

Other sites of similar age

The nearby site of Shangshazui is of a similar age, dated via a magnetostratigraphic method to *c.* 1.6-1.7 mya, with a simple core and flake technology, and faunal remains that further support the existence of mixed grasslands and woodlands at this time (Ao, et al., 2013b, p. 4). Artefacts of roughly this date have also been found at the Lanpo site, which has been dated via a magnetostratigraphic method to *c.* 1.6 mya (Ao, et al., 2012). Possibly also falling in between the cluster of earliest Lower Pleistocene sites in the Nihewan basin is the site of Banshan, where 95 artefacts have been reported (Liu, et al., 2013a, p. 216). Originally, Banshan was thought to cluster with other Nihewan sites at *c.* 1.36 mya, but new dating challenged this (Bar-Yosef & Wang, 2012, p. 322). Banshan has been dated with magnetostratigraphy to either *c.* 1.55 (Shen, et al., 2010, p. 171) or 1.32 (Zhu, et al., 2004, p. 561). Subsequent ESR dating to *c.* 1.35 mya perhaps reinforces the original stratigraphic interpretation (Liu, et al., 2014).

Xiaochangliang

Thousands of artefacts have been recovered from the site of Xiaochangliang and are along with more than 3000 faunal specimens (Shen, et al., 2010, p. 171, Liu, et al., 2013a, p. 216). Preservation is so good at the site that several specimens of microvertebrates were recovered (Bar-Yosef & Wang, 2012, p. 322). The artefacts have been dated with magnetostratigraphy to *c.* 1.36 (Zhu, et al., 2001); however, it also appears possible that the artefacts and the fauna might be mixed and redeposited (Peterson, et al., 2003), in which case they may not be genuinely associated, and the date from magnetostratigraphy would be a minimum date.

The artefacts include flakes, cores, and nodules (Shen, et al., 2010, p. 171). Some of the pieces are retouched, and mostly these have been identified as scrapers (Yang, et al., 2016, p. 11), but overall there are very low rates of flake modification. The flakes are mostly small,

and the tools are described as “informal” and the technology generally expedient in character (Keates, 2010, p. 411). Bipolar cores and flakes have been identified in the assemblage, and one report suggests that bipolar technique may be responsible for as much as 30.23% of all the lithic products they analysed (Yang, et al., 2016, p. 11). Bipolar technique was probably necessary for dealing with the small average clast size of raw material at the site, as well as the internal fracturing that made this raw material difficult to knap (Yang, et al., 2016, p. 4).

The raw material is local, but some confusion exists over its exact designation. It is either reported as quartzite described as having a “chert-like quality” (Shen, et al., 2010, p. 173), presumably implying it is fairly homogenous and with a silicified matrix, or simply described as varying grades and colours of chert (Keates, 2010, p. 412, Yang, et al., 2016, p. 4). The raw materials are locally available and usually in the form of angular or nodular blocks rather than pebbles or cobbles (Schick & Zhuan, 1993, p. 29), and are available as bedded nodules of chert or as chert contained within pyroclastic breccias. Some small amounts of vein quartz and basalt are also utilised in the assemblage (Keates, 2010, p. 412).

Four possible bone tools have been identified (Liu, et al., 2013a, p. 216), and use-wear analysis has been used to suggest that meat-processing was the dominant activity at the site (Keates, 2010, p. 411). Possible game could have included bovids, deer, horses, and gazelles (Ao, et al., 2013b, p. table 2), though whether the hominins of this time were capable of hunting these medium-sized prey is open to debate. The Xiaochangliang hominins may have scavenged the kills of hyaenas, which would also have provided a danger to hominins themselves. However, on examining the collection, Peterson et al. (2003) could not substantiate claims of cutmarks and percussive marks on the faunal assemblage. The artefacts from the site are mostly in a fresh condition, despite possible movement due to inundation by the Nihewan palaeolake (Keates, 2010, p. 409).

Dachangliang (Xiantai)

The site of Dachangliang is close to Xiaochangliang, and probably contemporary with it (Shen, et al., 2010, p. 173). Two earlier attempts to date the site via the magnetostratigraphic method have suggested a date of *c.* 1.36 mya (Deng, et al., 2006, Shen, et al., 2010, p. 171). A subsequent attempt to date it via magnetostratigraphy and fluvial cycles suggested an earlier date of *c.* 1.48 mya (Ao, et al., 2013a).

33 artefacts were recovered from the site, in association with 22 faunal specimens (Shen, et al., 2010, p. 173, Liu, et al., 2013a, p. 216). The artefacts include scrapers, cores, and flakes (Deng, et al., 2006, p. 338). The predominantly amorphous, multi-platform cores and flakes are made on a similar material to that from Xiaochangliang, but with a significant cherty component. Volcanic rocks and quartz are also noted for this site.

Palynological studies have indicated a steppic environment contemporary with the artefactual layers (Deng, et al., 2006, p. 344), and a 'stepwise' aridification throughout the Pleistocene, moving from a subtropical environment to a forested environment, and ultimately to include more grasses and herbaceous vegetation (Ao, et al., 2010a, p. 476).

Feiliang

Leaving a possible gap in the chronology of the Nihewan Basin of *c.* 10-20 ky, the site of Feiliang has been dated via a magnetostratigraphic method to *c.* 1.2 mya (Ao, et al., 2012, Deng, et al., 2007). 108 artefacts have been recovered here, including flakes, scrapers, and cores. These artefacts were found in association with 1419 faunal specimens (Liu, et al., 2013a, p. 216). Chert and quartz are reported as raw materials, transported into the site.

Madigou

The nearby site of Madigou is judged to be contemporary with Feiliang at *c.* 1.2 via stratigraphic correlation with the latter site (Li, et al., 2016, p. 102). 971 worked lithic artefacts were excavated at the site, including flakes, cores, choppers, and a few 'informal'

retouched flake tools. Raw materials include chert, siliceous dolomite, and basalt, all of which are locally available. The use of the raw material is described as “uneconomical” (Li, et al., 2016, p. 108), and the assemblage is interpreted as being primarily the result of hard hammer direct percussion. The assemblage as a whole is described as a Mode 1 technology similar to African Oldowan assemblages. Madigou excels in its palynological record (see Figure 24), which has been combined with other climate proxies to produce an in depth study, suggesting that the majority of hominin activity at the site took place in a warm and humid environment with a mix of grasslands and woodlands (Li, et al., 2016, p. 108). Pine, hazel, and walnut trees could have provided edible nuts, and some trees provide edible seeds, such as elm. Acorns were available, but would have required some form of processing to remove the tannins. Also edible from the local environment were hops, daisies, the young ‘fiddleheads’ of ferns, nutrient-rich rosehips, and some wild legumes. Wetland flora such as cattails and sedges also provide edible seeds.

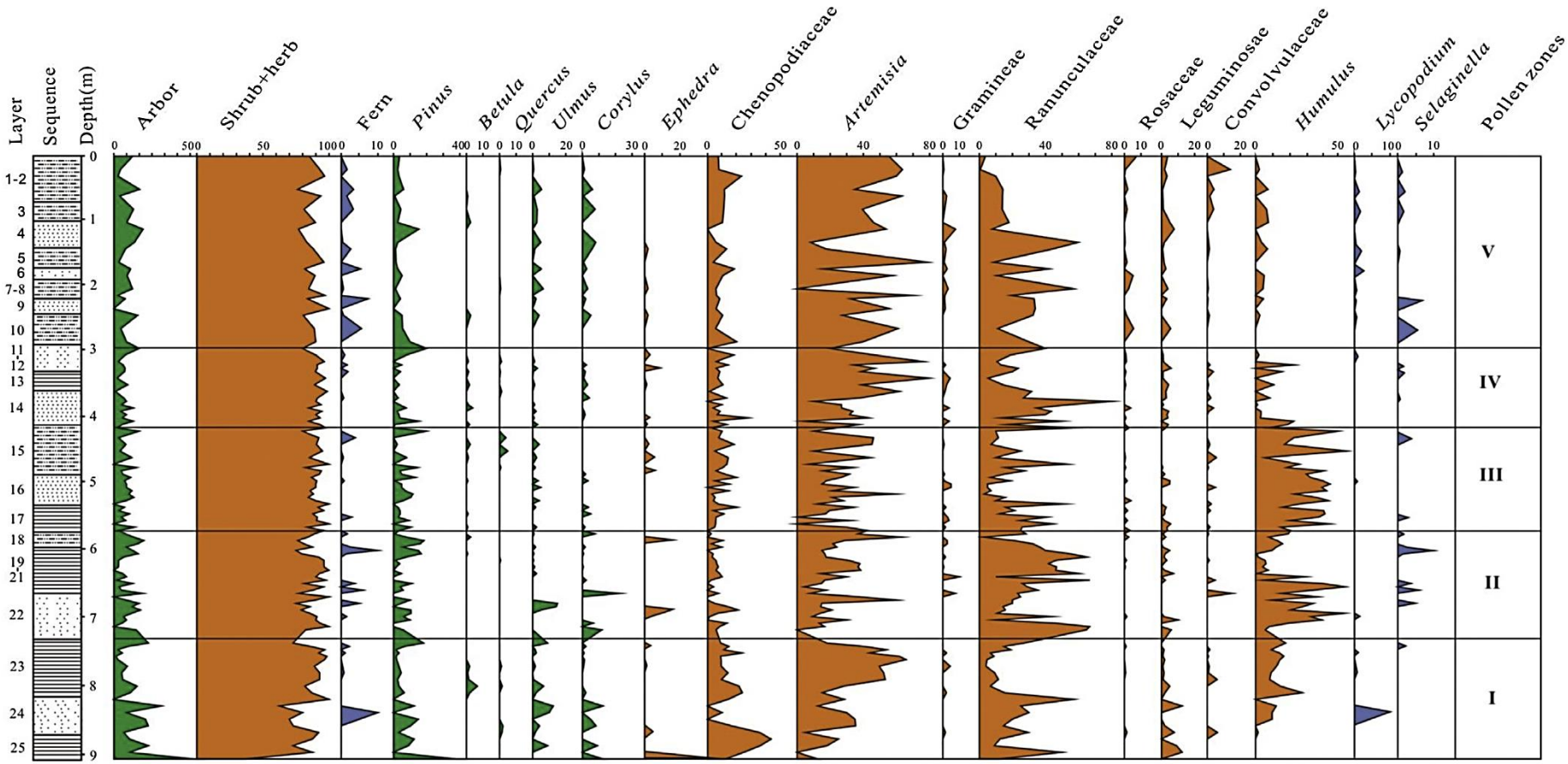

Figure 24 - The pollen percentage sequence from the section at Madigou. Artefacts come from layers 14, 16, and 19-22 (Li, et al., 2016, p. fig 4)

Donggutuo

The richest site in the Nihewan Basin is Donggutuo, with more than 10,000 artefacts in total and around 5m of cultural layers (Shen, et al., 2010, p. 173, Bar-Yosef & Wang, 2012, p. 322). The site has been dated via a magnetostratigraphic method to *c.* 1.06-1.12 mya (Ao, et al., 2013a, Wang, et al., 2005), although more recently ESR dating has placed it *c.* 750 ± 88 kya (Liu, et al., 2010a). The artefacts are quite small on average, and include flakes, retouched flake tools, and cores (Keates, 2010, p. 412, see Figure 25). Flakes are mostly unretouched, and those that are reflect only slight, simple modification (Schick, et al., 1991, p. 21). A large percentage of cores are bipolar cores, and there are also several bipolar flakes (Shen, et al., 2010, p. 171). A limited number of refits were possible with the excavated material (Schick & Zhuan, 1993, p. 29).

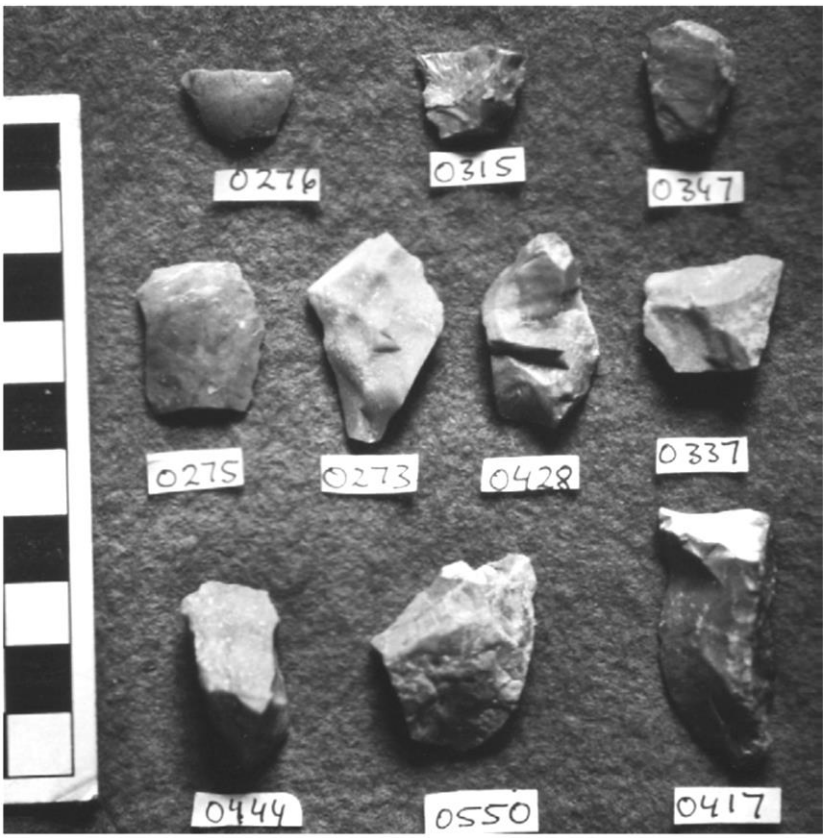

Figure 25 - Flakes and fragments from Donggutuo. Figure from Keates (2010, p. Fig 6)

The artefacts were made on a poor quality quartzite and chert (Shen, et al., 2010, p. 175), essentially the same kind of raw material as is found at Xiaochangilang and the other nearby sites (Schick & Zhuan, 1993, p. 29). There is also a volcanic rock component, including artefacts made on ignimbrites and lavas (Schick, et al., 1991, p. 17). In some ways the knapping techniques at Donggutuo are regarded as being more 'developed' than those at other Nihewan Basin sites in terms of flake tool diversity and core flaking strategies (Liu, et al., 2013a, p. 221). It has even been argued that the small artefacts from this site are distinctive of a Lower Palaeolithic 'microlithic' industry (as was also suggested in regards to Kuldara, see '2.3 Major Themes in the Lower Palaeolithic of Central Asia'), and a possible autochthonous origin for Late Pleistocene technologies (Liu, et al., 2013b).

More than 1500 faunal specimens have been recovered at the site, including two possible bone tools (Liu, et al., 2013a, p. 216), and the site is in close proximity to the Nihewan palaeo lake (Keates, 2010, p. 409). The lake would have been at a relatively low level during the hominin occupation, and three distinct kinds of environment seem to have been present during this time; firstly, a humid and warm grassy forest, becoming temperate and humid, finally becoming temperate and dry (Pei, et al., 2009). A small burrowing rodent, called a zokor, might have been a possible prey for hominins around this time (Ao, et al., 2013b, p. table 2). If they were able to hunt medium-sized game, bison, horse, and gazelle were also present in the landscape (Deng, et al., 2008, p. table 1). Canids were also present, which may have provided scavenging opportunities but also a source of danger.

Chenjiawan

Dated by magnetostratigraphy to *c.* 1.1 (Shen, et al., 2010, p. 171, Wang, et al., 2006), a total of 1625 lithic artefacts were excavated from the site of Chenjiawan (Guan, et al., 2016, p. 87). This site used to be considered as older than Donggutuo and Xiaochangilang on the basis of stratigraphy, but a geological faulting led to a revaluation (Schick & Zhuan, 1993, p.

29, Schick, et al., 1991, p. 19). 608 of the artefacts refitted into 157 different refit groups (Guan, et al., 2016, p. 89). A very high percentage of the artefacts were classified as 'debris', with only around 5% of the assemblage being classified as either a core or a tool. This lack of cores and tools may be due to the curation of artefacts away by hominins, as the high percentage of small artefacts appears to preclude natural disturbance.

On the whole, cores tend to be small on average, and bipolar percussion cores have been identified in the assemblage as well as bipolar flakes (Shen & Qi, 2004, p. 284). However, it has been suggested that most of the assemblage appears to have bee produced with freehand direct percussion, but this may underestimate the role of bipolar percussion knapping in the creation of the assemblage (Yang, et al., 2016, p. 12). The flakes are mostly short and irregular, and this may be due to the raw material used at the site (Guan, et al., 2016, p. 89). These raw materials are finer grained than the materials used at Xiaochangliang and Donggutuo (Schick & Zhuan, 1993, p. 29, Shen & Qi, 2004, p. 295). They are described as either being predominantly made on a fine grained volcanic breccia (Guan, et al., 2016, p. 87), or good quality chert (Schick, et al., 1991, p. 19). Remaining natural surfaces seem to indicate small clast size.

The faunal remains recovered from the site are fragmented and abraded (Shen & Qi, 2004, p. 283); however, the artefacts are described as 'fresh' (Schick, et al., 1991, p. 19), so this raises some questions about association of the two. At least the artefacts are probably *in situ*.

Huojiadi

At Huojiadi, 60 stone artefacts were recovered, mostly made on chert, but also including other siliceous rocks and quartzite (Liu, et al., 2010b, p. 400). The site has been dated by magnetostratigraphy to *c.* 1mya. The assemblage includes cores, flakes, retouched flake

tools. Scrapers in particular are very common, one third of the assemblage. At least one of the cores has been identified as a bipolar core (Liu, et al., 2013a, p. 218).

Around the same time, the site of Xujiapo, from which four lithics have been recovered, has been dated *c.* 1.01-0.91 mya (Liu, et al., 2013a, p. 216).

Maliang

After another slight hiatus in the Nihewan Basin sequence, the site of Maliang has been dated via magnetostratigraphy to *c.* 780kya (Shen, et al., 2010, p. 171, Wang, et al., 2005). Around 200 lithic artefacts were found at Maliang, associated with faunal specimens (Schick & Zhuan, 1993, p. 29), and it has been interpreted as a manufacture site (Shen & Qi, 2004, p. 290). These artefacts include flakes, some with retouch, and cores. The material is predominantly the local chert-like raw material known at other Nihewan Basin localities, although finer grained than the materials used at Xiaochangliang and Donggutuo (Shen & Qi, 2004, p. 295). Some technological attributes have been used by two authors to argue for 'developed' knapping skills on the part of the hominins who created the assemblage (Shen & Qi, 2004, p. 290). Use-wear analysis of the assemblage has suggested meat processing and bone processing (Shen & Qi, 2004, p. 294). Hominins of this time are more likely to have been capable hunters, and horse is the most obvious possible prey species in the faunal assemblage (Ao, et al., 2013b, p. table 2). Some fluvial abrasion has been identified on the artefacts, suggesting that limited disturbance or transport of the assemblage has taken place (Schick & Zhuan, 1993, p. 29, Schick, et al., 1991, p. 19). This disturbance may well relate to flooding of the site by the Nihewan palaeolake (Shen & Qi, 2004, p. 288). Magnetic sedimentological analysis has concluded that the occupation at Maliang took place during a glacial period (Ao, et al., 2010b), which based on the dating would correlate with OIS 20.

Dongpo

Lastly, the site of Dongpo has been dated using ESR to *c.* 321 ± 15 kya (Liu, et al., 2010a). This is the final site in the basin prior to the appearance of archaic *H. sapiens* fossils and Mousterian technology.

Nihewan Basin Summary

The lengthy chronology of sites in the Nihewan Basin has suggested to some authors that the area may have been occupied repeatedly from 1.7mya down to 0.3mya (Ao, et al., 2013a). This does not necessarily mean that it was occupied continuously. Dennell (2013b) has argued that harsh conditions may have precluded occupation during the winter months, and all year round during the harshest climatic conditions of the Lower-Middle Pleistocene. Dennell (2013b, p. 225) describes hominin occupation of the Nihewan Basin as "…discontinuous, infrequent, brief, and limited to favourable windows of opportunity". How early hominins might have survived the conditions of freezing, sub-zero winters in the area, is unknown, especially as evidence for fire-use and specialised hunting is absent. No fossil hominins exist at these sites to narrow down the species that may have been responsible for these assemblages, although *H. erectus* appears to be most likely based on the rest of the Chinese fossil record.

Mode 1 core and flake technology, potentially of varying complexity, persists throughout the Lower-Middle Pleistocene in the Nihewan Basin. The cores are mostly amorphous (Shen, et al., 2010, p. 175), flakes tools are retouched mostly in an *ad hoc* manner, and hard hammer reduction via direct percussion is the most common (Liu, et al., 2013a, p. 221). A bipolar component emerges not in the earliest assemblages, but soon after *c.* 1.36mya at Xiaochangliang where it is very common. Rather than persisting in the sequence, it then seems to disappear and reappear just prior to 1mya in the small flake industry of Donggutuo, Chenjiawan, and Huojiadi, before disappearing again. The increasing complexity of the

knapping strategies employed at Donggutuo that are suggested by some authors, and also a greater selectivity in the raw material strategies and core reduction strategies at Chenjiawan and Maliang, might represent an increase in behavioural complexity at and just after 1mya in the basin. Alternatively, these patterns may simply represent a snapshot of the diversity of technological strategies of Nihewan hominins, and might be representative of simple technological drift within a repertoire of possible behaviour.

The raw materials utilised at the Nihewan Basin sites suffer from substantial internal flaws and jointing (Yang, et al., 2016, p. 13), which may account for the prevalence of the bipolar method. Mostly the hominins at these sites used a low quality locally-sourced quartzite, although chert and quartzite described as 'chert-like' is available in the local area, and comprises a significant percentage of some of the later assemblages, it is slightly further out from some sites (Shen, et al., 2010, p. 175). Experimental knapping studies have anecdotally confirmed the efficacy of bipolar technique for production of small usable flakes on this raw material (Shen, et al., 2010, p. 178). The dominant reduction strategy results in the production of small, simple flakes on low quality local raw materials for expedient use (Shen, et al., 2010, p. 178). Such a strategy is fairly simple and very adaptable (Liu, et al., 2013a, p. 221). No traces of a Mode 2 or handaxe technology are currently known in the Nihewan Basin (Ao, et al., 2013a, Guan, et al., 2016, p. 91). Quite possibly the quality of the raw material was not high enough for the production of refined, bifacial core tools.

The palaeolake that many of the sites cluster around would have been a source of drinkable water in the early Pleistocene, and it would also have been an attractor to other animals in the region (Ao, et al., 2013b, p. 4). The action of the palaeolake may have served also to expose the quartzite bedrock that could have provided a raw material source (Ao, et al., 2013b, p. 4). The environment around the palaeolake during the time of occupation would have consisted of mixed grassland and woodland (Ao, et al., 2013b), an environment which

was established in the Nihewan Basin from *c.* 2.5 mya down to *c.* 500 kya (Ao, et al., 2013a). This mix may have resulted from an increase in aridity and an overall cooling throughout the early Pleistocene that reduced tree cover and increased the prevalence of grasslands within the basin (Ao, et al., 2010a). The early Pleistocene would have seen increased fluctuations of climate and environment (Li, et al., 2016, p. 109), rather than stability, further reinforcing Dennell's (2013b) suggestion that this high latitude region may not have been continuously occupied throughout the Lower-Middle Pleistocene. It is interesting to note, however, that the evidence from Maliang suggests that hominins were able to occupy the area even during glacial periods from around *c.* 0.8mya. In terms of edible floral resources, grasslands may have provided edible seeds, but this is likely to have been less productive for hominins than the large number of resources that can be available in wooded and humid environments, comparable in many ways to the resources thought to be available to hominins at Dmanisi (listed in section '3.1.1 Dmanisi'). Especially, the range of edible plant resources that can be identified at Madigou shows just how rich an area of mixed woodland and grassland near a lake shore can be. However, Shen et al. (2010, p. 177) suggest that use-wear analysis on lithics from the Nihewan basin sites indicate carcass processing as the most prevalent activity (with woodworking second), though whether these carcasses were acquired through hunting or through scavenging at these earlier sites is uncertain. Liu et al. (2013a, p. 218) have also suggested that the harsh and variable conditions of early Pleistocene northern China could have been mitigated by an increased exploitation of animal resources, and Ao et al. (2013b, p. 89) consider the mere coexistence of Palaeolithic sites with faunal sites to be an indicator that hominins preyed on horse and deer (although this may be an overestimation of their hunting capabilities, as scavenging the kills of other carnivores is also possible). Early occupation in the Nihewan basin may have focused on the rich plant resources from wooded areas, with occasional scavenging of carnivore kills, but later in the Pleistocene, occupation at Maliang might indicate that hunting had become a part of the

hominin behavioural repertoire by this time. Dennell (2013b, p. 228) concludes that none of the early Pleistocene sites in the Nihewan basin constitute strong evidence for hunting, and this is the more conservative interpretation.

The following sites from the remaining record of Lower-Middle Pleistocene China will be considered in a chronological order.

3.4.2 Lower Pleistocene Sites

Gongwangling (Lantian)

In Shanxi Province, cranial fragments and molars attributed to *H. erectus* have been recovered from a loess deposit at Gongwangling (Bar-Yosef & Wang, 2012, p. 322, Norton, et al., 2010, p. 163, Schick & Zhuan, 1993, p. 27). The fossils are associated with around 20 lithic artefacts that have been identified as flakes, cores, and scrapers. Mostly these artefacts are made on quartzite and quartz pebbles. A quartzite biface, similar to an African Acheulean handaxe, is described by Clark & Schick (1988, p. 443) as having come from the loess deposit at the site and being associated with the *H. erectus* fossils, but this is probably the surface find of a biface referred to by Wu (2004, p. 135).

For a while before any secure dating, the Gongwangling specimen looked to be a contender for the earliest *H. erectus* fossil in China. Faunal and palaeomagnetic dating originally suggested a late date of *c.* 1.10-1.15 mya (Wang, et al., 2014a, p. 185); however, recent re-dating has provided a more reliable date of *c.* 1.63 (Zhu, et al., 2015), which places the fossil in a warm interglacial period rather than in a glacial period as previously.

Faunal specimens associated with the Gongwangling hominin have suggested a steppic environment with mixed forest and brush, and swamp (Wang, et al., 2014a, p. 185), although the deposit that the cranium was recovered from may indicate relatively cold and arid conditions, at odds with the fauna and the dating (Wang, et al., 2014a, p. 186).

Longgupo (Wushan)

In Chongqing Province in southwestern China, a stratified site in a Triassic karstic cave has produced a possible hominin fossil attributed variously to *H. erectus, H. erectus wushanensis*, *H. habilis*, and *H. ergaster (Hou & Zhao, 2010, p. 14,* Norton, et al., 2010, p. 162). The fossil itself is a mandibular fragment with teeth, but might actually be attributable to a non-human ape rather than a hominin (Wu, 2000).

Combined ESR/U-series dating on teeth initially provided a date of *c.* 1.8-1.4 mya (Han, et al., 2012), contradicting some of the very early dates initially proposed on the basis of biostratigraphy *(Hou & Zhao, 2010, p. 15)*. However, more recent ESR/U-series results suggest a much earlier date of *c.* 2.48mya (Han, et al., 2017), which might vindicate early initial estimates, but is difficult to reconcile with the current record of Palaeolithic Asia if the fossil is regarded as a hominin. An early Pleistocene date seems likely, but the tentative possibility for a date right at the beginning of the Lower Pleistocene remains a possibility.

The fossil is associated with a lithic technology similar to other Mode 1 core and flake assemblages in China (Bar-Yosef & Wang, 2012, p. 323), but it does include a large tool component comprising various 'chopping' tools (Wei, et al., 2014, p. 158). 19 cores were identified in the assemblage, and the cores tend to have only a few removals each, typically only a single removal (Boëda & Hou, 2011, p. 150). This low concentration of reduction on the cores is attributed to difficult nature of the limestone for working. Evidence for bipolar technique of core reduction is reported in the form of 142 flakes bearing diagnostic signs of bipolar production (Boëda & Hou, 2011, p. 167), and pitted anvils (Wei, et al., 2014, p. 157). 16 percussors and fragments were reported, and on the basis of experimentation it seems likely that some of the fragments represent anvils (*enclumes*) used in bipolar knapping (Boëda & Hou, 2011, p. 174).

The artefacts were made on a very hard non-homogenous local Triassic limestone or 'mircrite' with microfractures *(Hou & Zhao, 2010, p. 15,* Wei, et al., 2014, p. 158), and the Longgupo hominins had to adapt to the idiosyncrasies of this raw material (Boëda & Hou, 2011, p. 175). Some limited number of raw materials other than the limestone are mentioned, such as sandstone and different igneous and metamorphic rocks (Wei, et al., 2014, p. 158), but it seems like raw material selection behaviour by the hominins at the Longgupo site was an important component of knapping success and quality in the assemblage (Boëda & Hou, 2011, p. 153).

Yuanmou (Shangnabang)

In Yunnan Province, also in the southwest, substantial Pleistocene fossil deposits that include hominin remains and artefacts have been found (Schick & Zhuan, 1993, p. 25, Bar-Yosef & Wang, 2012, p. 323, see Figure 26). Two hominin incisors found here have been attributed to *H. erectus yuanmouensis (Hou & Zhao, 2010, p. 12)*.

Some confusion still remains about the exact details and associations of the different artefacts and faunal specimens recovered (Schick & Zhuan, 1993, p. 26). At least 22 lithic artefacts have been recovered from the site, including flakes, cores, scrapers, and choppers, made on quartz and quartzite *(Hou & Zhao, 2010, p. 12)*.

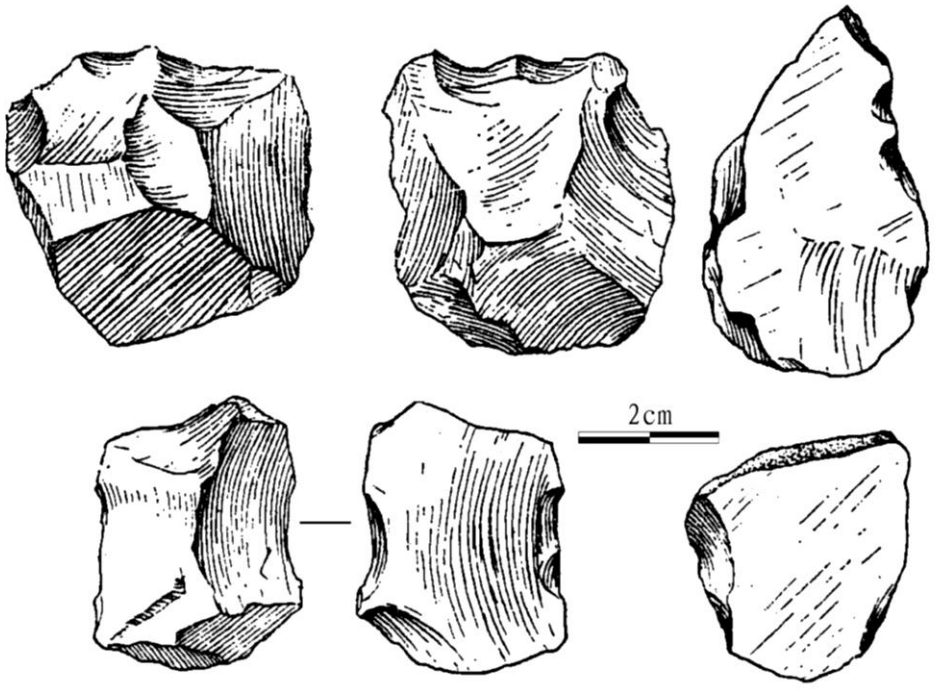

Figure 26 - Artefacts from the site of Yuanmou, associated with hominin fossil teeth. Figure from Hou & Zhou *(2010, p. Fig 2)*

A wide variety of dating methods including magnetostratigraphy, ESR, fission-track dating, and biostratigraphy have produced a date of *c.* 1.7 mya for this site *(Hou & Zhao, 2010, p. 12)*. These new dates have helped mitigate some of the concerns with the site's antiquity, but uncertainty still remains with some authors suggesting a Middle Pleistocene date (Schick & Zhuan, 1993, p. 26, Dennell, 2009, p. 181).

Longgudong (Juyuandong)

In Hubei Province, central China, the site of Longgudong is rich in faunal fossils that are interpreted as indicating a Lower Pleistocene date *(Hou & Zhao, 2010, p. 13)*. This date is supported by a combination of biostratigraphy and palaeomagnetism (Li, et al., 2017a, p. 456). Four teeth designated as *Homo*, possibly *H. erectus* with some *H. habilis* affinities, have been recovered, but these have been lost since their discovery and now only exist as casts (Li, et al., 2017a, p. 456).

632 stone artefacts have also been reported from the site, including cores, flakes, percussors, and flake tools *(Hou & Zhao, 2010, p. 14)*. Evidence for bipolar core reduction was identified within the assemblage *(Hou & Zhao, 2010, p. 14)*. Li et al. (2017a, p. 457) report on 27 artefacts that were excavated from the site, including flakes and cores. All of these artefacts were made on chert, with the exception of one quartzite flake (Li, et al., 2017a, p. 457). Two flakes from this sample are diagnostic of bipolar core reduction, and three of the cores are identified as bipolar cores (Li, et al., 2017a, p. 458). Overall, the assemblage is interpreted as expedient, casual flake production, and compared technologically with African Oldowan sites and other small flake sites in China, particularly in the Nihewan Basin (Li, et al., 2017a, p. 459). A few of the faunal specimens are reported as showing marks of modification by stone, and are interpreted as bone tools *(Hou & Zhao, 2010, p. 14)*.

Renzidong

In eastern China, in Anhui Province, the cave site of Renzidong has produced a rich faunal assemblage *(Hou & Zhao, 2010, p. 12)*, which is probably a natural death accumulation (Bar-Yosef & Wang, 2012, p. 323). Only tens of possible artefacts have been found in association (Bar-Yosef & Wang, 2012, p. 322), and both stone and bone artefacts are reported (Norton, et al., 2010, p. 163). The stone tools are classified as small cores, flakes, and flake tools *(Hou & Zhao, 2010, p. 12)*.

These claimed artefacts are not without ambiguity, and the ferrolite raw material is not known from other Chinese sites, nor particularly easy for the identification of diagnostic signs of anthropogenic fracture (Norton, et al., 2010, p. 163). The other raw materials identified include siliceous limestone and mudstone, sandstone, and gneiss *(Hou & Zhao, 2010, p. 12)*.

The deposits have been dated through biostratigraphy and ESR dating to the early Pleistocene, but these dates conflict slightly so some uncertainty remains (Norton, et al., 2010, p. 163), and there may, in fact, be no artefacts here.

Xihoudou (His-hou-tu) & Bailongdong

In Shanxi Province, a small assemblage of 32 artefacts have been found in association with a large number of vertebrate remains at Xihoudou (Bar-Yosef & Wang, 2012, p. 322, Schick & Zhuan, 1993, p. 27). The artefacts were made by flaking quartzite cobbles, and have been classified as choppers, cores, and flake tools such as scrapers (Schick & Zhuan, 1993, p. 27). The artefacts show abrasion from disturbance in a fluvial system (Bar-Yosef & Wang, 2012, p. 322). The site has been tentatively dated with faunal comparison and magnetostratigraphic methods to *c.* 1.27 mya (Bar-Yosef & Wang, 2012, p. 322, Norton, et al., 2010, p. 161), and to *c.* 1.4mya with a cosmogenic burial method (Kong, et al., 2013).

Possibly also of Lower Pleistocene age is the site of Bailongdong in Hubei Province, where six teeth attributed to *H. erectus* and a few artefacts have been recovered (Norton, et al., 2010, p. 162). These finds have no real date, but they appear to be probably late early Pleistocene on basis of biostratigraphy (Norton, et al., 2010, p. 161).

3.4.3 Middle Pleistocene Sites

Zhoukoudian

The famous series of localities at Zhoukoudian, just west of Beijing, provide some deposits that span the Lower-Middle Pleistocene divide. The area contains a series of karst limestone cave sites, providing 27 localities in total that collectively span almost the entire Pleistocene (Shen, et al., 2016, p. 6). However, only six of the localities have produced stone tools (Shen, et al., 2016, p. 9). Locality 13 has not been thoroughly dated, but fauna has been used to

suggest it might be the oldest of the lithic sites (Shen, et al., 2016, p. 9). Low quality quartz was used to manufacture the flakes, cores, and flake tools, found there, alongside one chert core (Shen, et al., 2016, p. 9).

However, the best evidenced and most relevant of the cave sites for the purposes of the current study is Locality 1.

Zhoukoudian Locality 1 (Longushan)

At Locality 1, the remains of at least 40 *H. erectus* individuals have been recovered (Norton & Gao, 2008, p. 732, Schick & Zhuan, 1993, p. 30). The site contains multiple occupation layers, but the hominin fossils and artefacts are primarily concentrated in layers 4, 8, and 9 (Schick & Zhuan, 1993, p. 30).

ESR dating of teeth has suggested a date range of 550-300 kya for the fossil layer (Grun, et al., 1997), and U-series dating has placed layer 3 around 500-400 kya, and the lower strata *c.* 770 kya (Shen, et al., 2001, Shen, et al., 2009). Somewhere between 20,000 to 100,000 lithics have been recovered from the site (Schick & Zhuan, 1993, p. 30). Vein quartz is the dominant raw material, but some tools are made on chert and crystal quartz, as well as fluvially-worked cobbles and nodules of other stone types (Bar-Yosef & Wang, 2012, p. 324, Schick & Zhuan, 1993, p. 30). The artefacts include flakes, cores, scrapers, percussors, and a few core choppers (Bar-Yosef & Wang, 2012, p. 324, Clark & Schick, 1988, p. 443). Some of the flakes are retouched, but no formal tool types are present and the retouch is informal in character (Bar-Yosef & Wang, 2012, p. 324, Schick & Zhuan, 1993, p. 25).

Bipolar percussion is very common throughout the sequence, and has been identified in the assemblage from cores and anvils (Bar-Yosef & Wang, 2012, p. 324, Clark & Schick, 1988, p. 440, Schick & Zhuan, 1993, p. 30, Shen, et al., 2016, p. 9, see Figure 27). Experimental studies of the bipolar knapping at this locality have suggested it to be less efficient than freehand knapping for successful flake production, and therefore an expedient strategy (Li,

2016). Freehand knapping by direct percussion becomes more dominant in layers 6 and 7, and there is a slow reduction in large tools from the earlier to the later phases of the sequence (Shen, et al., 2016, p. 9). Raw material selection appears to change slightly in the later layers 1-5, with an increase in good quality chert (Shen, et al., 2016, p. 6).

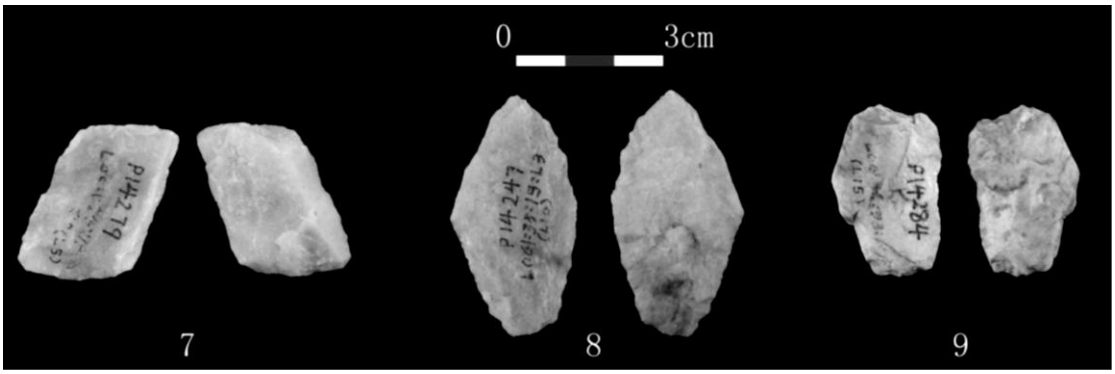

Figure 27 - Excavated examples of bipolar flakes from Zhoukoudian Locality 1, layers 4 and 5. Comparison with experimentally produced bipolar flakes have confirmed the identification of this reduction technique at the site. Figure from Li (2016, p. Fig 2), modified by current author

The assemblage is probably best characterised as another predominantly 'small tool industry', not so dissimilar to those in the Nihewan Basin (Shen, et al., 2016, p. 11). However, it is now undeniable that the Chinese record can no longer be thought of simply as a 'chopper' culture (as it originally was under the 'Movius Line' model), when all stratified Pleistocene sites are showing such an importance for small flake production (Shen, et al., 2016, p. 11).

The record of faunal remains is very rich, and some specimens exhibit butchery marks (Bar-Yosef & Wang, 2012, p. 324). Some putative hearths have remained unsubstantiated, and no direct evidence can be claimed for hominin use of fire (Weiner, et al., 1998); however, some of the bones that have been recovered exhibit evidence of burning (Bar-Yosef & Wang, 2012, p. 324).

Later dated localities at Zhoukoudian, such as Locality 15, lack bipolar technique and have retouched tools that attribute them to the beginning of the Middle Palaeolithic (Bar-Yosef &

Wang, 2012, p. 324). Locality 4 contains hominin remains identified as archaic *H. sapiens*, as does Locality 15, the latter of which has been argued to represent the local transition between *H. erectus* and local populations of *H. sapiens* that is supported by several researchers in this area (Shen, et al., 2004). Locality 26 is the famous 'Upper Cave' site, with Late Pleistocene burials (Norton & Gao, 2008).

Chenshan & Maozhushan

In Anhui Province, artefacts have been found at the sites of Chenshan and Maozhushan and dated to the Middle Pleistocene. Chenshan has been very roughly dated using ESR to *c.* 817-126 kya, while Maozhushan has been dated to *c.* 665-420 kya with ESR (Norton, et al., 2010, p. 161).

Chenjiawo (Lantian)

In Shannxi Province, and also from the 'Lantian' area shared by the Gongwangling site, Chenjiawo has provided artefacts and hominin fossils associated with faunal remains. Only four stone artefacts were recovered (Norton, et al., 2010, p. 163). These were associated with mandibular fossils attributed to *H. erectus* (Schick & Zhuan, 1993, p. 27). These individuals are possibly more primitive in some respects than the Zhoukoudian *H. erectus* individuals, but are argued to be less primitive than the Gongwangling specimen (Wang, et al., 2014a, p. 186).

The faunal remains at the site suggest a Middle Pleistocene date (Schick & Zhuan, 1993, p. 27), and this is supported by loess sequence correlation, which suggest a date of *c.* 650 kya in a warm period (Norton, et al., 2010, p. 161).

Liuwan

In the Luonan Basin, also in Shannxi Province, three different localities have been investigated at Liuwan. The first of these is a loess section without artefacts, but localities two and three have provided several artefacts including flakes, cores, scrapers and

percussors (Sun, et al., 2014, p. 195). Mostly these artefacts have been made on vein quartz with a few quartzite examples, and several artefacts provide evidence of bipolar percussion (Sun, et al., 2014, p. 196). OSL dating at Liuwan Locality 1 has been correlated with the stratigraphic sequences at Localities 2 and 3 to provide a date of *c.* 625-521 kya for the oldest artefact layers, and *c.* 575-568 kya for the youngest. (Sun, et al., 2014, p. 196).

Large cutting tools are commonplace in a surface context within the basin, but are unknown from the stratified assemblages of the Liuwan localities (Sun, et al., 2014, p. 196), or Longyadong (looked at later).

Lushi Basin

East of the Luonan basin, several artefacts of Middle Pleistocene age have been excavated from a loess deposit in the Lushi basin (Lu, et al., 2011). The artefacts represent a simple core and flake technology that has been compared to the technology from Zhoukoudian locality 1, and is dated to *c.* 620-600kya.

Huludong

Further hominin fossils have been found at a cave site near Nanjing, in Jiangsu Province. At Huludong, two partial crania and a tooth attributed to *H. erectus* have been found in association with a Middle Pleistocene faunal assemblage (Norton, et al., 2010, p. 164). No artefacts have been found in association with these fossils (Norton, et al., 2010, p. 161). An initial attempt at ESR dating of the deposits may have underestimated their date, and subsequent U-series dating on what? places it *c.* 620-500 kya (Norton, et al., 2010, p. 164).

Quyuanhekou (Yunxian)

Hominin fossils are also known from Quyuanhekou in Hubei Province. *H. erectus* fossils have been found at the site in association with around 200 lithic artefacts (Norton, et al., 2010, p. 161). The fossils represent two crushed crania from adult *H. erectus* individuals, possibly male (Norton, et al., 2010, p. 162). The lithics include cores and flake tools, all made on local

quartz and sandstone (Norton, et al., 2010, p. 162). A number of refits in the assemblage suggest that Quyuanhekou may represent a manufacture site (Norton, et al., 2010, p. 162). The site has been dated to *c.* 581 kya via ESR dating on associated teeth (Norton, et al., 2010, p. 161).

Fangniushan & Hexian (Longtandong)

Both in eastern China, Fangniushan in Jiangsu Province and Hexian in Anhui Province provide two further sites with Middle Pleistocene dates. At the former site 54 artefacts have been excavated, which were made on a local quartzitic and feldspathic sandstone (Norton, et al., 2010, p. 165). These have been dated to *c.* 432-209 kya (Norton, et al., 2010, p. 161). The karstic limestone cave site at Hexian, on the other hand, provides several hominin fossils but no artefacts (Schick & Zhuan, 1993, p. 31, Norton, et al., 2010, p. 161). The fossils are represented by cranial fragments and teeth, which have been attributed to *H. erectus* (Norton, et al., 2010, p. 164). These have been dated with a combination of ESR and U-series dating to *c.* 412 kya (Norton, et al., 2010, p. 161).

Yumidong

Recently published this year is the site of Yumidong in the Three Gorges region of the Yangtze River, in the south-west of China. Faunal remains from the sequence are indicative of a Middle-Late Pleistocene date, and uranium-thorium dating has placed the sequence as stretching from *c.* 400 kya down to the Holocene (Wei, et al., 2017a, p. 110).

Lithic artefacts are claimed for the majority of the sequence, including the oldest layer (Wei, et al., 2017a, p. 110), but an analysis or description of the artefacts from this oldest layer have not yet been published in English. The artefacts from the later layers are mostly unambiguous as worked, anthropogenic products, but not especially diagnostic of particular industries. The limestone artefacts seem to be representative of a core and flake technology with informally retouched flake tools, and the argument that these artefacts “have nothing

in common with Old-World prehistory including Europe, Africa, the Near East and even the Indian Subcontinent and northern China" (Wei, et al., 2017a, p. 119) seems extreme. Conservatively, this might be best described as a core and flake assemblage of probable Pleistocene age.

Longyadong

In the Luonan Basin, Shannxi Province, the cave site of Longyadong has provided artefacts dated to *c.* 356-273 kya with TL (Norton, et al., 2010, p. 161). A tooth, supposedly originally from the cave, was also recovered by locals and is attributed to *H. erectus* (Norton, et al., 2010, p. 163). Handaxes have been found in surface assemblages elsewhere in the Luonan Basin, but not from the cave site.

Heshangdun & Qizianshan

On the eastern coast of China are two further sites of Middle Pleistocene date. Heshang in Jiangsu Province has around 200 artefacts, on local quartzitic and feldspathic sandstone (Norton, et al., 2010, p. 165). Magnetostratigraphy has placed these artefacts *c.* 300 kya.

In Yiyuan county, Shandong Province, the Qizianshan cave site has provided *H. erectus* fossils from two localities, a fragmented cranium and several teeth (Norton, et al., 2010, p. 164). These finds have no artefacts associated with them, and are unfortunately not dated except by biostratigraphy using associated fauna, which suggests a Middle Pleistocene date (Norton, et al., 2010, p. 161).

Middle Pleistocene Sites in the Nihewan Basin

While previously typed as 'Middle Palaeolithic' technologies, artefacts from Motianling and Queergou may equally be thought of as Middle Pleistocene 'Lower Palaeolithic' technologies. OSL dating places Motianling at *c.* 315kya, and Queergou at *c.* 260kya (Guo, et al., 2015, Guo, et al., 2016). The artefacts excavated from these sites represent a simple core and flake technology, with flake tools such as notches and scrapers. The technology is

simple, comparable with earlier Nihewan basin sites, and contains no Levalloisian or Mousterian elements. Zokor, horse, and deer are possible prey species, as well as perhaps woolly rhino and ostrich.

3.4.4 Large Cutting Tools in China

The Movius Line

The presence of large cutting tools in the Chinese record is an issue of particular interest, due to the 'Movius Line' debate. The 'Movius Line' is the popularised name of a model proposed by the famous archaeologist Hallam Movius (1948, p. 409). He originally observed that a rough dividing line could be drawn across the Eurasian continent on the basis of core tools prevalence, separating off the 'chopper culture' regions of East Asia, South East Asia, Central Asia, and Eastern Europe off from traditional Acheulean regions. Carlton Coon coined the term 'Movius Line' two decades later to describe Movius' observation (Wang, et al., 2012, p. 1).

Movius (1948, p. 412) explained this pattern in primarily cognitive terms, as he saw East Asia as "a region of cultural retardation" in the Palaeolithic, and regarded its technologies as "monotonous and unimaginative". In Dennell's (Dennell, 2016) paper 'Beyond the Movius Line', he noted that Movius' views may well have been influenced by the work of his senior contemporary Teilhard de Chardin, who proposed a similarly unflattering view of the Pleistocene East Asian record. Aside from its overt racism, the model seriously underestimates the possible complexity and adaptability of core and flake technologies in the region. In terms of dispersal and hominin evolution, it also relegates East Asia to the periphery of the Lower Palaeolithic world.

As will be seen shortly, large cutting tools have been found in abundance at numerous surface sites in China, and even in a few stratified deposits. There is still some debate over whether these can be defined as true handaxes, true 'Acheulean' tools, or even bifaces.

Nonetheless, these discoveries have caused a recent reformulation of the Movius Line model by several researchers. Norton, Bae, Lycett and colleagues have endeavoured to replace the original formulation of the Movius Line model (the 'Movius Line *sensu stricto*'), with a new formulation that they define as a 'Movius Line *sensu lato*' (Norton, et al., 2006, Norton & Bae, 2008, Lycett & Norton, 2010, p. 56, Lycett & Bae, 2010). The Movius Line *sensu lato* does not propose that there are no Mode 2 technologies in East Asia, but instead seeks to identify a meaningful pattern in the regional presence, absence, and nature of those technologies within East Asia versus traditional Acheulean areas in Africa and Eurasia (Lycett & Norton, 2010, p. 56). This pattern is contingent on three observations:

1. The observation that there are relatively few handaxe sites in East Asia,
2. that the total numbers of handaxes recovered from these sites is relatively low,
3. and finally the argument that the handaxes recovered from East Asia are in some measurable sense morphologically distinct from the examples in traditional Acheulean areas (Norton & Bae, 2008, p. 1149, Lycett & Bae, 2010, p. 525).

As will be seen, the Movius Line *sensu lato* is also not without controversy, and the veracity of these three observations is intensely contested. In spite of these, a variety of explanations have been proposed to explain the Movius Line pattern.

Evidence for Large Cutting Tools (LCTs) east of the Movius line

The Dingcun site in Shanxi Province, northern China, has produced a large number of surface finds of bifaces, cleavers, and picks, mostly made on a dark hornfels material (Schick & Zhuan, 1993, p. 33). Although a small number of artefacts appear to have been excavated from a layer associated with mammal teeth dateable to *c.* 210-160kya, it is unclear whether any of the excavated artefacts are LCTs, because the surface and excavated assemblages are presented as one assemblage in the analysis (Yang, et al., 2014). Also in Shanxi Province, the Luonan Basin has proven to be a very rich area, where more than 90,000 lithic artefacts have

been recovered, including numerous 'crude' bifaces (Bar-Yosef & Wang, 2012, p. 325, Norton, et al., 2010, p. 161, Lu, et al., 2011, p. 142, see Figure 28). Most of these bifaces are surface finds on river terraces, but several have been found *in situ* in loess sequences (Bar-Yosef & Wang, 2012, p. 324). There has been some difficulty in dating finds generally in the Luonan Basin, but a magnetostratigraphic study has dated core and flake assemblages there to *c.* 800-700 kya and *c.* 400-300 kya (Lu, et al., 2011, p. 146). The same study has provided an age of 200-100 kya for some stratified LCTs (Lu, et al., 2011, p. 146). Most of the other handaxes in the sequence date to around 400-300 mya (Bar-Yosef & Wang, 2012, p. 325).

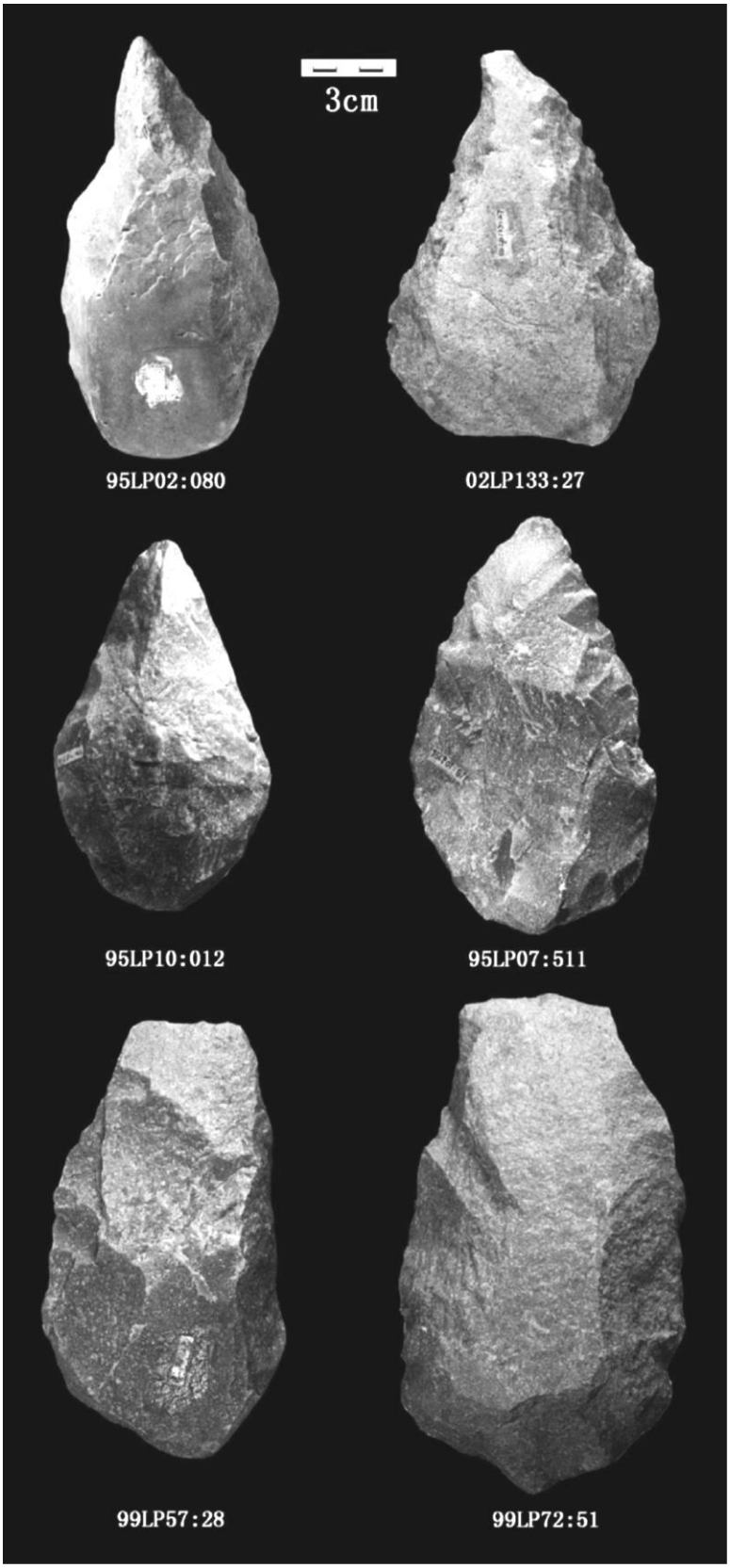

Figure 28 - Picks (top row), handaxes (middle row), and cleavers (bottom row) from the Luonan Basin. Figure from Gao & Guan (In Press, p. Fig 2)

In Lantian, also in Shanxi Province, where the sites of Gongwangling and Chenjiawo are located, several surface finds of handaxes are also reported (Wang, et al., 2014a, p. 186). Along the Bahe River Terraces, the sites of Jijiawan and Xiazhaijiacun have provided picks and possible handaxes (Wang, et al., 2014c, p. 653). Xiazhaijiacun's several examples of picks or handaxes may roughly date to *c.* 600-300 kya on the basis of stratigraphic correlation (Wang, et al., 2014a, p. 188). The third palaeosol at Jijiawan, which has provided the large cutting tools has been dated via OSL to *c.* 156 kya (Zhuo, et al., 2016, p. 320).

Lots of LCTs are reported from the Bose (or Baise) Basin in Guangxi Province, southern China. Exposures along the Youjiang River have provided bifaces, unifaces, and picks made on large, rounded cobbles (Bar-Yosef & Wang, 2012, p. 325). Some are surface finds, but the vast majority of LCTs from Bose have been excavated (Hou, et al., 2000, p. 1622), for instance at the Nanbanshan and Fengshudao localities (Wang, et al., 2008, Wang, et al., 2014b, Zhang, et al., 2010). These artefacts from several different localities, some purported to be found stratified beneath a core and flake industry, were also found in association with tektites and dated to *c.* 0.8 mya (Hou, et al., 2000, p. 1622, Wang, et al., 2008, Wang, et al., 2014b). Previously, a total of around 100 bifaces have been reported from the Bose Basin (Hou, et al., 2000, p. 1623, Huang, et al., 2012), although this number has almost certainly increased since it was first reported. At Fengshudao, handaxes, picks, and choppers are reported in association with bipolar flakes and bipolar cores (Wang, et al., 2014b, p. 116). The finds of handaxes in the Bose Basin are distributed throughout the basin to some extent, but are most prevalent in the northwest, possibly correlating with raw material distribution (Xu, et al., 2012, p. 13). A very wide range of raw materials are represented at the different Bose Basin sites, with sandstone and quartzite being the most commonly utilised (Huang, et al., 2012, p. 8). There is no evidence for raw material selection based on quality at these localities (Huang, et al., 2012, p. 8), and at Fengshudao specifically the raw materials utilised

in the assemblage have been shown to be in roughly the same proportions as those cobbles of material that are found within the local area (Wang, et al., 2014b, p. 117).

Surface finds of LCTs are distributed across the entire area between the Bose Basin and the Luonan Basin, encompassing most of eastern and central China (Bar-Yosef & Wang, 2012, p. 326). Large cutting tools, including handaxes, cleavers, and picks, have been reported from across the Danjiangkou Reservoir Region in Hubei and Henan Provinces in central China (Kuman, et al., 2014, Kuman, et al., 2016, Li, et al., 2014a, Li, et al., 2014b). These tools are made mostly on local poor quality raw materials, predominantly quartz phyllite and trachyte (Kuman, et al., 2014, Li, et al., 2014b). Curiously, these raw materials seem to be specifically selected for working into bifaces, as the excavated assemblages from the region have much more varied raw material usage (Kuman, et al., 2014, p. 135), or a predominance of quartz such as at Shuangshu (Li, et al., 2014b, p. 396). The result of an experimental study has actually suggested that the quartz phyllite cobbles, which is strongly foliated and therefore has large fracture planes, splits most effectively with a bipolar method of knapping to produce split cobble blanks suitable for LCTs (Li, et al., 2017b). In fact, freehand knapping via direct percussion emerged as the least efficient of all knapping techniques for blank production on this raw material, and bipolar characteristics comparable to those produced experimentally appear common in the assemblage (Li, et al., 2017b, p. 34). The LCTs described for the region appear consistent with Acheulean definitions of large cutting tools, with perhaps some morphological differences introduced by raw material factors and blank selection strategies (Kuman, et al., 2014, p. 147, Li, et al., 2014a, p. 171).

The recent publication of a possible bone handaxe or proto-handaxe from Chongqing in south-west China is intriguing, but photographs of the find remain rather difficult to interpret (Wei, et al., 2017b).

Four ideas in particular have dominated explanation of the perceived Movius Line pattern, now that region-wide cognitive deficiency has been rightly rejected. Isolation caused by geographic or climatic factors has been proposed by several authors as a possible cause, including the authors of the Movius Line *sensu lato (Lycett & Bae, 2010, p. 527, Lycett & Norton, 2010, p. 61)*. Raw material constraints, either within East Asia itself or via the dispersal routes into East Asia, have also been proposed as possible causes for the 'loss' of Acheulean technologies by hominins in East Asia (Bar-Yosef, et al., 2012, p. 10) . Raw material constraints seem unlikely to be a factor, as the use of quartzite for refined large cutting tools are known archaeologically from both South Asia and East Asia (Petraglia & Shipton, 2008, p. 965), and the workability of Chinese quartzite in particular for Acheulean knapping has been demonstrated experimentally (Bar-Yosef, et al., 2012, p. 16). Another possibility that has been proposed is the 'bamboo hypothesis', which suggests that the availability of bamboo is East Asia during the Pleistocene may have provided an alternative raw material for tools that rendered bifacial technologies redundant (Bar-Yosef, et al., 2012, p. 12). This idea is very difficult to test, as not only is the prehistoric extent of bamboo unknown, but the reliance of this theory on perishable materials means it is unlikely to be evidenced empirically *(Lycett & Norton, 2010, p. 61)*. Furthermore, experimental studies have yet to comprehensively test the possible utility of bamboo in Palaeolithic technologies (Bar-Yosef, et al., 2012). Lastly, Lycett & Norton *(2010)* have also proposed a 'demographic model', which suggests that populations in East Asia may have been too unstable to facilitate the dispersal of a complex Mode 2 technology. They support this argument with an iterative founder effect model.

However, a careful examination of the evidence suggests that there really is no discernible pattern to show the existence of the Movius Line, either *sensu lato* or *sensu stricto*. Almost certainly large cutting tools, and in fact all core tools, are disproportionately represented in

surface assemblages due to their ease of identification and tendency towards robusticity. The clear importance and variety of core and flake technologies in China alone should suggest caution in giving the Movius Line debate too central a place in the Asian Palaeolithic discussion. Furthermore, large numbers of LCTs are now known from the Chinese record. Some authors have argued that these LCTs cannot be regarded as 'true' handaxes as they are known as distinctive types from Acheulean regions. However, studies of handaxe morphology have found considerable continuity between the East Asian examples and examples of handaxes from traditional Acheulean areas (Wang, et al., 2012, Petraglia & Shipton, 2008). Despite this, some authors have argued that East Asian handaxes may have arisen as an autochthonous development independent of other Acheulean traditions (Wang, et al., 2012). Kuman et al. (2016) have argued that large cutting tools in China represent an example of convergent technology, and that the overall larger size and preference for cobbles as blanks set the Chinese examples apart (Kuman, et al., 2016, p. 62, Li, et al., 2014a).

Although the East Asian pieces have been noted to be generally thicker in the studies of handaxe morphology (Wang, et al., 2012, Petraglia & Shipton, 2008), an independent origin seems very unlikely considering the antiquity of the Acheulean tradition in nearby South Asia, which currently antedates that in East Asia by at least 1.1 my (Pappu, et al., 2011). Li et al. (2014a) argue that a 'true Acheulean' industry does exist in China, and that Norton & Bae's (2008) criteria for low frequency of LCT sites and low frequency of LCTs at LCT sites cannot be used to argue against the existence of true Acheulean industries in this area. Gao & Guan (In Press) have recently argued that the majority of Chinese handaxes centre on 'pick like' morphologies, which they see as digging tools with behavioural functions that complement the use of choppers. In this interpretation, the lengthy chronology of pebble industries and relative isolation from western Acheulean industries is used to explain perceived differences in the industries.

Ultimately, it seems unsatisfactory to divide between the East Asian handaxes and the wider Acheulean tradition. It seems most parsimonious to admit that handaxe production as known from other Acheulean-producing areas such as Africa, South West Asia, and South Asia has been demonstrated for the Chinese record. Some of the behavioural and demographic realities of this industry in this region, however, are still up for debate. The chronology of handaxes in the Chinese record remains very problematic with so few dated, stratified examples, but provisionally it might be suggested that non-Mousterian handaxe technologies appear in China in the middle of the Middle Pleistocene around 400 kya, and persist until the late Middle Pleistocene, not necessarily continuously. Overall, it seems unlikely that the Movius Line is a helpful term for debate, or a genuine behavioural pattern, or even a useful research heuristic.

3.4.5 Summary

The Chinese record is very rich, and contributes greatly to our understanding of Pleistocene hominin occupation in Asia. However, the nature of this record also raises a number of questions. In particular, some possibilities exist for a very early emergence of hominins, possibly even pre-erectus hominins, using an Oldowan type toolkit around 2mya. What does seem reasonable to conclude is that some form of *H. erectus* is present in China from at least the middle of the Lower Pleistocene, with a core and flake technology that became established as an adaptation and developed across the region temporally as well as geographically.

These core and flake industries dominate the Lower and Middle Pleistocene record in China. Some authors have proposed a split between small flake technologies in northern China, and chopper-based core and flake technologies in the south (Guan, et al., 2016, p. 90). On the other hand, quite possibly this over-emphasises the role of core tools in the interpretation of these assemblages, and may simply reflect raw material variability rather than a genuine

behavioural pattern. There are few formal tool types in any of these assemblages, especially the earliest ones, and raw material appears to play a large role in dictating the final form of the tools (Clark & Schick, 1988, p. 445).

Raw material usage is very diverse in China throughout the Pleistocene, and seems to be responsible not only for tool form but also for some of the different knapping strategies identified at the sites, such as the use of the bipolar percussion technique. Evidence for bipolar percussion is present in the south, potentially from the very earliest point in the Lower Pleistocene, but it doesn't appear up north in the Nihewan Basin until slightly later in the Lower Pleistocene. Use of bipolar percussion to work cores is evidenced throughout most of the Lower-Middle Pleistocene, and if the new dating from Longgupo is accepted, then bipolar is evidenced from the very earliest date in China, and even prior to Dmanisi. Bipolar percussion begins to be replaced by freehand direct percussion from the late Middle Pleistocene onwards, observable as a trend in both the Nihewan Basin sites and the Zhoukoudian localities.

Bipolar percussion has been found in association with handaxes in China, and is even used as a technique to produce handaxe blanks. Such handaxes appear in the Middle Pleistocene, and are present in the north, central and eastern areas. Claims for the original Movius Line concept, and the reformulated Movius Line *sensu lato*, cannot be supported on the basis of the Chinese record, and it seems most parsimonious to regard these as true Acheulean technologies that form a continuous link with the wider Old World record.

Where the palaeoenvironment is known from Chinese sites, there is good evidence for hominins adapting to quite harsh and variable conditions at high-latitudes, and managing to occupy areas seemingly continuously throughout the Lower-Middle Pleistocene. Increased animal resource exploitation may have been necessary to adapt to these conditions, as well as the controlled use of fire in the Middle Pleistocene that could also have played a role.

Sites with palaeoenvironmental evidence seem to suggest the importance for early hominins of mixed habitats of grasslands and steppe, with wooded patches of forest and waterbodies. These environments seem to grade from humid to arid. Non-lithic resources available in these environments, particularly in upland areas may have proved important for the initial dispersals of hominins into China (Schepartz, et al., 2000, p. 10).

Ao et al. (2010a) argue that the progressive aridification and cooling of the Chinese environment throughout the Pleistocene may have facilitated hominin occupation of Northern China by opening up the more open, grassland environments that hominins had chosen to exploit. While the impressively rich record of the Nihewan Basin does seem to support this idea, it might not be unproblematic to assume the simple relationship between hominin occupation and grasslands implied by the Savannah Hypothesis (see '4.2.1 Savannah Hypothesis challenged'). Central Asia sees an equivalent process of aridification and cooling during the Middle Pleistocene, which is more often seen as a climatic deterioration. If the aridification and cooling process indeed favoured hominin occupation in North China, it seems unlikely that it would have a similarly beneficial effect in Central Asia, where such cooling would be accompanied by increased glaciation and leading to further aridification, and a dramatic increase in aeolian processes of soil erosion.

The arrival of *H. sapiens* took place from about 200 kya onwards, as is evidenced at the Xinglong site (Peng, et al., 2014), and also Chaoxian in Anhui Province and Lingfengdong in Fujian Province, both around the 200 kya mark (Norton, et al., 2010, p. 161).

3.5 Mongolia

The Mongolian Lower-Middle Pleistocene record suffers from many of the issues that affect the other surrounding regions in Asia. A large area over which limited investigation has been

possible has resulted in several surface sites containing pebble choppers and bifacial artefacts, but no securely dated or incontrovertible proof of hominin occupation associated with Lower Palaeolithic technologies in the Lower-Middle Pleistocene.

Okladnikov (1978, p. 319) claimed a substantial antiquity for several finds made on survey in eastern Mongolia during the late 1960s and the 1970s. These finds of quartz and quartzite worked pebbles and choppers are described as “extremely archaic” (Okladnikov, 1978, p. 319), and compared by the author to early African and European assemblages. Unfortunately, with no firm context or date, these have to be disregarded. A number of other pebble tools from surface contexts in Mongolia have been ascribed to the Lower Palaeolithic, including the quartzite and basanite flakes and chopping tools from the Kolobochi assemblage collected in the south-west, an assemblage of lithics made on red jasper from Ulan Nor (Zwyns, et al., 2014, p. 5027). The site of Yarkh has provided yellow jasper choppers, bifacially worked pieces designated as handaxes by Okladnikov (Shackley, 1984, p. 25), but is likewise still fairly limited in the information it can provide on hominin occupation. Choppers and other ‘pebble tool’ assemblages have been found at surface sites such as Bayeb-Ukga and Kobdo-Zargalant in western Mongolia, Nariyn-Gol-17 (Valley of Lakes, Derevianko & Shunkov, 2008, p. 396), and well as the site of Tsagan-dyrs that has also provided one possible biface (Shackley, 1984, p. 25). Levallois and Acheulean artefacts have been reported for the cave site of Tsagaan Agui (White Cave, Derevianko & Shunkov, 2008, p. 399, Derevianko, et al., 2000), but the dating of these to the Lower Pleistocene is controversial and not widely accepted (Jaubert, 2015, p. 455).

3.5.1 Dno Gobi

In the Dno Gobi depression, a surface site with bifaces has been reported near to outcrops of jasper (Derevianko, 2008, p. 26). Derevianko (2008, pp. 25-6) refers to the technology as “late Acheulean” and “early Stone Age”, and although large handaxes and handaxe blanks

are described from the site, there are also “discoidal and Levallois cores” present. The handaxe types are described as “amygdaloid, subtriangular”, and “tabular”. Nearby outcrops of dark brown jasper provide the raw material for tool production at Dno Gobi, which has been interpreted as a workshop (Derevianko, 2008, p. 26). This deflated surface assemblage is only dated typologically, substantially limiting what can be said about it.

3.5.2 Flint Valley

At the surface site of Flint Valley (Tsakhiurtyn Hondi), in the south-eastern area of the Arts Bogd Range in the Gobi Desert, Derevianko (2008, p. 26) refers to “millions of artifacts ... from the Late Acheulean to the Late Paleolithic.” The total area of the ‘workshop’ is estimated at 20 km^2, with the densest 1 m^2 area producing up to 600 artefacts (Derevianko, 2008, p. 26). Bifacial and Levallois reduction techniques are both present (Derevianko, 2008, p. 26). A Pliocene flint breccia provided the raw material for the artefacts present in these surface assemblages (Derevianko, 2008, p. 26). The handaxes from the site are described as varying in condition “with lightly, moderately, or heavily abraded surfaces” (Derevianko, 2008, p. 26). The Flint Valley artefacts come from deflated surface assemblages, with probable mixing of material from several periods (Derevianko, 2008, p. 26).

3.5.3 Summary

Okladnikov was the first to identify the bifacial technique in Mongolia at the sites of Yarkh and Dno Gobi (Derevianko, 2008, pp. 25-6). However, these sites are contentious, and currently no uncontested, stratified Acheulean sites are known for this region. Even in surface assemblages, where finds of proto-handaxes and biface preforms have been claimed (Zwyns, et al., 2014, p. 5027), the evidence is rather limited for an Acheulean industry in Mongolia. Jaubert (2015, pp. 455-8) has noted that “…genuine Acheulean pieces seem rare, if not absent..”. Substantial uncertainty exists over whether many of the artefacts reported from the region as Lower Palaeolithic result from anthropogenic action (Jaubert, 2015, p.

458). In all likelihood, handaxe technologies in Mongolian surface assemblages represent early Mousterian technologies, and it seems probable that hominins using these technologies were the first to colonise this region (Yi & Clark, 1983, p. 183). The pebble component of these assemblages is probably not period or technology specific, and may not represent a Lower Palaeolithic technology.

Lacking as it does the tactical positioning of similarly poorly provisioned areas such as Iran, Afghanistan, and Pakistan, little can be taken for granted in the Mongolian record. Certainly it is worth noting its proximity to northern China, but the additional latitude and accompanying climatic conditions cannot be assumed to be amenable to early hominin occupation.

3.6 Siberia

The earliest Palaeolithic evidence from Siberia is represented by core and flake assemblages and some possible Acheulean bifacial artefacts (Chlachula, 2001, p. 159). In particular, pebble tools described for the site of Diring-Ur'akh were initially attributed to around 1.5-2 mya on the basis of palaeomagnetism (Larichev, et al., 1987, p. 425). Numerous issues exist with the association of these artefacts to the deposits, with the geoarchaeological framework of the site itself, and with the use and interpretation of thermoluminescence dates taken on the sediments (Huntley & Richards, 1997, Kuzmin & Krivonogov, 1999, Waters, et al., 1997). The deposits are probably best regarded as Late Pleistocene (Dennell, 1998, p. 281, Kuzmin & Krivonogov, 1994). More recently the Karama site in the Altai has been reported at *c.* 600-800 kya (Kuzmin & Kazanskii, 2015), but similar problems also hamper the dating of this site.

Artefacts attributed to Lower Palaeolithic pebble or chopper technologies were found on river terraces at Filimoshki, Kumary I, and Ust-Tu (Larichev, et al., 1987, p. 420, Yi & Clark, 1983, p. 182). These were given Pleistocene ages based on the river terraces they were found associated with, but were argued to be possibly Lower Palaeolithic due to the primitive nature of their typology (Yi & Clark, 1983, p. 182). Some doubt still remains over whether these are genuine artefacts or the result of natural processes (Larichev, et al., 1987, p. 421, Yi & Clark, 1983, p. 183).

Several artefacts were found in a derived context at the northern Altai site of Ulalinka (Chlachula, 2001, p. 147), including choppers, scrapers, and 'peculiar' cores, all made on quartz or obsidian pebbles (Okladnikov & Pospelova, 1982, p. 710). These were regarded as very ancient and ascribed to the Lower Palaeolithic on the basis of typology (Okladnikov & Pospelova, 1982, p. 710). These were designated as a pebble tool industry, but both their interpretation and their antiquity is disputed.

Lower Palaeolithic artefacts have been claimed at numerous other sites in Siberia, including Kurtak, Latamna, Mal'ta, Torgalyk, Mokohovo, and on the terraces of the Ob River (Chlachula, 2001, pp. 147-59). Some of these artefacts are disputable as artefacts, most lack dates, and the few that do have dates remain contentious.

3.6.1 Summary

Very few dates can be attributed to the Siberian material, and none of clear Lower-Middle Pleistocene activity. On the current understanding of the out of Africa model, Siberia is unlikely to have been an inhabited zone during the Lower-Middle Pleistocene. It seems most likely that Siberia would have been populated by hominins through either Central Asia or East Asia, and possibly both. The indication from both of these regions is that hominins may not be capable of adapting to sustained occupation in the furthest northern grassland areas of Central or East Asia, let alone extend up into zones of boreal forest, for instance around

present day Siberia. In these boreal and periglacial zones, taphonomic factors and the difficulty of conducting archaeological survey adds an additional element of obfuscation. Where we might give the benefit of the doubt to questionable dates and proposals from South West or South Asia, certainty begins diminishing the further north and east from known habitable zones.

3.7 Summary & Conclusions on Neighbouring Regions

The information in Table 1 is intended to digest the information presented in this chapter, and it highlights and reinforces the key themes so far identified. For the regions represented only with surface finds, their antiquity must be regarded as speculative. This is less contentious for regions like Iran, which must surely have seen Pleistocene occupation, but is necessarily more speculative for regions like Mongolia and Siberia, where the earliest dates for occupation are still under debate. The features that do become clear from this table, however, is that 'Erectine' hominins are broadly in evidence where fossils have been found for this timeframe in Asia. Furthermore, Mode 1 technology, and occasionally Mode 2 technology, have been attributed to all areas during this period. All regions show a great diversity of raw materials used in knapping, pebbles and cobbles are used extensively, and several regions have evidence for bipolar core reduction on anvils.

The purpose of summarising the Lower Pleistocene record of these areas is to understand what types of hominins were present in the areas neighbouring the study region, the nature of the associated technologies, and where possible, other aspects pertaining to their adaptation and behaviour. This allows for a broad understanding of the populations present in Asia during this time that might have had the opportunity to disperse into Central Asia. This is particularly pertinent for the Lower Pleistocene of Central Asia, because the current record contains only one securely dated stratified site. It should also be considered whether

the record of the neighbouring areas provides any indication as to the plausibility of an earlier Lower Pleistocene dispersal into Central Asia prior to the site at Kuldara.

The purpose of considering the Middle Pleistocene record of these neighbouring areas; however, is to gain an impression of how isolated or connected Central Asia may have been within Asia at this time. It is also useful in helping to contextualise changes in technology or behaviour within the study region. The Middle Pleistocene record accounts for all but one of the securely dated sites in Central Asia, and therefore an understanding of the contemporary archaeology of the neighbouring areas is crucial in discussing both technological change within the study region, and possible dispersal through the study region.

Table 1 - Table summarising some of the features of sites discussed in this chapter by region.

Country	Earliest Date	Relevant Technological Features	Raw Materials Reported	Hominin Fossils
Georgia	1.78-1.85 mya	Mode 1, core and flake, choppers, and bipolar core reduction.	Basalt, andesite, granite, quartz, rhyolite, rhyodacite, quartzite, and some sedimentary. Pebbles and blocks.	*H. erectus*
Iran	None	Surface finds of possible Mode 1 technologies, core and flake, core-choppers, bifaces/handaxes, cleavers, picks, and bipolar core reduction.	Andesite/trachyandesite, basalt, quartzite, limestone, sandstone, chert, tuff, quartz, mudstone, and jasper. Cobbles and pebbles.	None
Pakistan	>1.9? mya	Mode 1, core and flake, handaxes.	Quartzite. Cobbles and pebbles.	None
China	1.66 (2.48?) mya	Mode 1, core and flake, choppers, bifaces/handaxes, picks, bipolar core reduction.	Volcanics and metamorphics, basalt, breccia, flint, chert, limestone, dolomite, quartz, quartzite, sandstone, mudstone, gneiss, ferrolite(?), phyllite, and trachyte. Nodules,	*H. erectus*

			pebbles, and blocks.	
Mongolia	None	Core and flake, choppers, handaxes(?).	Quartz, quartzite, basanite, jasper, and flint. Pebbles.	None
Siberia	None	Core and flake, choppers.	Quartz and obsidian. Pebbles.	None

A lack of well dated early sites really hampers the understanding of many of these individual regions, and also raises problems when trying to understand them in concert to elucidate issues of hominin dispersal. A few exceptional sites trace out the chronology of the Asian continent, but outside exceptional zones such as South West Asia and East Asia, dating is poor and coverage limited. Evidence of hominin presence in some regions, and even the permanence of that presence in areas they must have occupied to disperse across the continent, drops rapidly in certainty as we move outside of these exceptional zones. This constitutes a great obstacle to a finer understanding of the timing and nature of hominin dispersal in Asia, and also to the reconstruction of those patterns of hominin occupation and hominin lifeways that facilitate it.

The very earliest occupation of Asia is still not well known or secure. The age of Riwat in Pakistan at 1.9 mya is potentially only a minimum age, and the earliest ages currently claimed for China are around 2.48 mya at Longgupo. It is only relatively recently that it has it become clear that dates in excess of 1.5 mya can be substantiated in Asia, and it remains a possibility that the Asian record may yet further revolutionise global dispersal chronology with further finds. The record of Asia as a whole is still understudied and as such may develop in unpredictable ways.

Georgia and China both provide suitably rich records, and can therefore be used to suggest certain traits that we would expect to find in the adaptive behaviour and lifeways of any hominin that might disperse into and occupy Central Asia in the Lower Pleistocene. However, these isolated sites and dates add little to substantiate the actual chronology of dispersal and occupation that must have taken place to facilitate such findings either side of the Asian continent. Iran must certainly have been occupied during the Early Pleistocene, as it is a necessary bridge for hominin dispersal into East Asia. Despite this, the record is patchy

in this region, and the dated record non-existent. Pakistan provides only a few sites, in a marginally better context than those of the Iranian assemblages. Still, the picture it provides is little more than a suggestion of occupation at this time, and a hint of what that occupation may have looked like in one area. No credible evidence has yet been provided for Lower-Middle Pleistocene hominin occupation in Siberia or Mongolia. A large area combined with limited investigation, means that this picture from these two areas is far from conclusive, but researchers should be cautious in dismissing the possibility of an earlier occupation of these regions. Conservatively, it can be said that the early dates that have been proposed for Siberia and Mongolia are yet to be conclusively demonstrated.

The ambiguities of the Central Asian record are somewhat compounded by the ambiguities of the contemporary records in neighbouring regions. Central Asia finds itself isolated from well-dated regions of the Lower-Middle Pleistocene by the patchy records of its immediate neighbours. Nevertheless, they provide some kind of framework for understanding that record. Hominins are present from at least 1.66 mya in China, this means that they must have been capable of dispersing through Iran sometime between 1.8-1.6 mya. The Majuangou III and Dmanisi locations demonstrate Lower Pleistocene occupation by hominins between 40-44°N. All of the dated Lower-Middle Pleistocene Karatau Pebble Culture sites are well below this latitude, and it seems very possible that hominins could have occupied areas far into the study region during this timeframe if the resources existed to support them.

Core and flake technologies are widespread within the Lower-Middle Pleistocene record of the regions that neighbour Central Asia. Although such technologies are often viewed as ‘simple’, there is evidence that they are supported by adapting levels of behavioural complexity, and are constantly developing to enable hominins to survive in local conditions.

Raw material use is diverse across Asia, with differing degrees of selectivity in evidence, but demonstrating a high level of complexity in selection methods at some sites.

Bipolar technologies are also widespread in Asia from the earliest period of the Lower Pleistocene, and in particular these seem to be a way of dealing with poor quality and pebble clast raw material. It can be concluded that the technologies and behavioural strategies required to occupy Central Asia were probably already widespread in the neighbouring regions almost a million years before the first dated site from the study region. If the northern route between Central Asia and East Asia is accepted as viable, then it remains a possibility (if unlikely) that hominins using a simple core and flake technology with a bipolar component could have colonised Central Asia from East Asia. Dmanisi still represents the earliest accepted example for the use of bipolar technique in Asia, but the recent re-dating of Longgupo in China might push this back to 2.48 mya.

Handaxes first appear in China in the Middle Pleistocene, and it remains an open question whether these arrive via the Northern or Southern routes. The Northern route may seem difficult for hominins due to environmental conditions, with a deterioration in climate during the Middle Pleistocene. However, the difficulty of crossing the Brahmaputra-Ganges drainage basin in South Asia should not to be underestimated as a barrier to dispersal (Dennell, 2009, p. 435).

It seems likely that *H. erectus* was the first hominin species with an opportunity to occupy Central Asia in the Lower Pleistocene. Almost certainly these hominins would have brought with them a core and flake technology. It seems likely that bipolar percussion and adaptable raw material strategies would have been available to them behaviourally. Handaxe technologies would have passed through Iran prior to 1.5 mya, but gaps in the Central Asian record, and the record of crucial neighbouring regions to the south, preclude any easy judgements on when such a technology arrived in Central Asia. The well-established

Acheulean tradition in South Asia would indicate that Lower Palaeolithic Acheulean technologies would have entered Central Asia along its southern border, if they did enter at this time. Mixed grassland and woodland may have represented important environments for hominins for their subsistence. Evidence also suggests that local proximity to waterbodies and raw material sources were features of occupied areas in the regions of Asia surrounding Central Asia at this time, such as at Dmanisi and the Nihewan Basin.

Chapter 4. Hominin Dispersal and Occupation in the Lower Pleistocene

4.1 The Nature of Dispersal & Hominin Competency

With the current wide acceptance by most researchers of some version of the 'Out of Africa I' model for early human origins, the spatial aspect of the early human record has focused on the timing and mechanisms affecting the initial peopling of regions from African points of origin. Palaeolithic researchers have often relied on an implicit understanding of these mechanisms to give broader context to their regions of study. Fundamentally, any such models are attempting to explain the timing of the appearances of different technologies and species of hominins in these regions within the broader known context of the Out of Africa I model. While several broad scale syntheses examine the chronological and environmental aspects of these changes in the archaeological record, the theoretical basis that informs how these changes and imputed processes are described is rarely considered. Furthermore, few studies have explicitly examined in a testable way what mechanisms drive dispersal for the early genus *Homo*, with only a few notable exceptions. Both of these gaps in the present literature leave the exact nature of hominin dispersal uncertain. The following discussion will briefly examine both the language and some of the proposed mechanisms of hominin dispersal, including aspects of hominin 'competency' and ranging behaviour, all of which are important considerations for spatial modelling in a Palaeolithic timeframe.

4.1.1 The Language and Logic of Dispersal

It is impossible to be certain that the oldest dates and the youngest dates for specific technologies or hominin fossils within regions give an accurate representation of chronological presence or persistence. Therefore, the language used to describe these processes takes on an even more significant role in the explanatory process, because it often entails implicit assumptions about the logic and nature of dispersal that are rarely questioned. It can be argued that the explanation of hominin dispersal has a 'narrative'

element and a ‘mechanical’ element. The narrative element is concerned chiefly with outlining the chronological and regional aspects of dispersal, while the mechanical aspect focuses more abstractly on the demographic factors and driving forces that underlie this chronology.

The record that informs interpretation of these dispersal processes is in some sense ‘static’, being represented by individual finds of technologies or fossils, usually with secure dates that place them as individual ‘snapshots’ within the global chronology. The record itself is static, but the explanations of population movement and expansion are dynamic and inferred from this static record. Addressing the specific nature of this evidential record has led some Palaeolithic researchers to adopt the terminology of First Appearance Datum (FAD) and Last Appearance Datum (LAD) from the discipline of Palaeontology. For example, this has allowed Rick Potts (2013) to compare changes in amplitude in the climate record with hominin FADs and LADs as a proxy for speciation, extinction, and adaption events in early human evolution (see the section entitled ‘4.2.2 Variability Selection Hypothesis’ below). The advantage of such an approach is that it assumes little in regards to the dynamic processes, and does not violate the static logic of the record itself.

Most discussions of global dispersal, however, rely on implicitly assumed relations between the static record and dynamic systems of dispersal. The differing levels of ‘purposiveness’ implied by the choice of language in describing these processes is also related to the level of pre-planning and agency attributed to early hominins in these theories and models, and whether they should be considered as (and therefore modelled as) humans or animals. Colonisation has been a popular term to describe the process of early hominin appearance in areas or environments that they appear previously absent from. The term colonisation has a dual meaning, being both a biological/ecological term for the arrival of a species in a novel environment, but also being an anthropological/historical term referring to some of the

imperial practices of European powers in more recent times. Due primarily to this latter meaning of the term, colonisation can be seen as a linear directed process, implicitly assuming some level of intent or purpose on the hominin colonisers. Dispersal may be seen as a more neutral term, and is preferred here for that reason, but comes with its own issues. For instance, dispersal can be seen to emphasise movement away from an origin point, while colonisation focuses on the arrival in a new territory. In this sense, it may be argued that it is more appropriate to discuss the colonisation of Central Asia by early hominins, rather than dispersal into Central Asia. The incredibly sparse record available for Central Asia suggests that initial colonisation may far exceed current FADs in age. Therefore, it is preferred in the present study to refer to dispersal rather than colonisation.

Occupation is a term that also has multiple associations. Occupation can be thought of as emphasising the continuing and active lifeways of a population within a landscape, but is also associated with military control of an area, and is also associated with the specialised roles for individuals that emerge in agrarian and post-agrarian societies. Occupation does, however, emphasise the continuous and on-going nature of the process of living in a landscape, and for this reason is still preferred to other terms in the present study. Occupation is used here to refer to this on-going process of living in the landscape, while dispersal is used to refer to the broad-scale pattern of movement that emerges from this mobile process of repeated occupation. It should be noted that it is possible to have multiple simultaneous dispersals and occupation of different groups, and that the use of the terms dispersal and occupation in connection to Central Asia is not intended to imply individual dispersal events or individual group occupations.

The vast spatio-temporal scale over which these patterns of behaviour are discussed can likewise lead to confusion and unintuitive conclusions. In periods of later prehistory, it is not uncommon to talk of or infer individual pathways and routeways in the landscape that may

have been actively used by individuals or groups within that time period. In the Lower-Middle Pleistocene, phrases such as “dispersal pathways of early hominins” (Holmes, 2007) are not meant in the same sense, and instead refer to probabilistic models of aggregate behaviour. There remains an underdeveloped understanding of what these patterns of aggregate behaviour mean in the context of spatial analysis, and how their unique spatio-temporal scale affects the process of modelling them. There is still substantial difficulty in identifying and describing the exact mechanisms that drive or enable dispersal, and in particular whether explanations of dispersal should focus foremost on environmental, technological, or cognitive factors.

There also remains an issue in overemphasising the role of the environment in the process of hominin dispersal, a situation known as Environmental Determinism (ED), in that it leaves little or no role for hominin action and agency (see ‘Environmental Determinism’ in section ‘7.1.1.1 Data Collection and Formatting’). It is clear that environmental factors must have played a major role in driving the process of hominin dispersal, but the role of hominin agency in this process remains debatable versus the possibility of ED, and furthermore is difficult to model in a timeframe when the majority of available data is environmental rather than cultural in nature. Hominin adaptation that may be described as primarily technological or cognitive in nature could allow dispersal into and occupation of new habitats, but these factors are more difficult to study than palaeoclimatic factors, as the archaeological record is equivocal on the relationship between technological or cognitive changes and hominin fitness or hominin niche adaptability. Nonetheless, over the period of the Lower-Middle Pleistocene, some basic features and developments can be outlined in regards to what might be thought of broadly as ‘hominin competency’.

4.1.2 Hominin Competency

In several ways, the bodies and behaviours of hominins change and develop throughout the Lower-Middle Pleistocene. This constellation of features and traits might be thought of as 'hominin competency'. Body mass estimates for *Ar. ramidus* and *O. tugenesis* using scaling models from non-human great apes suggests a body mass for Miocene-Pliocene hominins similar to that of modern wild chimpanzees, around 49.6kg for males and 40.4kg for females (Grabowski, et al., 2018). Mean body mass increases to around 58.6kg in early *Homo*, 69.4kg in *H. erectus*, and 72.1kg in Mid-Pleistocene hominins (Ruff, et al., 2018, p. table 7). The postcranial remains from Dmanisi at 1.8mya suggest that they are fairly short in stature, and more similar to early *Homo* than to *H. erectus* in build *(Lordkipanidze, et al., 2007, p. 308)*.

Sexual dimorphism in body mass is high to intermediate in the Australopithecines, but according to Ruff et al. (2018, p. table 8) seems to reduce substantially within the genus *Homo*, although sample sizes are small for the earliest periods. The Dmanisi hominins show substantial intra-species variation, and Rightmire et al. (2019, p. 490) have suggested that some of this may be due to sexual dimorphism. However, the sample number is very low, and age-related factors are also likely to complicate this picture. If a change in sexual dimorphism signals a major behavioural or adaptive change in the hominin lineage, it seems most parsimonious to suggest that the brunt of this change is between Australopithecines and *Homo*, rather than within the genus *Homo* during the Pleistocene.

The primate foot evolved primarily as a grasping organ to aid in arboreal climbing, and full adaptation of the foot to modern bipedal locomotion arrives relatively late after the split from the Last Common Ancestor (LCA) with chimpanzees. Adaptation to habitual bipedal locomotion may be visible in *Ar. ramidus* fossils around the Late Miocene-Early Pliocene (Fernández, et al., 2018), eventually becoming similar to modern human locomotion some time during the Pleistocene. Analysis of hip extension suggests that *Ar. ramidus* were

capable of the hip extension necessary for bipedal walking and also for powerful vertical climbing, with the latter capability being rapidly reduced even in *A. africanus* and *A. afarensis* by the Pliocene (Kozma, et al., 2018). Analysis of uncinate processes that protrude from cervical vertebrae indicate that *A. afarensis* and *H. erectus* are not adapted to arboreal locomotion, while *A. sediba* appears to retain some arboreal adaptation into the early Pleistocene (Meyer, et al., 2018). In talar morphology, *A. sediba* and *africanus* retain more primitive morphology, while *A. afarensis* and *Homo* show a more derived morphology linked to the development of a high medial longitudinal arch and obligate bipedalism. The feet of the Dmanisi hominins are deemed modern in many respects, but it appears that their methods of 'push-off' and loading differ from strict modern human locomotion (DeSilva, et al., 2018, p. 118). The configuration of the spine and lower limbs suggests a broadly modern form of locomotion for the Dmanisi hominins (Lordkipanidze, et al., 2007, p. 309). Later footprints attributed to *H. erectus* in Kenya indicate that a more modern form of locomotion seems to have evolved by 1.4-1.5mya, and *H. erectus* foot fossils from Ethiopia suggest that running adaptations are present by at least 1.53mya (DeSilva, et al., 2018, pp. 119-120).

Brain size scales with body mass, but throughout the Pleistocene brain size does also increase relative to body size, measurable by Encephalisation Quotient (EQ). Mean cranial capacity goes from around 800-900cc and an EQ of about 3.4-2.5 in the early Pleistocene and early Middle Pleistocene, to around 1100-1200cc and an EQ of around 3.8-4.3 in the mid-later Middle Pleistocene (Ruff, et al., 1997, p. table 1). The cranial capacity of the specimens from Dmanisi ranges from around 550-730cc, far below the range of cranial capacities known for Asian *H. erectus*. In east and southeast Asia, the earlier Javanese specimens range from 850-1250cc, and the later specimens at Zhoukoudian range from 915-1225cc. *(Rightmire, et al., 2019, p. figure 1,* Rightmire, 2004, p. table 1). Dmanisi cranial capacity is most similar in absolute terms to early *Homo*, but they share many cranial features with *H. erectus (Gabunia, et al., 2000a, p. 1020,* Lordkipanidze, et al., 2007, p. 308),

so it is unclear exactly how this may have impacted on their adaptive behaviours and capabilities. In primates, increasing brain size has been connected with increasing group size (Dunbar, 1992, Dunbar, 2009), and increases in group size and body size have been related to both feeding competition and predation risk, which increase for primates in open environments (Janson & Goldsmith, 1995).

In terms of hominin dentition, there is a gradual trend towards more gracile forms of dentition into Pleistocene. Australopithecines and Paranthropines rank high on 'mass-additive' factors that indicate robustness and morphological complexity, while *H. habilis* and *erectus* rank between these values and those of *H. sapiens*, with Mid-Pleistocene *Homo* samples being slightly closer to modern values *(Irish, et al., 2018, p. table 1)*. Early *Homo* fossils show an average and relative molar enamel thickness similar to Australopithecines, and reducing slightly through the Pleistocene (Lockey, et al., 2020, p. 4), and absolute crown strength is likely to decrease in relationship to enamel thickness over this period (Schwartz, et al., 2020, p. table 1). Molar root volume broadly decreases throughout the Pleistocene, with *H. erectus* being somewhere between early and late *Homo* values (Kupczik, et al., 2019, p. table 2). It should be noted that Australopithecines and Paranthropine dental robusticity represent a derived subsistence specialisation of increasing molar robusticity versus earlier species such as *Ar. ramidus*, and so the trend of decreasing dental robusticity in *Homo* is at least partially a reversal of this trend and a return to a more generalised morphology (Ungar, 2019, p. 402). Microwear on teeth shows generally low textural complexity among the Australopithecines, suggesting a specialised diet. *A. africanus* shows more textural complexity than other Australopiths, as do *Homo* specimens, suggesting a more generalised diet and a growth in diet breadth into the Pleistocene (Ungar, 2019, p. 403). It should be noted that older cranial specimens in the Dmanisi assemblage demonstrate substantial dentoalveolar remodelling, a reflection of extreme occlusal wear (Rightmire, et al., 2019, p. 491). If brain size is increasing while dentition decreases, we must assume that methods of

food sourcing and processing offset this shortfall in the energy requirement budget (Aiello & Wheeler, 1995). Perhaps hominins are targeting more nutrient-dense food sources, or extracting more value from existing food sources through means of increased processing intensity with stone tools or fire (Wrangham & Carmody, 2010). Use of fire by hominins is contentiously suggested from around 1.6mya, but is most widely accepted by 1mya (Attwell, et al., 2015, p. 4, Berna, et al., 2012). The comparative approach of Veneziano et al. (2019) supports the idea that reductions in canine size and mandibular robusticity in the genus *Homo* over this period are causally-related to technological developments.

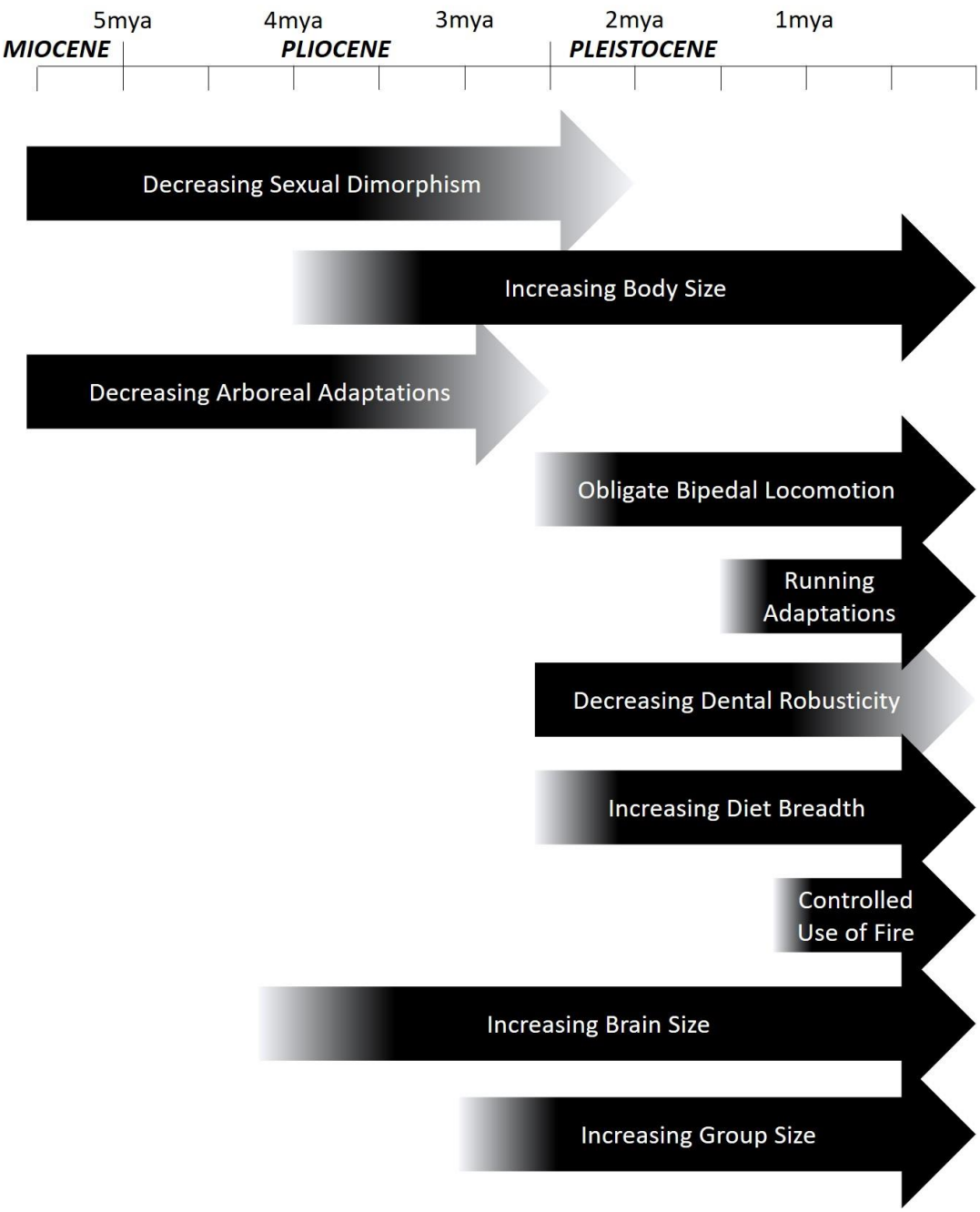

Figure 29 - A summary of the development of broad traits of hominin competency, focused especially on the Pliocene-Pleistocene.

Figure 29 provides a summary of the development of traits regarded here under hominin competency. We can expect that early Pleistocene hominins would have been generally relatively smaller-bodied and small-brained than Mid-Pleistocene hominins. It seems likely that their group sizes were smaller, which along with their smaller stature would have made them easier prey, or at least poor competition, for specialised carnivores. They are unlikely to have retained much functional arboreal adaptation compared with their Miocene-Pliocene ancestors, but seem likely to have needed the sheltered environment provided by wooded environments. Mid-Pleistocene hominins, being larger-bodied, and possibly also in larger groups, are likely to have been able to withstand the increased food competition and predation risk of open landscapes more effectively. The increased efficiency of their bipedal locomotion, likely to also include running adaptations, meant that they could range over larger distances between resources, and therefore exploit sparser, more challenging environments.

Increasing mean encephalisation over the course of the Pleistocene is likely to enable more complex and cognitively-tasking behaviours. This might include increases in the kind of logistical and tactical thinking required in hunting or resource-scheduling in more challenging environments, and more complex processing of vegetal resources (the leeching of tannins from acorns or the gathering of sweet tree waters, for instance, represent vegetal resources that require some level of knowledge and technology to process). At a minimum, larger brains are energetically expensive, and suggest that hominins are able to access richer subsistence resources, possibly through increased meat consumption or a more developed processing of vegetal resources.

4.1.3 Hominin Ranging

Hominin dispersal represents the aggregate pattern of long-term ranging behaviour. It is the end result of the short-term distances travelled by hominins in the habitual gathering of resources, during on-going occupation, which are themselves a reflection of the interaction between hominin competency, behavioural adaptation, dietary quality, and resource distribution and quality. Isotope analysis has suggested that Australopithecines and Paranthropines are likely to have had similar lifetime ranging behaviours to modern chimpanzees and bonobos, at least in terms of female extra-group movement (Copeland, et al., 2011), although this does not shed light directly on their more daily movements. Because ranging behaviour is the result of a complex interplay between bodily requirements, diet quality, and adaptive behaviour, estimates for hominin home ranges vary substantially whether modern hunter-gatherer or extant ape models are used. Based on body size, Anton et al. (Antón, et al., 2002, p. table 4) estimate for *H. habilis* a home range of 0.47km^2 with an ape-like diet, up to 2.9km^2 with a human-like diet. *H. erectus* as a whole is estimated at 0.73km^2 and 4.52km^2 respectively, and for African *H. erectus* and the Dmanisi hominins this is reduced slightly to 0.66km^2 and 4.14km^2. Dennell (2007, p. 47) equates this to an 'operating radius' of 5.1-5.6km, which he shows agrees well with reported raw material transport distances in the Lower-Middle Pleistocene record globally, which range broadly from 0-10km in distance, with some outliers showing possible transport distances of 30-35km. Sel'ungur is the only stratified site in the Lower-Middle Pleistocene of Central Asia where raw material transport has been well-mapped, and the situation appears to support this idea of an 'operating radius' between 5-10km, as the represented raw materials are in immediate proximity or within a 5km radius of the cave (Krivoshapkin, et al., 2020, p. 91). This idea of an operating radius up to 10km will become relevant when the results of the analyses are discussed in 'Chapter 7. Modelling Methods & Results', as a 10km radius buffer will be introduced to understand the relationship of the sites to the surface data produced.

Because of the scale of the analysis, the resolution of the surfaces produced in the analysis, and any possible error in the exact coordinates of the sites, a buffer provides a more accurate assessment of the relationship of the sites to the surfaces. The literature on hominin ranging has ensured that the dimensions of this buffer (10km) is behaviourally meaningful.

4.2 The Role of Environments and Resources

One of the key changes that has been taking place recently in hominin dispersal and in our understanding of the hominin niche is a movement away from discussion of discrete 'patches' of environments amenable to hominin occupation, and movement towards conceiving of landscapes as continuous distributions of resources, a theoretical change that has real methodological implications for spatial modelling. Previously, researchers have tended to list environments reported from environmental reconstructions of individual sites (e.g. galley-forests, savannah, grasslands, lake edge, etc.), sometimes highlighting and discussing specific elements of these environments, and often focusing on the importance of 'mosaic' environments. This approach has probably emerged due to the site-based focus of early hominin archaeology, at the expense of a wider landscape approach. It has also allowed for the continuation of a long-standing assumption of the importance of grassland savannah in the evolution of hominins in Africa, and their subsequent expansion out into Eurasia. This is an idea that goes back as far back as the 19th century (Domínguez-Rodrigo, 2014), and more recently has been reframed for the Late Pliocene/Early Pleistocene by Dennell & Roebroeks (2005) in the concept of 'Savannahstan'. In the Savannahstan model, they have noted that grasslands were probably continuous between West Africa and China during the late Pliocene. Where these grasslands stretched across Central Asia they dubbed them 'Savannahstan', and the authors suggested that this could have facilitated hominin dispersal out of Africa and into Asia around this time. This is an interesting observation, and an interesting model, from the perspective of the current project, as it proposes a dispersal

mechanism for Central Asia that does not apply to south Asia. However, recent research is revealing a more complex picture of the role of savannah grasslands in hominin evolution and dispersal, which is slightly at odds with a simple, discrete habitat concept.

The use of a discrete habitat concept has had a direct impact on the way models of hominin dispersal have been structured, with several researchers using datasets that present environmental factors in the form of discrete habitats, biomes, or vegetational zones. For instance, Hughes et al. (2007) produced a cellular automata model that focused on weighing the impact of vegetation, distance, and 'continental configuration' on rate of hominin dispersal. They used the BIOME4 dataset, which consists of palaeo 'mega-biomes' simulated from a variety of data including latitude and climate factors from Last Glacial Maximum (LGM) climate models (Kaplan, et al., 2003). For the purposes of the study, Hughes et al. (2007) assumed that grassland biomes were easier to disperse through than other environments. They concluded that *H. erectus* was poorly adapted to the environments prevalent in Eurasia, proposing that this was a primary factor involved in the timing of dispersal of *H. erectus* into Eurasia. However, the assumptions made in this study amounted to Environmental Determinism (ED, see '7.1.1.1 Data Collection and Formatting'), in that they used the expansion and contraction of a 'mega-biome' uncritically as a shorthand for expansion and contraction in the range of *H. erectus*, without actually considering hominin-driven factors of adaptation. This has undermined any conclusions the authors could draw on the nature of hominin dispersal from their results, because, hominins are not necessarily tied to one kind of biome or macro-environment, as will be seen subsequently, and are likely to have exploited the productive and ecologically diverse transitions between environments.

Using similar assumptions, Holmes (2007) applied a systematic study employing a Geographical Information System (GIS) with PRISM2 (Pliocene Research, Interpretation, and Synoptic Mapping) biome data. Holmes (2007) supplemented the PRISM2 data with

additional faunal data, and used existing hominin sites and a Weight-of-Evidence technique to produce probability surfaces for hominin occupation. This technique was used to calculate the relationship of known East African hominin sites to each other as well as the environmental variables in the PRISM2 dataset, and extrapolated from these relationships to predict the probability of hominin sites in other areas of Africa and Eurasia. This amounts to an inductive predictive model of site location, which as a class of analysis have disadvantages of their own (see the section 'Affordances and Predictive Modelling' in '7.1.1.2 Amenability Analysis'). The results of the model were tested against the locations of known South African sites, and failed to predict their locations with any level of accuracy. This predictive model also gave low values to areas such as India and Java, where hominin occupation is well attested in the early Pleistocene. It also predicts very high values for Northern Scandinavia and several other areas that are very unlikely to be inhabited at this time. The extreme coarseness of the PRISM2 data, and its discrete nature, is probably much to blame for the failure of the model, as it classifies diverse environments across continents into a limited number of categories of 'ecozone'. A single ecozone that spans much of a continent conveys little of the great variation that exists below this level in the landscape. The very high probability in Holmes' model for occupation in the north of Central Asia is used to argue in support of an early dispersal into the region north of the modern day extent of the Caspian Sea, which is also unlikely due to the likely extent of the Caspian during that period of the Lower Pleistocene (see the section 'Large Water-bodies (Surface Water)' in '7.1.1.1 Data Collection and Formatting').

Ultimately, it is the use of environmental data that provides both of these studies with their method of assessing hominin dispersal, but it is the use of that data in the form of discrete, biome-level datasets that limits and undermines their conclusions. The use of such datasets is symptomatic of a discrete habitat concept that assumes concrete and insurmountable divisions between vegetational zones are reflected directly in hominin range extent. It is

argued here that the discrete habitat concept is itself misleading, fails to accurately account for hominin dispersal behaviour, and is merely widespread due to convenience as a framing device, and ease of use for hypothesis-generation and testing in analysis.

Despite arguments by some authors to address the continuous nature of the archaeological record (Foley, 1981a, Foley, 1981b, also see 'Discrete Habitats and Discrete Data' in '7.1.1.1 Data Collection and Formatting'), it is only relatively recently that researchers have begun to conceptualise environments of early hominin sites as juxtapositions of continuously distributed resources, rather than as discrete patches of inter-locked elements, and this is concurrent with other changes also taking place in the biological sciences (Blackwell, 2007, Macdonald & Johnson, 2015, Stoddard, 2010). This is preferable to a view of the landscape as composed of discrete environments or habitats, because it deconstructs these broad units of analysis and allows a more realistic understanding of the interaction between hominins and the individual elements of their environment. As an approach it also allows for the possibility of hominin occupation outside currently known habitats. This is an advantage in relation to the current understanding of the hominin niche, which emphasises flexibility and adaptive opportunism (Potts, 2013).

4.2.1 Savannah Hypothesis challenged

The long-standing role that grassland savannah is assumed to have played in hominin dispersal has been challenged by several studies. Kingston (2007) initially drew attention to the poor definition of what constituted 'savannah' in the savannah hypothesis, and especially as regards the prevalence of a wooded component in this environment. This issue has been developed further by Cerling et al. (2011), whose analysis of stable carbon isotopes has suggested that, although there is a general trend to decreasing woodland from the Pliocene into the Pleistocene in eastern Africa, the early-mid Pleistocene environment is better characterised as a 'mosaic', wooded-grassland savannah, rather than a predominantly

grassland savannah. This has been supported by van der Made & Mateos' (2010) study that used large mammal biogeographic data, essentially as a proxy for the hominin niche, to examine factors affecting hominin dispersal. They concluded that open environments played an important role in enabling hominin dispersal into Asia, and subsequently also into Europe. More recently, Feakins et al. (2013) have provided further support for a 'mosaic' savannah interpretation in the same region by suggesting that the C4 biomass expansion that occurred in the Pleistocene did take place in a context of reducing grasslands.

Recently, Domínguez-Rodrigo (2014) has given a comprehensive analysis of the savannah hypothesis, tracing its history and use in archaeology and palaeoanthropology, dividing it into two possible formulations, and discussing these formulations in relation to the environment associated with *Ardipithecus ramidus*. Of the two formulations, Domínguez-Rodrigo describes one as relating to a 'mosaic' of environments, and the second as synonymous with grassland. Domínguez-Rodrigo cites several examples which use the latter definition of savannah, but argues in favour of the mosaic interpretation of Cerling et al. (2011), with Pliocene savannah being more humid and more wooded than its modern-day counterpart. Crucially, it is concluded that the 'original philosophy' of the savannah hypothesis, that of hominin colonisation of novel habitats in response to environmental pressure, can remain unchanged, while acknowledging that Pliocene savannah also provided a less stark contrast to the more wooded habitats normally associated with earlier hominins. This is particularly interesting when compared with the environmental evidence of the early Pleistocene hominin sites in Asia, as Dmanisi in Georgia and several localities in China's Nihewan Basin seem to indicate the importance of a wooded environment alongside a grassland component.

4.2.2 Variability Selection Hypothesis

As an alternative to the savannah hypothesis, Potts (2013, p. 6) has formulated the 'variability selection hypothesis' which states "…that the adaptations of hominins and other organisms have been shaped by the instability of environmental and survival conditions over time and space", and that this variability selection "…enables the evolution of organisms better at adjusting to environmental variability through their physiological, behavioural, and ecological plasticity".

Potts' has not been the only author to suggest this. Referring to the glacial/interglacial succession in their extensive examination of the role of climate in human evolution, Gribbin & Gribbin (1990, p. 110) state that: "…repeated tightening of the evolutionary screw and easing off of the pressure hastened the evolution of the human line, by putting cunning and adaptability at a premium, and providing opportunities for an *intelligent* upright ape to succeed in a changing world."

In comparing the available indicators of environmental conditions, Potts has argued that extremes in any one environmental indicator cannot account for the 'key adaptations' of the hominin lineage (Potts, 2013), and proposing instead that the variability itself, manifest in a variety of environmental measures, is the primary source of selective pressure for these adaptations. There is some circumstantial evidence to suggest this, as Potts has highlighted that First Appearance Dates (FADs) and Last Appearance Dates (LADs) in the hominin lineage relate to wider biogeographic events, particularly emphasising the role of climate and vegetation change in habitat instability in the Plio-Pleistocene and late middle Pleistocene (Potts, 2013). Furthermore, hydrological effects are implicated through the erosion and deposition of material, as well as the periodic formation of wetlands and bodies of water, and its causal connection to the availability of consumable resources and their spatial distribution.

4.2.3 Mosaic Environments

Drawing on the previously discussed work of Cerling et al. (2011), Feakins et al. (2013), and Kingston (2007), Potts (2013) has also highlighted the temporal variability of vegetation in the Pliocene grassland expansion, and the 'mosaic' composition of savannah environments. He is correct in highlighting a major issue in the implementation of the Savannah Hypothesis, that work on current formulations of the hypothesis conflate two crucial aspects of organism-environment interaction by failing to "…clearly distinguish between habitat-specific selection (e.g., in a stable spatially-heterogeneous setting) and variability-driven processes of evolution." (Potts, 2013, p. 7) This argument also holds potentially quite specific relevance for the early Pleistocene record in northern China and Central Asia. The previously discussed climatic fluctuations evident in the palaeoenvironment of the Nihewan Basin may not only have precluded continuous occupation of the basin, but forced the development of strategies and adaptations, which may be visible in the increasing complexity of the knapping and raw material sourcing strategies at some Nihewan Basin sites. Furthermore, this effect could be considered as a possible source of environmental and evolutionary stress all across the high latitude (*c.* 40°) Asian sites in southwest and Central Asia. The northernmost extent of the hominin range in China and Central Asia might provide an extremely creative 'crucible' for hominin behavioural and anatomical adaptation during the Lower-Middle Pleistocene.

Potts (2013) has argued that the current literature still lacks explicit discussion linking macroscale climate dynamics with the localised landscape in which hominin subsistence and adaptation takes place, and the prevalence of the discrete habitat concept may prove to be an obstacle to developing this integrated link. It is not clear that pre-defined habitats should represent a valid unit of analysis for hominin occupation, or that they provide a meaningful concept for understanding the nature of hominin-environment interaction. Furthermore, they almost entirely remove hominin agency and adaptation from the process (a situation of

ED). The prevalence of the 'mosaic' environment concept may also highlight a weakness in pre-defining habitats. Finlayson (2014, p. 23) has cautioned that: "A mosaic of habitats only exists in our minds when we predefine habitats … variety of elements is instead what the species needed to make a home, its habitat." A recent study by Reynolds et al. (2015) has charted the use of the term 'mosaic' in the discussion of hominin habitats, and has found its use to be increasing, while still lacking in critical definition. It also seems that Finalyson's opinion that use of the term is currently inadequate is widely shared in the discipline (Reynolds, et al., 2015, p. 65). This has been further supported in a study using large mammal biogeographical data to infer palaeoenvironmental conditions from 2.6-1.8 mya in western Eurasia (Kahlke, et al., 2011). Kahlke et al. (2011) concluded that two factors in particular enabled hominin dispersal into western Eurasia: 1) a diverse mix of habitats, resulting in diverse resource availability, and 2) relatively stable and mild climates. This does not necessarily contradict Pott's Variability Selection Hypothesis, which is posited on increased amplitude in climatic variability in East Africa. Rather, it suggests that the adaptive creativity fostered in high amplitude areas can lead to dispersal and continuous occupation of stable and mild, but previously inaccessible areas.

The importance of variability of environment in the evolution of early *Homo* in Africa has already been highlighted by Gribbin & Gribbin (1990, p. 87) who argue that: "…the most important feature of the African part of the Rift Valley system is that it provides an enormous variety of habitats. There are dramatic changes over a short geographical range, providing an environmental patchwork, because of changes in altitude and in rainfall and water drainage patterns over short distances. Instead of a uniform spread of tropical jungle, patches of dense forest are interspersed with more open woodlands and grassy savannahs."

Although Dennell & Roebroeks' (2005) 'Savannahstan' concept is interesting from a Central Asian perspective in its observation of grassland extent during the Late Pliocene-Lower

Pleistocene, the relationship this observation has with hominin occupation and dispersal is not clear under examination. Firstly, the use of grasslands as a discrete or homogeneous habitat is problematic. Also, the role of grasslands in hominin subsistence is in the process of being re-examined and, appropriately, diminished.

Instead, Finlayson's (2014) "variety of elements" is a starting point for identifying what continuous resources should be considered in mapping hominin occupation. In particular, Finlayson has drawn attention to several of these elements that currently receive limited attention in models of hominin occupation or dispersal. The chief one is the subject of his most recent book *The Improbable Primate: How Water Shaped Human Evolution (Finlayson, 2014)*.

4.3 Resources – A 'Variety of Elements' Approach

4.3.1 Drinkable Water

Water is not often discussed as distinctive of human identity and adaptation, and early technologies are not directly or obviously connected with water procurement and consumption. As a result, water has often been neglected in discussions on hominin subsistence. It is also likely that most researchers have underestimated the difficulty of acquiring water, as well as the importance of these key resource to hominins. However, some researchers studying the Central Asian Palaeolithic have also specifically highlighted the importance of water in such a continental environment (Chlachula, 2010, Taimagambetov, et al., 2013). While hominins would likely not be limited by some modern concerns of water hygiene, they would likely not be able to drink water that was highly saline, or at an inaccessible state in the hydrological cycle (e.g. 'in-aquifer' groundwater, see Figure 30). Rain in arid and semi-arid environments is absorbed quickly, and the saturation zone in these areas is also much lower than in other environments. This means that rain would provide a very brief boon that hominins would likely not be able to take any long-

term advantage of. Plants, which would be able to take advantage of rain, would also be a viable source of water for hominins. However, many of these plants are poisonous or indigestible for modern humans, and possibly also for our early Pleistocene ancestors, rendering the majority of water taken up by plants inaccessible. It is also unlikely that early Pleistocene hominins would be able to utilise the often complex or laborious tactics used by modern human groups to acquire water in arid and semi-arid regions. Whether they could make use of water storage technologies must remain speculative, but based on existing arguments about the exploitation of tubers, and the possibility that these hominins used basic digging sticks, the most complex water-acquiring behaviour we could reasonably expect among early Pleistocene hominins would be digging with sticks in areas of saturated sediment (a possible tactic in some arid areas after precipitation has occurred). Digging for water during times of aridity or high bacterial contamination is a behaviour reported for African elephants, zebra, warthogs, baboons (Hubbard, 1928, Stommel, et al., 2016), kangaroos (Norbury & Norbury, 1992), and chimpanzees (Galat, et al., n.d.). Chimpanzees are also known to dig for food using tools (Motes-Rodrigo, et al., 2019).

Ultimately, early Pleistocene hominins would have been reliant on regular access to drinkable (not saline or brackish) water. In Central Asia, this probably means springs, streams, small lakes, and areas immediately around where large rivers feed into otherwise saline water bodies. Access to water is likely also to have driven hominin ranging behaviour, with hominins having to cover longer distances between water sources and sparser food resources in more arid conditions. During dry seasons, chimpanzees can be seen ranging further than usual into more open environments in response to food and water scarcity (Hernandez-Aguilar, 2009).

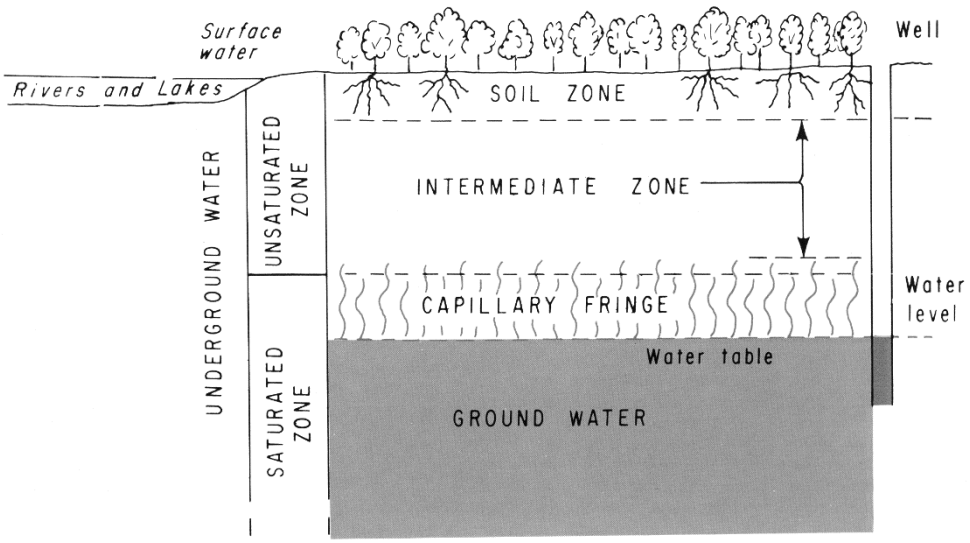

Figure 30 - This diagram conceptualises the relationship between the various stages of underground water. The well depicted on the right-hand side of the diagram is an example of a modern human water access technology unavailable to Pleistocene hominins, but historically crucial for modern human groups surviving in Holocene Central Asia. Figure from Heath (1983, p. 4)

4.3.2 The 'Tectonic Landscape Model'

King & Bailey (2006) have published on a theory of hominin evolution and dispersal, which has subsequently become known as the 'complex topography hypothesis' or the 'tectonic landscape model' (Winder, et al., 2015). This model has been elaborated and supported in a wide body of subsequent literature published by King, Bailey, and colleagues (Bailey & King, 2011, Bailey, et al., 2011, Devés, et al., 2014, Devés, et al., 2015, Holdaway, et al., 2015, Winder, 2015, Winder, et al., 2015). The central claim of the tectonic landscape model is that 'morphologically complex environments' are important in the early evolution and subsequent dispersal of hominins (King & Bailey, 2006), and in particular, they highlight broken, tectonic landscapes. In many ways this agrees with the argument put forward by Gribbin & Gribbin (1990, p. 87), which identifies environmental, topographic, and hydrological variability as key features of the important role of the African Rift Valley system in early hominin evolution. Several of Bailey & King's publications have mapped roughness of terrain on a variety of scales against the earliest known hominin sites, and they have found a good correlation between active tectonic landscapes and early hominin sites. Although none

of the papers makes an explicit break from a habitat-concept of 'mosaic habitats', the authors do attempt to separate and examine the different factors that might be driving this relationship. These include the possibility that complex topographies give a tactical advantage for humans in hunting and predation risk, versus flat, savannah-like environments. This tactical advantage over prey has been examined in relation to landscapes in the Kenyan Rift Valley, and with specific reference to the early Pleistocene site of Olorgesailie (Kübler, et al., 2015, Kübler, et al., 2016). They also propose that this topographic complexity could provide shelter for hominins from predators and other hazards. Another factor they consider is the increased fertility of soils in volcanic areas, the broken landscape serving also to retain soil against erosive processes. They further consider that a broken landscape with varied elevation and fertile soil will provide a varied floral and faunal environment for hominins, as is suggested to be the case at Dmanisi by Lordkipanidze et al. (2007, p. 305). Lastly, they also affirm the importance of dependable water resources, showing that tectonic landscapes have increased opportunities for basin features to form, trapping surface water. All of these factors are found in tectonically active landscapes (although not exclusively), and can be continuously renewed by on-going tectonic activity. The coalescence of these factors in such landscapes is seen by the authors as providing a resource-rich environment that enables hominins to more easily adapt to fluctuations in the climate, even as the factors produce such an active environment may work against the preservation of a long-term archaeological record. These environments are argued to provide the context for increasing terrestriality during the early evolution of the genus *homo*, and also the context for hominin expansion into Eurasia (Winder, et al., 2015). This potentially also agrees with Schepartz et al. (2000, p. 10), who have argued for the importance of mixed habitats and non-lithic resources in upland environments for the occupation of East Asia.

Certainly, a volcanic soil would be especially fertile (as is the loess of Central Asia, see 'Chapter 5. Physical Geography and Climate of Present Day and Historical Central Asia'), and the varying altitude will also encourage varied fauna and flora. It would provide a heterogeneous mix of resources in a small area, which is attractive for a niche generalist and opportunist like a hominin. Maslin & Christensen (2007) have also affirmed the role that tectonic activity has in creating lake basins, encouraging this close relationship between tectonic activity and hominin occupation. An area with high relief would also provide good views over the landscape, but we cannot be certain whether or how this would be exploited behaviourally by early Pleistocene hominins (If they are competing directly with carnivores and other hominin groups in hunting, herd observation will be important. If we credit them with even basic sociality, being aware of other hominin groups in the landscape takes on further importance).

'Rocky places'

Finlayson (2014) has suggested that 'rocky places' (overhangs, caves, rock shelters, etc.) begin to grow in importance relative to the reducing role of wooded landscapes for shelter in the late Pliocene-early Pleistocene, and this agrees with King & Bailey's (2006) focus on shelter for hunting and against predation. Shelter plays on important role in Chimpanzee nesting locations, as a study of chimpanzee nesting sites has found that they prefer wooded areas on slopes, and habitually reuse nesting sites in patterns that are similar to the distribution of early hominin sites (Hernandez-Aguilar, 2009). Finlayson's suggestion that rocky places begin to increase in importance for hominins is supported by his survey of reported environments published in fossil site reports, which shows an increase in rocky places from the Australopithecines onwards (although the number of sites in his sample is very small). The vast majority of archaeological cave sites are in limestone or dolomite karst features (Hunt, et al., 2015), and it would be reasonable to assume that these geologies will be most susceptible to karstification in tectonically-active areas where they will be more

prone to jointing and fracturing through stress, and more exposed to erosion through uplift. Therefore, tectonic areas, especially areas with specific geologies, are likely to provide more of these types of rocky places than non-tectonic areas. Eroding, exposed limestone might also provide access to siliceous raw materials such as chert.

Hard metamorphic and igneous rocks

Tectonically-active areas will tend also to have more metamorphic and igneous rocks, as there will be more regional metamorphism due to stress and more volcanic activity creating volcanic rocks and causing contact metamorphism. These rocks can be very effective raw material for knapping into stone tools, and although flint and other siliceous rocks are a common raw material in Central Asia, many sites in the study region also report the frequent use of igneous and metamorphic rocks. These hard metamorphic and igneous rocks also tend to have very low porosity, encouraging precipitation into overland run-off and basins, and hampering infiltration. A possible exception to this is infiltration along faults and joints, which are likely to be more prevalent in rocks in tectonically active areas. This is impossible to gauge without fieldwork on the ground, but the broad pattern of low porosity and increased run-off should still be valid at a continental scale. All of this has to be considered, when we talk about the factors that go into predicting continuously distributed resources in the landscape, and their relationship to hominin dispersal and occupation.

4.5 Summary

The current chapter has examined very broadly the nature of hominin dispersal and occupation processes, and how the language and models used by Palaeolithic researchers affect our study and interpretation of these processes. The ontological and geospatial issues surrounding the study of these dispersal processes is unique to their vast spatio-temporal scale, and analyses must be explicitly structured to account for this.

Environment plays a key role in hominin dispersal, but this role has often been misunderstood, and rendered in geospatial models in a simplistic way that diminishes the role of hominin agency. Traditional approaches have tended to use the concept of discrete habitats, such as vegetational zones or biomes, uncritically to explain the role of environment in hominin dispersal processes, without considering the hominin side of behavioural and anatomical adaptation, and especially the hominin potential as an adaptive opportunist not necessarily limited to a strict biome habitat. In particular, savannah and grassland environments have long been held to have an important place in discussions of early hominin evolution and dispersal, diminishing the role of wooded and rocky environments, both of which are argued here to be more important in the early Pleistocene than is commonly supposed.

The centrality of savannah environments has been challenged in recent years by several studies, and the focus is changing to emphasise the role of intensity of amplitude of climatic changes and the availability of distributed resources necessary for hominin occupation regardless of discrete habitat biome. The present study accepts Finlayson's argument to consider a 'variety of elements', and the analysis has been structured around providing a methodology for such an approach (see 'Discrete Habitats and Discrete Data' in '7.1.1.1 Data Collection and Formatting').

A wide variety of possible resources for hominin occupation have been considered here, several of which have also been highlighted by Finlayson, as well as the authors of the Tectonic Landscape Model. It is argued here, that the focus of spatial analyses of hominin dispersal and occupation should be on the variety of heterogeneous elements involved, not on discrete habitats such as savannah, or a poorly defined 'mosaic' of habitats. Tectonically active landscapes are relatively unique in that they contain a high frequency of these resources. In particular, these broken, topographically complex landscapes provide an

abundance of Finlayson's 'rocky places', which provide raw materials for knapping, but also shelter that may give an advantage for hunting and protection from dangerous carnivores. These complex topographies with dense rock types also increased the possibility for hominins to access surface water. Both hydrology and geology appear to be key for understanding hominin subsistence, although exactly how they relate to the hominin niche and hominin dispersal processes is still a matter of debate. An acknowledgement of the changing competencies of hominins throughout the Lower-Middle Pleistocene also allow us to consider more clearly the role that hominin-driven aspects of behavioural and anatomical adaptation play in these wider processes, without uncritically placing environmental factors as the sole driving force.

For many of the reasons outlined above, the present study has focused on the analysis of hydrological and geological factors in Central Asia, and the 'affordances' they provide for hominins, and so the next chapter will consider the physical setting of the study region from this perspective, and highlight some of the key aspects that are relevant to considering early Pleistocene dispersal and occupation.

Chapter 5. Physical Geography and Climate of Present Day and Historical Central Asia

Although Central Asia is often thought of primarily as a desert-steppe environment historically inhabited by nomads (Codrington, 1944, p. 30), this is only one aspect of this vast area. An extremely continental climate, strong aeolian forces, and substantial summer insolation can create some of the most arid environments on earth, but also can be tempered by other factors to produce protected, humid, and incredibly fertile areas. Mountains, glaciers, adjacent foothills and piedmont environments, depressions related to orogenic areas, plains and lowlands, deserts, rivers, and waterbodies both saline and freshwater all combine in one interconnected system to produce diverse and varied environments.

In this chapter, the major aspects of the physical geography of Central Asia will be described, and the connections between them explained. Where relevant, their relationship to present day and historic climate will also be considered. The chapter concludes with a summary of this inter-connected system, and develops ideas for hominin landscape use and movement in the study region.

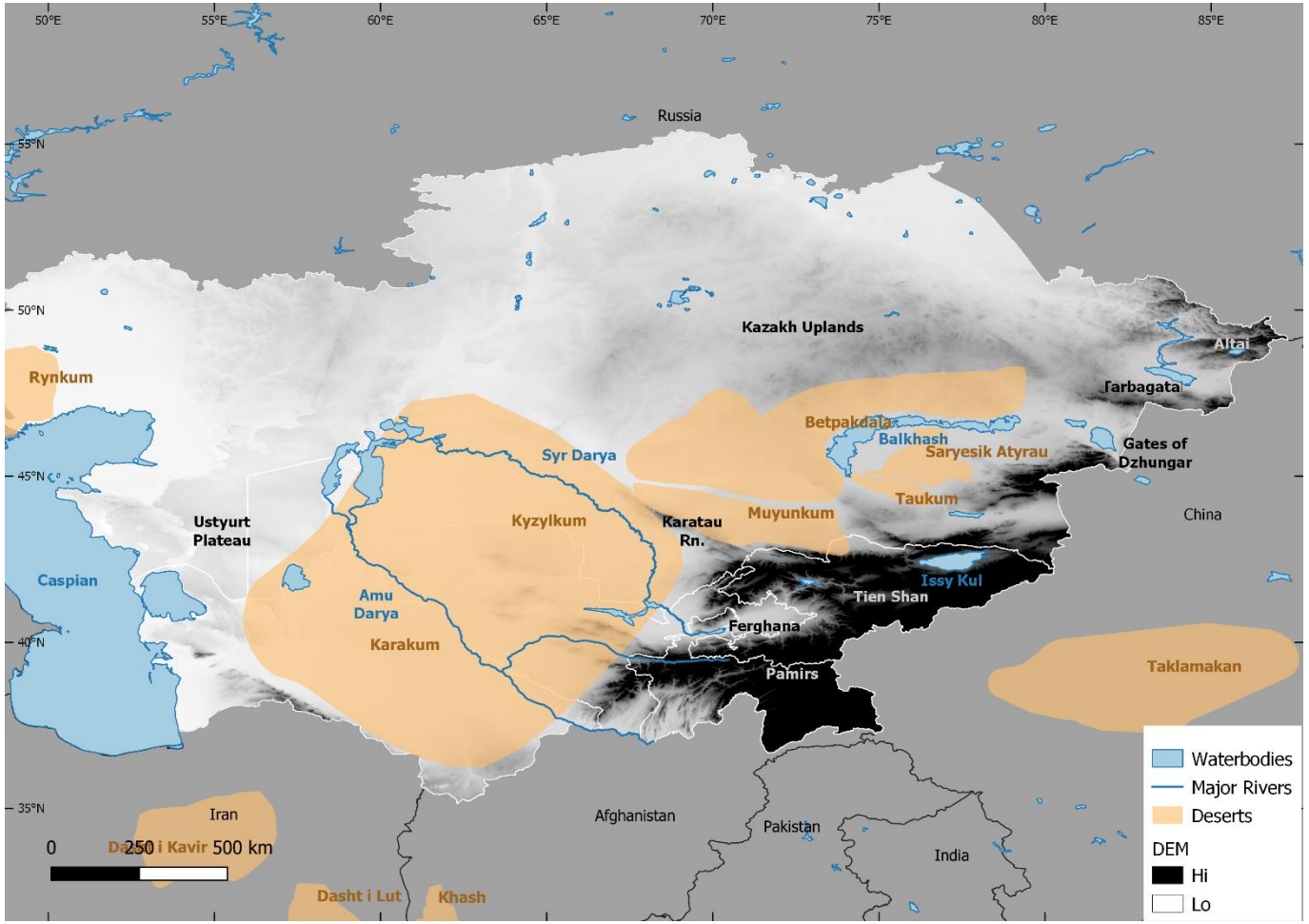

Figure 31 - Map showing major physical features of Central Asia, including deserts, waterbodies, and with topographic features labelled.

5.1 Physical Geography of Central Asia

Central Asia is primarily characterised by limited vegetational cover (Li, et al., 2015, p. 12345). Around 40% of Central Asia's landcover is grassland, and around 38% is desert (Xu, et al., 2016, p. 391). Grasslands predominate in the mountains and foothills, and in the relatively more humid areas north of the major deserts, while substantial forest cover is limited to the mountainous regions. In most of Central Asia, the growing season lasts from mid-Spring to mid-Autumn, with snow cover and freezing temperatures limiting vegetational activity outside of this time (Gessner, et al., 2013, p. 75). In some of the more sheltered foothills of Central Asia's piedmont regions, the growing season can begin as early as February, but then only lasts until June-July.

5.1.1 Mountains, Tectonics, and Orogenesis

The western half of the study region where it meets the shore of the Caspian, as well as much of the centre, is relatively low-altitude. However, the eastern and southern areas of the study region are increasingly high-altitude and mountainous. These mountain ranges dominate the inner continent of Asia, and in their overall area and extended environmental effects constitute a very significant part of its physical geography. They provide a stark contrast in the geomorphology that has a substantial influence on the expression of a variety of climate variables throughout the study region. The mountainous areas provide the origin and primary source of runoff for the major rivers that meander through the open lowlands of Central Asia, and drain into the major waterbodies. Many of the mountain ranges contain glaciers, which feed into these major rivers. Their topographic complexity and relative difficulty to access meant that these mountains remained one of the last areas in the region to be mapped by European explorers (Sinnot, 1992, p. 77), even as traditional pastoralists in these high-altitude areas continued to subsist and thrive. As forbidding as these

mountainous areas of Central Asia seem to interlopers to the region, they can be incredibly fertile and productive landscapes for human groups with enough local knowledge to exploit them effectively.

The extreme orogenesis that has taken place in the interior of Asia is at least partly an ongoing effect of the collision of the Indian Subcontinent with the Asian continent around 50mya, which reactivated pre-existing belts of orogenesis in areas such as the Tien Shan and the Tibetan Plateau (Molnar, et al., 1981, Neil & Houseman, 1997, p. 571). The mountain chains have historically not only functioned as a barrier to human movement and contact, but rather the many connecting passes and valleys through them have provided "channels of persistent human intercourse through the centuries" (Codrington, 1944, p. 30), which have shaped human movement through the landscape rather than blocking it completely.

Starting from the northeast of the study region, the Altai mountains are shared between Kazakhstan, Russia, Mongolia, and China. Between the Kazakh Altai and the Tarbagatai mountains to the south lies the Zaisan basin, through which both stretches of the Irtysh river flow through either end of lake Zaisan. Going south from here, many of the mountain ranges are shared between Kazakhstan and China, forming a natural border. The Dzhungarian Alatau, which is also known as the Zhetysu Alatau in Kazakhstan, separates the Dzhungarian depression in China from the Balkhash-Alaqol depression in Kazakhstan, and provide a substantial obstacle to east-west movement along this border.

The gates of Dzhungar represent a narrow, windy, passage through the area where the Dzhungarian Alatau and the Tien Shan almost meet. In fact, the area of the pass is a graben formation, where two faults either side have formed due to the orogenic activity in the mountainous areas to the north and south (Sinnot, 1992, p. 77). The area of the passage is narrow enough that an observer can easily look from the foothills on one side to the foothills of the other. While the area of the passage itself is relatively arid, the foothills either side are

humid, green, and have fast flowing rivers, even into the most arid months of the year. It is important to note that the gate of Dzhungar provides a possible means of access between the current study region and north-western China, and that it also provides some fertile and sheltered environments that could be effectively exploited by hominins.

South of the Dzhungarian Alatau, the huge range of the Tien Shan covers roughly 800,000km^2 in area, and about half of its extent lies above 3000masl (Aizen, et al., 1997, p. 1393). It has been a persistent feature of Asian orography throughout the Mesozoic and Cenozoic down to the present, and reactivated orogenesis in phases periodically throughout this time (Neil & Houseman, 1997, p. 573). Caught between the relatively stable Tarim basin to the south and the Dzhungarian basin to the north, the comparatively weak area of the Tien Shan has seen significant orogenesis. The Borohoro mountains form part of the Tien Shan range, and join the Dzhungarian Alatau in Kazakhstan, potentially creating a blockage for east-west movement. The Karatau range extends northwest from the main line of the Tien Shan in southern Kazakhstan, relating to the Ferghana fault. The Karatau is often divided between the Greater and Lesser Karatau, with a small gap of deflated area evident between these areas. The Karatau range is an isolated area of complex topography in the middle of deflated areas under the impact of strong aeolian forces. Small valleys in the Karatau range provide relatively humid, vegetated, and protected pockets in an otherwise inhospitable, steppe and steppe-desert environment.

Meeting in a complex tectonic 'knot' the Pamirs represent some of the highest areas of elevation in the study region, with the highest peak at 7,495 masl (Sinnot, 1992, p. 78). To the south they connect with the Hindu Kush and the Karakorams. This complex of extremely high mountains frames the western-most side of the Tarim basin, and effectively funnels movement north or south from this point. Further to the west, the Kopet Dagh range is shared between Turkmenistan and Iran, and in Turkmenistan the region around the range is

bare, rocky, and sandy, although some accumulations of loess are present (Babaev, 1994, p. 6). The highest peak in the range reaches only 2,872masl. Whereas mountainous areas in Central Asia generally see a relative increase in humidity and a decrease in temperature when compared to lowland areas, the Kopet Dagh stands out among Central Asia's mountains as still being relatively arid and desert-like.

5.1.2 Glaciers and their Hydrological Effect

Glaciers are present in several of the high-altitude mountainous zones of Central Asia, and they play an extremely central role in the hydrological cycle of the region. Glaciers function as a sink of solid precipitation and freshwater storage, and therefore act as a significant source of overland runoff when they melt (Hagg, et al., 2013, p. 62, Kriegel, et al., 2013). Runoff from the mountainous regions is the main determining factor in the balance of water resources within arid Central Asia (Yafeng & Jiawen, 1990, p. 261). In this way, glaciers and glacial dynamics can have impacts far beyond the peri-glacial zone, controlling the volume and seasonality of runoff from mountainous regions, impacting vegetational cover in and nearby mountainous regions. Glacial dynamics, and glacial runoff, have the largest impact on regional systems where the season of ablation is dry and the mountainous region is in proximity to arid lowlands, as is the case in Central Asia (Hagg, et al., 2013, p. 62). One of the key factors affecting volume of runoff from the mountain regions is the nature of the precipitation. Solid precipitation adds to glacial volume, and results in higher volumes of runoff, while liquid precipitation in the same regions results in reduced volume of runoff. This is connected to temperature, as the increasing temperature between 1940-1991 in the Tien Shan has shown a reduction of solid precipitation for an increase in liquid precipitation, while runoff volume has remained similar or reduced in rivers originating in the Tien Shan over this period (Aizen, et al., 1997, p. 1403).

The Amu Darya has been classed as one of the rivers in the world with the highest percentage of runoff from mountain discharge, with more than 90% of its runoff joining the fluvial system within its mountainous portion (Viviroli & Weingartner, 2004). This makes sense, as runoff contribution is likely to be limited in the arid lowlands after the river exits the mountainous region. Glacial melt water is a hugely important contributor to the Aral Sea (Kaser, et al., 2010), via the Amu Darya (Hagg, et al., 2013, p. 63) and the Syr Darya (Kriegel, et al., 2013).

Glaciers in the Tien Shan mountain range have been reducing in size continuously over the past few centuries, such as in the area of Urumqi (northwestern China) where the glaciated area has reduced by *c.* 44% since the 'Little Ice Age' (Yafeng & Jiawen, 1990). For the period between 1950-1980 some 73% of 227 glaciers surveyed in the mountainous regions of Central Asia and nearby China are classified as being in retreat. Since the mid-1970s, glaciers have reduced in size by 23% in the part of the Tien Shan mountains that form the catchment area of the Naryn river, a tributary of the Syr Darya (Kriegel, et al., 2013). Hagg et al. (2013) estimate that glacial volume in the upper reaches of the Panj River is likely to reduce by anywhere between 36-45% by the year 2050, depending on different estimates of global warming. This will have concomitant effects on seasonal runoff and also landcover (via agricultural impact). Glaciers are sensitive to both annual precipitation and summer temperatures (Rupper, et al., 2009, p. 339). It seems that increasing summer temperature may be responsible for this glacial retreat in at least some areas of the study region (Kriegel, et al., 2013, p. 60, Rupper, et al., 2009, p. 344). However, some areas in the Karakoram and the western Pamirs are showing slight gains in glacial mass (Kääb, et al., 2012, Gardelle, et al., 2013).

5.1.3 Intra-montane and Inter-montane Depressions

The corollary of mountainous areas are the areas of inter-montane and intra-montane depression. These tend to be consolidated tectonic features that provide some stability between regions of active or former orogenesis. Both mountainous areas and depressions relate to the existence, and expression, of tectonic faults. The Dzhungarian basin is in the territory of modern China, but nonetheless related to areas of orogenesis within the study area. The basin is described as either “consolidated Precambrian basin” or “trapped Paleozoic oceanic crust” (Neil & Houseman, 1997, p. 573). Along with Tarim basin to the south and east of the study region, the Dzhungarian basin has provided a relatively stable foreshore to the Tien Shan mountain range, which both basins are in the process of being thrust under.

With extensive catchments from nearby mountain areas, intramontane depressions can form substantial glacier-fed lakes, such as the large Issyk Kul and Son Kul lakes of Kyrgyzstan within the Tien Shan range. Outside of, but adjacent to, mountainous areas depressions can be fed from overland originating in the mountains to produce large freshwater lakes. In eastern Kazakhstan, for example, the large and shallow Balkhash depression contains a very large freshwater lake, Lake Balkhash, into which numerous rivers feed, notably the Aksu, the Ili, and the Karatal rivers (Issanova & Abuduwaili, 2017, p. 33). To the northeast, the basin is connected with the smaller Alaqol basin, where the gate of Dzhungar is located. A number of sandy deserts are also contained within the Balkhash basin, and depressions in Central Asia can also provide contained areas for the accumulation of loess deposits.

This coalescence of substantial overland runoff from mountainous areas with fertile soils of accumulated loess, combined with some protection from the stronger aeolian forces of the open plains, means that depressions in and adjacent to mountainous regions can provide an extremely productive microclimate. The Ferghana depression (sometimes Ferghana valley) is

just such an extremely fertile sedimentary basin created by tectonic deformation (Burov & Molnar, 1998), and is shared between the modern territories of Uzbekistan and Kyrgyzstan. But as well as being considerably fertile, they can also contain some sandy deserts, such as the Ferghana Depression does (Issanova & Abuduwaili, 2017, p. 32), and as previously noted for the Balkhash depression.

Basins are geomorphologically related to areas of orogenesis, provide sheltered, depressed areas for the accumulation of loess and the development of sandy deserts, but can be incredibly fertile areas depending on the overland runoff that enters their catchments.

5.1.4 Peri-Mountainous Foothills and Piedmont Areas

In the transitional zone where the mountains meet the plains and deserts, there are zones of forested piedmonts and foothills of fine-grained loess, created by substantial aeolian deposition. This loess can be extremely fertile when it is properly watered by precipitation, overland runoff, or systems of irrigation (Von Le Coq, 1928, p. 52). Where the loessic foothills meet the plains proper, the growth of sometimes substantial classic alluvial fans (ongoing and from non-extant hydrological regimes) can be observed (Lioubimtseva, et al., 2005, p. 289). Below the piedmont zone, at an altitude of 300-700 masl, the lower foothills of Central Asia can be relatively arid semidesert (Sinnot, 1992, p. 78). It is an area of sierozem soils with a high carbonate content and steppic vegetation, typically receiving around 300-500mm of precipitation annually (Dodonov, et al., 1999, p. 584).

What can be described as the piedmont zone exists between 700-2500 masl, and is characterised by rich, brown soils. The vegetation in the lower end of this altitudinal range tends towards xerophytic shrubland, gradually changing into broad-leaved forest towards the upper end of the range (Dodonov, et al., 1999, p. 584). The piedmont can provide some very dense vegetation. These can be more dense bushes in arid areas, but grading into temperate forests in cooler, less arid areas. Around 600-1,800 masl a broad-leaved forest

environment is typical, while between 1,700-1,800 masl, a narrow belt of coniferous forest is not uncommon (Sinnot, 1992, p. 78). Above 1,800 masl, this coniferous belt gradually gives way to a subalpine zone that begins to predominate, which then transitions into alpine meadow and meadow-steppe.

Aside from receiving overland runoff from mountainous areas, the upper foothills and piedmont also provide large numbers of springs, where groundwater emerges. These springs are particularly present around areas of tectonic faulting, although they can be seasonal in nature, sometimes drying up entirely for some times of the year. It can be a tremendously productive and varied environment, due to the relative humidity compared with the plain, and the rapidly changing environments with altitude increase. Topographical complexity and varied elevation can result in extremely diverse vegetational cover (Mathis, et al., 2014, pp. 170-71). Within a few kilometres in the area around the lake Son Kul basin in Kyrgyzstan, steppic grassland gives way to alpine meadow and woodland with variation in elevation.

5.1.5 Deserts and Dust Storms

At the opposite end of the spectrum from the mountainous regions, but nonetheless distinctive of Central Asia, are the extensive flat plains that comprise the deserts, steppe, and forested steppe areas of the study region. Around 60% of the area of Kazakhstan is flat plains, around half of which is desert (Issanova & Abuduwaili, 2017, p. 32). Most of the area of Kazakhstan below 50°N can be classified as desert or semi-desert, with most of the area above broadly classifiable as steppe or forest-steppe.

In the other countries of the study region, deserts also comprise a large part of the lowland areas. Deserts constitute more than 40% of the land surface by area of Central Asia (Issanova & Abuduwaili, 2017, p. table 2.1). In order of the largest absolute areas, desert covers almost a third of Kazakhstan, around 80% of Turkmenistan, and more than 50% of Uzbekistan. The smallest and most predominantly mountainous territories of Kyrgyzstan and Tajikistan

contribute only 6% of the total desert area of Central Asia. While Kyrgyzstan is around 35% covered by desert, Tajikistan has the lowest balance of desert to land area, with only 7% of the land surface covered by deserts.

These deserts provide a diversity of arid environments, because they can be of various sedimentological compositions, ranging from sandy to stony, fine-grained clay deserts, 'takyr' formations, and salt deserts (Issanova & Abuduwaili, 2017, p. 29). This diversity of arid environments is reflected in the fact that only around a third of the deserts in Central Asia can be classed as 'classic' sandy deserts, most of which are located within Turkmenistan (42% of the total sandy deserts) and Kazakhstan (40%), and to a lesser extent Uzbekistan (17%). As noted previously, a small area of sandy desert exists in the Ferghana depression. Many of these sandy deserts, subject to strong aeolian processes, have formed sand massifs of various morphologies.

The Karakum is the largest of the Central Asian deserts, covering more than 350,000km^2 between the Amu Darya, the Kopet Dagh mountains, and the foothills of the Pamir mountains (Issanova & Abuduwaili, 2017, p. 29). The area of desert above the Aral Sea is known as the Pre-Aral Karakum, and the newly created desert forming as the Aral has retreated over the last 60 years is known as the Aralkum. The Kyzylkum is the second largest desert in Central Asia, and is also a sandy desert. It lies between the Amu Darya and the Syr Darya rivers, covering an area of about 300,000km^2. North of the Caspian, in an area of fine-grained sediments, is situated a comparatively much smaller sandy desert known as the Naryn. Between the Caspian and Aral seas, the Ustyurt Plateau is an arid, desertified area filled with sand, saline lakes, and salt marshes, evaporites left over time by multiple transgressions of the two seas into the plains. Precipitation and overland runoff are more or less non-existent here.

Within the Balkhash depression are situated the sandy deserts of Saryesikatyrau and Taukum. Lake Balkhash borders them on the north and the nearby mountains of the Tien Shan and the Dzhungarian-Zhetysu Alatau contain them to the south and east (Issanova & Abuduwaili, 2017, p. 32). They are dissected by the Lepsa, Karatal, and Ili rivers. To their west, on the other side of the Shu river, is the sandy desert of the Muyunkum, and north of that, and at roughly twice the size, the Betpakdala desert.

The deserts of Central Asia are arid and deflated areas of the landscape. In spite of their reputation as barren and broke uplands (Brill Olcott, 1997, p. 21), the deserts of Central Asia contain substantial biodiversity, including the dense and hardy saxaul trees, as well as Bactrian camels and Asian wild asses (Issanova & Abuduwaili, 2017, p. 29). However, as a result of their aridity, often limited vegetation grows to consolidate the soil, and aeolian activity and aridity in concert provide an effect of deflation, where small particles become entrained to form dust storms.

Dust Storms

The frequency of dust storms in the deserts of Central Asia can be very high, at around 50 days per year (Ding, et al., 2002, p. 388). In some areas, the frequency can be as high as 80 per year, which is among the highest frequencies in the world (Goudie, 2002, p. 299). Nearby Dzhungaria, in western China, also receives a high frequency of dust storms (Littmann, 1991, p. 394). In mountainous areas, the frequency of dust storms is reduced, with areas such as the southern and eastern Pamirs receiving 8-14 days per annum (Goudie, 1983, p. 507).

In present day Central Asia, summer-autumn is the peak time for dust production in arid regions due to low precipitation, increased surface drying, and minimal vegetation cover (Dodonov, et al., 1999, p. 581). During the summer, low-pressure systems created by the westerlies create dust storms from source regions in the deserts of Central Asia as they move eastwards (Wake, et al., 1994), often leaving accumulations of dust in areas adjacent

to the mountainous zones (Ding, et al., 2002, p. 388). Areas to the south of Central Asia, in Afghanistan, India, Iran, and Pakistan also provide source regions for dust particles (Middleton, 1986). Frequent and sudden intrusions of cold fronts into Kazakhstan during the summer months have been connected to dust storm causing cyclones (Littmann, 1991, p. 398). This differs to the seasonal pattern of the dust storms that affect the Chinese Loess Plateau, which occur predominantly during the winter season as a result of the prevailing cold and arid conditions and the increased aeolian activity of the winter monsoon winds.

The majority of Central Asia's dust storms occur in the large corridor of land between the Caspian and Aral seas (Littmann, 1991, p. 394), where dried out coastal and lacustrine deposits provide source areas for dust (Parajuli & Zender, 2017, p. 56). The floodplain of the Amu Darya also provides a source area for dust. It seems likely that recent agricultural and industrial practices have affected both an increase in dust storms and the ongoing desiccation of the Aral sea (Goudie, 2002, pp. 298-301). The rapid retreat of the Aral Sea within living memory has opened up a large area of salt pans and fine sediment vulnerable to erosion, and therefore a major new source of dust for dust storms (Indoitu, et al., 2015). The source regions of dust can alter on a yearly basis, as seen in arid western China, where varying strength of the Westerlies is responsible for such a pattern (Han, et al., 2008). In Central Asia and China, altitude is associated with increased dust storm frequency, which Littmann (1991, p. 410) suggests may be an effect of the interaction between aeolian processes and gross landscape morphology. Although some individual dust particles can travel substantial distances in Asia, these tend to accumulate in small amounts at high elevations in mountainous areas (Wake, et al., 1994, p. 230). More substantial accumulations at lower elevations in Central Asia are composed predominantly of dust from local desert sources within the region. During dust storms, the dust is so pervasive in the air in that it collects in large amounts on clothes (Von Le Coq, 1928, p. 51). Dust storms turn the sky dark, producing a haze of dust held in suspension that can collect into dark brown

clouds. These can be seen approaching from many kilometres away, and this fine-grained dust is often inhaled by the inhabitants of Central Asia. von Le Coq (1928, p. 63) describes the unpleasant experience of regularly coughing up "…solid streams of loess…" during his excavations. The loess is, however, extremely fertile, and in many areas has been used as a fertiliser (Von Le Coq, 1928, p. 60). Up to the present day, bricks are still made out of loess machined from loessic foothills.

Although aridity and aeolian activity are necessary preconditions for dust storms, there is not a simple correlation between dust storm frequency in Asia generally with either precipitation, temperature, windspeed, or seasonality. Rather, Littmann (1991, p. figure 3) outlines three kinds of seasonal regimes that appear to affect dust storm frequency, of which Central Asia (and nearby Dzhungaria) falls into his third category 'winter rains only'. This distinguishes Central Asia and its mechanisms of dust storm genesis from areas of China with dust storms ('summer rains on tropical margins'), and also South Asia ('winter and summer monsoonal rains'). At least for Central Asia, this means that temperature is positively correlated with dust storm frequency, while precipitation and thunderstorms are negatively correlated, and peak dust storm activity takes place in late Summer (Littmann, 1991, p. 410). This results in a negative correlation between actual evapotranspiration and dust storm frequency in Central Asia, whereas other areas of Asia show a positive correlation.

5.1.6 Rivers & Waterbodies

As a predominantly arid to semi-arid, strongly continental region, the distribution of water in Central Asia is a crucial determining factor of the environment. Runoff from precipitation and glacial melting in mountainous areas such as the Tien Shan have a defining role in the hydrological systems of the foothills and plains of Central Asia, and the precipitation that feeds much of this runoff is in turn affected chiefly by the regional orographic expression in

those mountainous areas (Aizen, et al., 1997, p. 1394). Glacial runoff accounts for 10% of average hydrological input for valley rivers emerging from the Tien Shan range, although this rises to 20% during periods of reduced precipitation.

The rivers of Central Asia carry water far into the arid plains and lowlands, so that their courses have been of great importance to historical settlement. Aridity is slightly ameliorated in the areas immediately surrounding waterbodies and rivers (Li, et al., 2015, p. 12346, although their effect can sometimes be negligible in extremely arid areas, for instance, shore environments of the Caspian in Turkmenistan are still extremely arid (Babaev, 1994, p. 6), and the manipulation of these watercourses emanating from the mountainous regions has been the basis of historical agriculture over much of Central Asia (Von Le Coq, 1928, p. 53). In the otherwise arid landscape of the plains, rivers can provide small, linear stretches of greenery. As for the most part they do not drain out to any oceans, these rivers are "universally and inevitably destined to lose themselves in sand" (Codrington, 1944, p. 30), but they also to feed into some of the largest terrestrial lakes in the world. At times in the past, increased humidity has led to growth in the waterbodies of Central Asia. For instance, from the 16th-19th Century, the period of the marginally more humid 'Little Ice Age', it seems that the water-level of Central Asia's lakes was higher (Yafeng & Jiawen, 1990, p. 263).

One of the most dramatically changing waterbodies in Central Asia, the Aral Sea, is largely dependent on being fed by two of the major rivers of the region, the Amu Darya and the Syr Darya, which are themselves largely dependent on glacial meltwater (Lioubimtseva, et al., 2005, p. 291). The Amu Darya provides slightly more than half of the water that drains into the Aral (Hagg, et al., 2013, p. 63). The Amu Darya emerges from the confluence of the Panj and the Vakhsh rivers, where it is fed primarily from runoff from the mountains of Tajikistan and Afghanistan. The Naryn river, a tributary of the Syr Darya, brings water through the

Ferghana Depression (Kriegel, et al., 2013, p. 52). Within living memory the Aral Sea was the fourth largest terrestrial lake globally, but it is rapidly disappearing, and being replaced by salt pans full of fine sediment (Indoitu, et al., 2015). Intensive irrigation agriculture is practised in the desertified regions along the Amu Darya and Syr Darya (Gessner, et al., 2013, p. 75), and these have a substantial impact on how these rivers supply runoff to the Aral. Human water-use generally has grown to become a major part of the water 'deficit' causing the retreat of Central Asia's lakes (Yafeng & Jiawen, 1990, p. 263). Mismanagement of irrigation systems in Central Asia has resulted in increased saline input into the major rivers from irrigated areas, and it is estimated that somewhere around 50% of Central Asia's irrigated areas are affected by increased salinity or waterlogging (Qadir, et al., 2009, p. 136).

Lake Issyk Kul, which lies in a depression within the Tien Shan and is the largest lake in Kyrgyzstan, is fed by glacial runoff. During the period between 1910-1987, its water-level has dropped on average 5.7cm every year (Yafeng & Jiawen, 1990, p. 263). Most lakes within arid Central Asia are similarly retreating. The obverse of this pattern is the increase in area of medium sized lakes within the Tien Shan that are directly fed by glacial melt waters, which over the period of 1990-2010 have increased at the expense of the glaciers themselves (Wang, et al., 2013). Lakes that are not directly fed by glacial melt waters in the Tien Shan have decreased in area over this same timeframe. The proportion of glacial melt water being stored in glacial fed lakes is increasing, meaning that, even as the glaciers retreat, a lower proportion of the melt water provided by their retreat is entering the river systems of Central Asia. The second-largest lake in Kyrgyzstan is Lake Son Kul, an alpine lake also located within the Tien Shan, and ultimately draining into the Syr Darya. The lake appears never to have been fed by glaciers during the Holocene, but rather was probably fed by snow melt, precipitation, and groundwater as it is in the present day (Mathis, et al., 2014, p. 170). Depending on prevailing conditions, even the glacial lakes in mountainous regions can become saline. This is hypothesised to have happened during the period between 6900-4900

years BP to lake Issyk Kul, when reduced humidity may have caused the lake to evolve towards being more saline.

However, not all waterbodies in Central Asia are fed by overland runoff from mountainous areas. In the north of Kazakhstan, precipitation is substantial enough that arable farming is reliant on it (Xu, et al., 2016, p. 391). In the extremely arid area of Turkmenistan, dominated by the Karakum desert, 'Takyr' formations provide unique but limited natural water sources. These Takyrs comprise shallow landscape depressions filled with fine-grained sediments, are found across the desert areas of most of southern and south-western Turkmenistan. Takyrs act as natural moisture traps that provide runoff, and have historically been exploited as a source of water (Maman, et al., 2011). The very fine-grained sediments in takyr depressions form a crust that helps to collect water during precipitation events, and can be the only significant water source in some areas of Turkmenistan. Unlike 'solonchaks', which are very similar features geomorphologically, takyrs do not contain large quantities of evaporite salts, and their runoff is therefore non-saline and fresh. Infiltration of either weeds or wind-blown sands reduce the efficacy of the takyrs as a moisture trap, they therefore occupy a kind of 'Goldilocks zone', where too much arid aeolian activity or too much humidity promoting weed colonisation can both harm their efficacy.

5.1.7 Land Cover

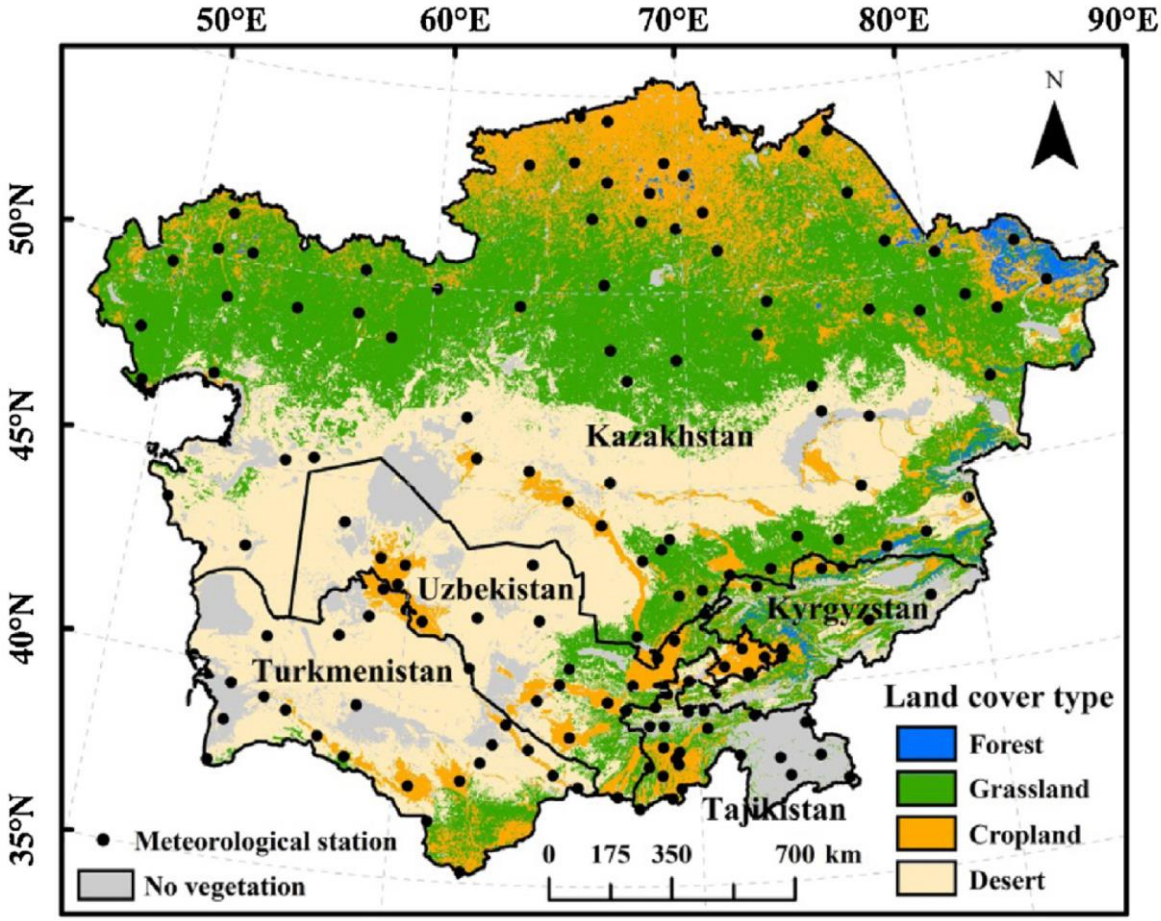

Fig. 1. Spatial distributions of meteorological stations and different land cover types in Central Asia. Non-vegetated areas in grey include bare areas, water bodies, and permanent snow and ice.

Fig 1. From Hu et al. 2016

On a regional scale, hydrology is the main climate factor driving vegetational change in Central Asia in the present day (Xu, et al., 2016). Precipitation-fed croplands are possible in the north of Kazakhstan, and in the mountainous regions, while the croplands in the plains and deserts are fed through irrigation systems. North of the deserts are a wide variety of transitional shrublands and steppe areas used for rangelands (Gessner, et al., 2013, p. 75). Vegetation in Central Asia is reliant on water in the soil zone, shallow groundwater fed by precipitation where available, and glacial melt water brought into the plains by the river

network (Li, et al., 2015). In the most arid region of Central Asia, Turkmenistan, and also in the similarly arid region of Xinjiang, adjoining Kazakhstan, soil moisture at a depth of 0-10cm is very low. In the rest of Central Asia, however, this is the zone of most soil moisture, with moisture reducing at increasing depth. Climate factors have the largest impact on soil moisture between 0-10cm, in particular precipitation and evapotranspiration (as a result of solar irradiation and air temperature). This is why the quality and character of vegetational cover in Central Asia is closely related to patterns of precipitation in the region. Gessner et al. (2013) suggest that around 80% of Central Asian land cover is sensitive to precipitation anomalies. Grasslands are the most sensitive to water stress, with forests and desert vegetation responding slower (Xu, et al., 2016). The effect of changes in precipitation on vegetational cover has a time-lag of about 1-3 months.

5.2 Temperature and Precipitation in Central Asia

The variation of temperature and precipitation in Central Asia is heavily influenced by regional topography. In turn, it also influences the volume of water in glaciers, overland runoff, and waterbodies. Seasonal temperature change in Central Asia is high amplitude in nature (Li, et al., 2015, p. 12346). As the region is strongly continental, summers tend towards being hot and dry, while winters tend towards being cold and (relatively) humid (Xu, et al., 2016, p. 391).

5.2.1 Temperature

Temperature in Central Asia is most affected by two factors; firstly, the north-south gradient, with cooler temperatures to the north, and secondly the lowland-high altitude gradient, with cooler temperatures in the higher elevation mountainous regions (Gessner, et al., 2013, p. 75). In the Tien Shan, elevation is the primary factor influencing the distribution of temperature variation (Mathis, et al., 2014, p. 170). Mountainous regions commonly have a mean annual temperature below 0°C (Xu, et al., 2016, p. 391). The mean annual

temperature in the mountainous area around lake Son Kul is slightly warmer than this at *c.* 1.5°C, but in spite of this the lake can still be frozen from anywhere between 6-9 months a year.

Mean summer temperature in Central Asia can range from around 30°C-20°C, with colder temperatures in the north and warmer temperatures in the south (Gessner, et al., 2013, p. 75). In the winters, the mean temperature in Central Asia is commonly below 0°C. Mean winter temperature can range from -20°C in mountainous regions and the north of the study region, up to 5°C in some areas of Uzbekistan and Turkmenistan. In the past, temperatures in mountainous areas seem to have been broadly similar to the recent past. Climatic reconstruction from sediments in the Son Kul lake basin suggest that mean annual temperature in the Tien Shan mountain range between 8350-2000 years BP may have been around, and even slightly warmer, than present conditions (Mathis, et al., 2014, p. 178). However, current climate changes trends seem likely to increase the temperature of Central Asia in the near future (see '5.3 Human Intervention and Climate Change').

5.2.2 Precipitation

As a predominantly arid or semi-arid environment, Central Asia in the present day has a relatively consistent moisture deficit (Li, et al., 2015, p. 12346). Precipitation increases on a rough gradient from the south towards the north, but also on a regional level from basins and plains increasing with altitude into mountainous regions (Xu, et al., 2016, p. 391). As with temperature, seasonal variation in precipitation is high amplitude in Central Asia. In the north of the study region, mean annual precipitation is *c.* 400mm, dropping to <100mm in parts of the south. Mountainous regions receive the most, broadly ranging from 600-800mm per annum. The lake Son Kul basin, in the Tien Shan, currently receives just under this range, at 550mm per annum (Mathis, et al., 2014, p. 178). Palaeoclimatic reconstruction from sediments in the basin suggest that this is at the lower end of the range for the basin's

annual precipitation for the recent Holocene, as the figure is estimated to range from 550mm-700mm per annum over the period between 8350-2000 BP. In the Kopet Dag mountains in Turkmenistan, annual precipitation is *c.* 300mm, dropping below 150mm in the Karakum desert (Maman, et al., 2011, p. 844).

Most of the precipitation in present day Central Asia occurs in the winter and spring with cyclonic storms from January to April, and not much precipitation at all in the summer months (Goudie, 2002, p. 291, Littmann, 1991, p. 391). There are some regional exceptions to this. Most precipitation in western Central Asia is during the winter-spring, with springtime maxima, when warm moist airs are brought in under the influence of the Siberian anticyclone (Gessner, et al., 2013, p. 75, Wang, et al., 2013, p. 2, Maman, et al., 2011, p. 844). In the centre of the study region, around southern and central Kazakhstan, rainfall is limited, but distributed fairly equally throughout the year (Gessner, et al., 2013, p. 75). In the north of the study region, the otherwise steppic environment receives enough precipitation that its agriculture can be largely rainfed. Further north and east in the study region, the Siberian High and nearby mountainous regions work to supress precipitation in the winter, with the maximum precipitation occurring spring-summer, resulting in much regional variation. Based on the differing interaction between western cyclonic air systems and the Siberian Anticyclone, Aizen et al. (1997, p. 1394) divide the Tien Shan into western, northern, eastern, and central areas. In the western area of the Tien Shan, where the action of the Siberian Anticyclone is weakest and the effect of the westerlies is strongest (Kriegel, et al., 2013, p. 52), precipitation is around 80mm per month during its springtime maxima, and 50mm per month from autumn-winter. In the northern Tien Shan, the Siberian Anticyclone is strongest and suppresses winter precipitation. The maxima occur from spring-summer, with up to 120mm precipitation per month. In the eastern and central areas of the Tien Shan, surrounding orographic expression limits the amount of moisture entering the region, resulting in low winter precipitation of around 10mm per month. However, strong

convection promotes a summer maxima that can reach up to 130mm per month. For instance, in the vicinity of the high altitude lake Son Kul in the Tien Shan, Kyrgyzstan, the precipitation maxima are usually in March-May, but also in July, later than many other regions of Central Asia, and during these maxima around half of the annual precipitation in this area is achieved (Mathis, et al., 2014, p. 170).

5.3 Human Intervention and Climate Change

Central Asia is particularly vulnerable to climate change, and is expected to become even more arid in the near future (Lioubimtseva & Henebry, 2009), with projections of warming being somewhere between +1-2°C by 2030-50 (Lioubimtseva, et al., 2005, p. 294), or even +7°C by the end of the 21st century (Mannig, et al., 2013). The greatest seasonal increase seems likely to affect the winter months. This continues a strong trend of increasing temperature since at least 1941, and a weak trend of decreasing precipitation over that same period by some measures (Salnikov, et al., 2015). Increases in temperature during the period 1960-2013 seem to have been most extreme in northern and western Kazakhstan (Li, et al., 2015, p. 12348). The precipitation changes over this same period have seen a sudden increase between 1986-2000, and more recently a slight downturn from 2000-2013, which has been suggested to indicate an increase in the fluctuation amplitude of precipitation change (Li, et al., 2015, p. 12348, Lioubimtseva, et al., 2005). Although by some measures Central Asia as a whole seems to have seen a slight increase in precipitation since 1960, it should be noted that this has not been distributed evenly across the region. Areas that saw an increase in precipitation during this period include some of the major oases, and it seems likely to have been a localised effect of expanding irrigation in those areas (Lioubimtseva, et al., 2005, p. 292), rather than any general amelioration in the aridity of Central Asia. Areas of northern Kazakhstan have seen a net decrease in precipitation over this time (Li, et al., 2015, p. 12348), and as noted previously, the agricultural crops of northern Kazakhstan are largely

reliant on direct precipitation for their hydrological input, and so are likely to suffer greatly from this reduction.

Overgrazing and massive irrigation in the last century have contributed to desertification in Central Asia (Lioubimtseva, et al., 2005, p. 286). Increasing loss of soil moisture with increasing temperature and decreasing precipitation is likely to accelerate this desertification in many areas of Central Asia (Li, et al., 2015, p. 12350). The disappearance of the Aral as a result of human intervention has already created a new desert, and is having an impact on the frequency of dust storms in the region (Indoitu, et al., 2015). The newly created 'Aral kum' has provided a large expanse of fine-grained sediments vulnerable to erosion and entrainment in dust storms. The dust deposited nearby in the region exhibits a similar composition to the surface sediments from this desert, confirming it as the probable erosional source (Opp, et al., 2017).

A history of agricultural monoculture during the Soviet era has had a long-lasting ecological and economic effect in Central Asia (Lioubimtseva & Henebry, 2009). The ecological system of Central Asia is fragile, and sensitive to extreme variations in climate (Li, et al., 2015, p. 12346), so it seems likely that this situation will be further compounded with the ongoing effects of climate change. Present climate in arid Central Asia, and predicted future climate, is likely to be more heavily influenced by local human interventions than it is by global climate change (Lioubimtseva & Cole, 2006). Changes in climate seem likely to increase in amplitude in the near future, and effects are already observable in landcover changes, such as a loss of 8% of grassland to shrubland between 2005-2015 (Li, et al., 2015). Takyr formations, which provide vital runoff in one of the most arid areas of Central Asia, have been degrading in recent decades. Maman et al. (2011) report a loss of about 20% of takyr surfaces in their study region of Turkmenistan over the period 1972-2011. Glaciers seem also likely to reduce in area by somewhere in the region of 36-45% in the upper reaches of the

Panj River, a source of the Amu Darya, by the year 2050 (Hagg, et al., 2013). Although absolute annual runoff into the Amu Darya seems unlikely to change as a result of this, a change in its peak from summer to spring is likely to have adverse effects for agriculture in the region. The growth in medium glacial lakes within the Tien Shan mountain range, noted previously, is likely to lead to more frequent and catastrophic outburst floods (Wang, et al., 2013). There is an especially large density of these in the area of the Tarbagatai rangE.

With current climate trends as a guide, it seems that Central Asia will face serious water scarcity over the next few decades. Temperatures seem likely to increase while precipitation seems likely to decrease. These factors, in combination with previous Soviet mismanagement of this landscape and its resources, seem likely to lead to an environmental and agricultural crisis that will present a substantial challenge to the peoples of Central Asia in the near future.

5.4 Summary and Conclusions on the Present Day Physical Geography and Climate of Central Asia

The physical geography and environmental conditions of Central Asia can be very broadly described with reference to some simple heuristic axes. From north to south, and also from lowland to mountain, generally precipitation increases and temperatures decrease. From the northwest to the south and east, generally, altitude increases. The volume of overland runoff is highest in the mountainous areas, and decreases further into the plains. The plains of the north and west are generally deflating, providing source areas for the aeolian dust that accumulates against the mountains to the south and east of the study region. However, the simplicity of these descriptions does not fully convey the great variety of environmental conditions that are available throughout Central Asia, and in the areas adjacent to and including the mountainous areas.

Mountains dominate the landscape of Inner Asia, and their effect on the environment in terms of determining the actions of aeolian processes, the continental climate, temperature variance, precipitation distribution, and the nature, quantity, and timing of overland runoff means that their influence is felt far into the plains, deserts and lowland areas. Many of the mountain ranges contain glaciers, which function as stores for solid precipitation, and introduce a time-lag effect from precipitation to overland runoff. The glaciers and their runoff feed large intra-montane lakes, and drain far out into the plains to feed large lakes in the depressions. Below the alpine zone, many mountainous areas provide forested, humid, and sheltered environments, that gradually give way to more arid lower foothills and plains. Springs are common in tectonic areas of the mountains and foothills; however, water features can vary substantially on a seasonal basis. During archaeological survey in the region, I have observed rivers change from being traversable one month, to completely impassable the next. The same unpredictability affects sources of drinking water, where springs can dry up periodically and unpredictably. It is likely that mountains provided substantial obstacles that may have conditioned hominin movement and ranging, but they also provide sheltered, varied, and fertile environments in their upper foothills and piedmonts that are likely to have attracted hominins, and perhaps encouraged dispersal along the periphery of mountainous areas, the IAMC.

The plains and rangelands are a more hostile and exposed environment, and the numerous deserts of various types are the most hostile of all from a hominin perspective. Perhaps these areas could provide good visibility, opportunities for defence, and opportunities for game hunting for a very capable, large-bodied hominin. But occupation of these areas also comes with substantial drawbacks, not least of all the aridity, limited plant resources, and strong aeolian forces that include choking dust storms. Some of these environments may have greened more during more humid periods, especially in sheltered depressions where large rivers traverse them, but are likely to have proved tough and inhospitable. The

sheltered depressions can be arid and desertified, but also tend to localise overland runoff from major rivers in their catchment areas to provide substantial freshwater lakes. Access to water is a determining factor for the productivity of this strongly continental region, and is likely to have been so also in the Pleistocene, when aridity was more and less intense at different intervals (see 'Chapter 6. Pleistocene Climate and Environmental Record of Central Asia'). As has been noted, climate change and human intervention over the recent past has been degrading the environments of Central Asia, and this is likely only to increase into the future.

Historically, Central Asia lies between the cultural influence of China to the east, and the Persian cultural sphere to its south and west (Codrington, 1944, p. 30). This is not an historical accident, but represents at a broad level the reality of the region's connectivity with other areas of Asia. Attractive environments would encourage hominin occupation and dispersal through the foothills and piedmont areas of the study region. These regions follow the mountain chains of Central Asia, roughly from the south, eastwards, and north to the Altai. Whether hominins of the Lower-Middle Pleistocene would have been able to cope with the temperatures of this most-northerly mountainous area, especially during winters or harsh glacial conditions, is uncertain. Whether the plains would have provided sufficient affordances to them, even during ameliorated interglacials, is also uncertain, and both will be considered further in 'Chapter 6. Pleistocene Climate and Environmental Record of Central Asia'. The mountain chains that block east-west movement at this eastern border of the study region would have provided substantial obstacles to movement. However, some breaks in the mountains, such as at the gate of Dzhungar in the southeast, may have provided modes of egress into the area of Dzhungaria, and onwards into China. It seems likely that, by simply occupying the sheltered foothills and piedmont environments of Central Asia, hominins would be drawn into a predominantly east-west movement over time, whether from southwest Asia into China, the reverse, or possibly in both directions.

The main reason that diminishes the possibility of serious dispersal into the region from China is the fact that the area bordering the Gate of Dzhungar is extremely arid and desertified. For this reason, it should be considered that initial dispersal into Central Asia is likely to come predominantly from a southern route into the study region.

Chapter 6. Pleistocene Climate and Environmental Record of Central Asia

The focus of this chapter is to establish what the current state of knowledge is for the Lower-Middle Pleistocene environment in Central Asia, and how it connects to global changes in climate throughout the Pleistocene. This chapter will also assess what major obstacles and affordances for hominin occupation are presented by the climate of the study region during this time, and how they vary over time for specific glacial and interglacial periods.

Global climate can be thought of as the response over time of global weather systems to climate 'forcing', which is the difference between the amount of solar radiation absorbed (insolation) and the amount reflected by the earth (Bradley, 2015, p. 36). Some of the largescale factors that affect insolation are related to orbital factors such as the obliquity, eccentricity, and precession of the earth's orbit. These orbital factors resolve into cycles of differing amplitude, known as Milankovitch cycles, which become more or less dominant in different weather systems over time and are thereby responsible for changes in climate periodicity. Of particular relevance to the Pleistocene is a shift in the periodicity of multiple climate variables known as the Middle Pleistocene Transition (MPT, Head & Gibbard, 2005), which reflects a shift in Milankovitch cycle, and therefore also in the dominance from one orbital regime to another. Insolation varied by orbital factors has a causal connection to sea surface temperature and global ice volume, and is in this way connected to the Oxygen Isotope Stages (OIS), which are defined in relation to the ratio of ^{18}O to ^{16}O and therefore to the total water in free circulation or trapped in ice globally at any one moment in time. It is within the context of these climate forcing mechanisms that regional weather systems find resolution in local response to global climate.

Central Asia in the present day is relatively arid and prone to dust storms, and this is in large part due to its continental climate, being positioned far into the interior of Asia, and with substantial topographic barriers to precipitation. This continental aspect, a reflection of

long-term plate tectonic movements, has long been a feature in the climate of Central Asia; however, its resolution in regional climate has not been uniform over time. The climate of Central Asia underwent three major benchmarks of change associated with increasing aridification and orogenesis, at around approximately 4-3.5mya, 2.5mya, and 0.8mya. The first of these represents the onset of aridification in continental Asia, associated with a period of tectonic activity (Dodonov, 1991, p. 193). The second benchmark represents the formation of the oldest loess deposits in several areas of continental Asia, including Central Asia. The last of these benchmarks represents the MPT, which is visible in all of these records, and represents an important turning point in the environment of Central Asia in particular, as it's the point at which several factors coalesce to make glacial periods harsher and longer in duration. Dust storms have been a feature of Central Asian climate throughout this time, and into the present day, resulting in large accumulations of wind-lain sediment, known as loess deposits. As the climate has varied over time, so too have the dust storms varied in frequency and intensity, and these variations are recorded in the extensive loess deposits of Central Asia. Times of substantial loess deposition would have provided an environmental challenge for hominins, but its accumulation also provides a detailed stratigraphic record with some environmental preservation that might help shed light on the kind of environment, and the kinds of resources, that may have been available for hominins to exploit. The correlation of these loess deposits with other environmental records of the Pleistocene has proven to be essential for their dating, and three of these will be considered in particular; the well-studied sequence of the Chinese Loess record, the global Oxygen Isotope Stages, and the lake bed cores taken from Lake Baikal in Russia.

6.1 The Pedocomplex-Loess Sequence

Central Asia can be conceptualised as a region divided broadly into areas of net aeolian erosion and areas of net aeolian deposition. The arid deserts and plains of the northern, central, and western areas of Central Asia are in the process of deflating, while the piedmont

regions and their surrounding plains in the southern and eastern areas of Central Asia accumulate substantial deposits of wind-blown sediment, known as loess. Although initially subject to some controversy amongst geologists in the early-mid 1900s, aeolian processes are now accepted as the mechanism through which loess accumulations occur (Dodonov, 1991, p. 185). Deserts with sparse vegetation, the floodplains of large rivers, and eroding bedrock in mountainous regions provide areas where fine-grained clays, silts, and sands can be eroded from parent rock through aeolian, fluvial, and glacial/cryofracturing mechanisms, and brought into suspension by the wind (Frenchen & Dodonov, 1998, p. 3). For areas like Tajikistan, where loess accumulation is most substantial, the eroding source areas for the dust lie to the north and the west in the Qyzylkum and Qarakum deserts, and the floodplain of the Amu Darya (Ding, et al., 2002, p. 388). This process is visible in the present day in the form of dust storms, which also affect regions to the east, south, and west of Central Asia, including areas of China, Afghanistan, and Iran. Loess accumulation can be very rapid, although it varies over time. The deposition of substantial accumulations of loess in this general area of Asia appears to begin around 2.5mya with some of the oldest loess deposits in Central Asia (Dodonov, et al., 1999, p. 581), Wucheng (China, Kukla, 1987), and also Iran (Wang, et al., 2016) dating to this time. This indicates a continuation of a general shift towards aridification in continental Asia that began around 3-4mya (Dodonov, 1991, p. 193), probably also coupled with increased aeolian activity and a decrease in vegetation cover. The deposition of loess throughout the Pleistocene is seen to coincide with this process of aridification (Dodonov, et al., 2006, p. 57). In the study region, thick accumulations of loess alternate in sequence with thinner preserved palaeosols. These alternations represent an oscillation between two kinds of depositional environment, one where aeolian input is substantial, and one where it is much reduced. These alternations are themselves ultimately an indication of oscillations in global climate forcing mechanisms, and the oscillations between glacial and interglacial periods. The palaeosols seem to have been laid down during

interglacials, while the much thicker loess deposits seem to have accumulated under glacial conditions. In Central Asia, the vast majority of the stratified Palaeolithic sites from loessic areas appear in palaeosols. Environmental preservation can be generally good in the loess and palaeosols, which, when combined with the high resolution of the sequence itself, means that these deposits provide a valuable environmental archive for the region.

6.1.1 The Role of Weather Systems and Gross Landscape Morphology in Long-Term Aridification and the Glacial-Interglacial Succession

On the continental scale, the Asian monsoon systems, in combination with the opposition between North Atlantic-Mediterranean westerlies and the Siberian-Mongolian Anticyclone are primarily responsible for the patterning and levels of precipitation in Central Asia (Dodonov & Baiguzina, 1995, p. 708). In terms of the long-term aridification of Central Asia throughout the Pleistocene, the gross morphology of the Tibetan Plateau in particular is associated with increasing aridity in the region, as it has had a significant impact on the amount of moisture capable of penetrating into Central Asia from the monsoon cycles (Chen, et al., 2008, Tungsheng, et al., 1996). Uplift of the Tibetan Plateau and associated orogenesis in the mountain chains of inner Asia, particularly the Tien Shan, Ghissar mountains, the Pamir Plateau, and the Karakorums, are broadly associated with the benchmarks of increased aridification throughout the Pleistocene (Davis, et al., 1980).This was at least partly due to the increasing isolation of continental Asia from the monsoon cycles that bring moisture into the interior (Dodonov, 1991, p. 193). For example, moisture input from the South Asian monsoon cycle was reduced after the MPT, with the Himalayas and the Hindu Kush to the south of Central Asia providing the primary obstacle to moisture input from this monsoon system (Dodonov, et al., 2006, p. 58). The reduction in moisture input throughout the Pleistocene had concomitant effects throughout the climate system of

Central Asia. For instance, the timing of glacial advances through the Late Pleistocene coincide with cold periods, but are seen to be asynchronous with the growth of western hemisphere ice sheets due to a lack of available moisture in Central Asia to provide for glacial growth (Abramowski, et al., 2006).

Against this background of stepwise aridification, these weather systems oscillated between glacial and interglacial periods coincident with global oxygen isotope stages (Liu & Ding, 1998). Humid interglacials represented increased summer monsoonal activity extending into the region along with the dominance of westerlies, while during glacial periods continental high pressure systems limited monsoonal ingress, with a concomitant increase in the intensity of regional aeolian processes (Dodonov & Baiguzina, 1995, p. 708, Dodonov, et al., 2006, p. 58). This increase in the intensity of aeolian processes, along with a reduction in precipitation and vegetational cover, accounts for the increase in available dust for erosion and deposition as loess during glacial periods (Dodonov, 1991, p. 185, Frenchen & Dodonov, 1998, p. 3).

It has also been suggested that the connection between loess/palaeosol alternation to orbital periodicity can be taken to suggest that global ice volume may also have been an external forcing mechanism for loess/palaeosol formation (Ding, et al., 2002, p. 398). This is additionally corroborated by the role of global ice volume as a forcing mechanism in the MPT (Head & Gibbard, 2005). Furthermore, for the late Pleistocene it seems that the Asiatic Polar Front has had an important role in aeolian dynamics that has been largely ignored with a focus on the opposition of westerlies to the Siberian-Mongolian anticyclone (Machalett, et al., 2008), and so this should also be considered a possible factor for earlier in the Pleistocene.

6.1.2 Timing and Intensity of Loess Accumulation in Central Asia

Sections of the loess/palaeosol succession are found at a variety of localities across the south of the study region. A combination of palaeomagnetism, grain size analysis, and palaeontological evidence has enabled researchers to correlate across these sections to reconstruct the succession. The oldest loess horizons in Central Asia are from the Chashmanigar, Khonako, Karamaidan, and Obigarm sequences, all of which are located in the south of the study region. The oldest horizons at these loess sequences are dated with palaeomagnetism to the Matuyama epoch, and with palaeontological comparison to the Middle Villafranchian fauna, placing their date collectively *c.* 2.4-2.0mya (Dodonov, 1991, p. 186). This period saw an increase in the frequency of dust storms (Dodonov & Baiguzina, 1995, p. 709), in agreement with the evidence for intensifying weather systems in the region linked to the uplift of the Tibetan Plateau. Numbered incrementally from the top of the loess/palaeosol succession, the 34th-33rd palaeosols contain the palaeomagnetic signature of the Olduvai subchron, and are therefore a little younger than the oldest loess horizons. Ding et al. (2002, p. 391) identify the upper boundary of the Olduvai subchron near the base of the section at Chasmanigar, suggesting an age of *c.* 1.77mya for the base of their sequence. Higher in the succession, the Jaramillo subchron is reported as coinciding with the 16th-15th palaeosols. The Matuyama-Brunhes reversal has been reported as being in the 8th loess horizon, between the 10th and 9th palaeosols (Dodonov, et al., 2006, p. 48), for instance at Chasmanigar, Obigarm, and Khonako (Dodonov, et al., 1999, p. 584). A faunal assemblage attributed to the Lower Cromerian from the sequence at Lakhuti 2 underlies the Matuyama-Brunhes reversal, and is therefore in agreement with the identification of this magnetic reversal. However, the reversal is reported at the base of the 9th palaeosol at Karamaidan (Forster & Heller, 1994), possibly suggesting some regional difference in the onset of aeolian dynamics, or possibly differential erosion of loess deposits during interglacials. As can be seen in figure 4 of Forster & Heller (1994), a wide-ranging study of magnetic susceptibility

has provided correlation between the succession represented at the Karamaidan section, the Xifeng section, and global oxygen isotope stages, demonstrating a more detailed and realistic chronology for the loess succession than that provided by the early TL dates.

In the 1970s-80s, a number of thermoluminescence (TL) samples were taken from several loess sections to be processed in Kiev to provide dates for the palaeosols (Dodonov & Baiguzina, 1995, p. 707, Dodonov, et al., 1999, p. 581). The resultant dates proved to be far younger than other dating methods at the time seemed to suggest, which caused some suspicion among researchers. Further fieldwork, as well as work correlating the Central Asian loess sequence with the Chinese loess sequence and global oxygen isotope stages, demonstrated that the TL dates had in fact underestimated the ages. It seems that TL dates beyond *c.* 100kya or the 1st palaeosol were systematically underestimated, and only provided a relative chronology for the loess/palaeosol succession (Zhou, et al., 1995).

It appears that aeolian processes intensified fairly gradually over the Pleistocene, in line with rhythms of climatic cyclicity over the breadth of the Pleistocene (Dodonov & Baiguzina, 1995), as suggested by the sedimentation calculations from the Darai Kalon section (Dodonov, et al., 1999, p. 591), but also with some relatively rapid changes in the Middle and Late Pleistocene. Middle-Upper Pleistocene loess deposits are thicker than early Pleistocene ones, representing an increase in intensity of aeolian processes and therefore an increase in material deposited. The MPT provided a turning point in the intensity of loess accumulation, and a shift in cyclicity of loess/palaeosol formation, a shift which has been well-documented, for instance, at the reasonably complete section at Chasmanigar (Ding, et al., 2002, p. 394). Using the previously described palaeomagnetic events in the sequences as constraints, Dodonov & Baiguzina (1995, p. 710) have estimated the duration of the palaeosol/loess cycles at *c.* 34-50ky in the Lower Pleistocene, and *c.* 80-100ky in the Middle-Late Pleistocene. Based on estimates of sedimentation rates, in seems that loess accumulation increased

drastically in the Late Pleistocene for Poland, Hungary, and Siberia, as well as Tajikistan. However, it still appears that the highest absolute accumulation rate in Tajikistan occurs during the Middle Pleistocene. From this it must be concluded that we see an intensification of several weather systems in Central Asia during the Middle and Late Pleistocene, resulting in increasing aridification, increasing dust storm frequency, and increasing length of glacial periods. All of this amounts to a severe climatic downturn, and an increasingly difficult environment for hominins versus that of the earlier Pleistocene. It is unlikely to be a coincidence that interglacials with well-developed soil horizons have provided the evidence for Palaeolithic hominin occupations in Central Asia.

6.1.3 Regional Geomorphology of Loess in Central Asia

The longest and thickest loess sequences in Asia are preserved in China and Central Asia. This is at least in part this a reflection of the fact that these areas contain large arid deserts that serve as deflation zones. Loess in Central Asia tends to be deposited in piedmont areas adjacent to desert zones (Dodonov, 1991, p. 186), the deserts themselves and the piedmont plains being subject to erosion by dust storms (Dodonov & Baiguzina, 1995, p. 707). Regional tectonic uplift in Central Asia has also been responsible for aridification of intermontane depressions, encouraging deflation and loess accumulation in these areas (Dodonov, et al., 2006, p. 48). For the most part, the dust deposited in loess tends to be fairly local to the region in which it is deposited. For example, mineralogical analyses of loess in the Kyrgyz mountains and the Kashmir valley has suggested that the aeolian deposits are composed primarily of material deflated locally, but with some finer sediments incorporated from further afield. The bulk of the loess deposits are situated between 2000-2500masl (Dodonov, et al., 1999, p. 584), which agrees with current observations of contemporary dust storms that suggest that this is roughly the altitude of highest dust particle density (Dodonov, 1991, p. 186). However, less substantial deposits of loess are sometimes found much higher than this. The maximum thickness of the loess deposits in Central Asia can be around 100-200m,

as they are, for instance, in the piedmont region around Tashkent (Uzbekistan), and in areas of Tajikistan (see Figure 32). In spite of its thickness, loess deposition generally follows underlying relief (Dodonov & Baiguzina, 1995, p. 707).

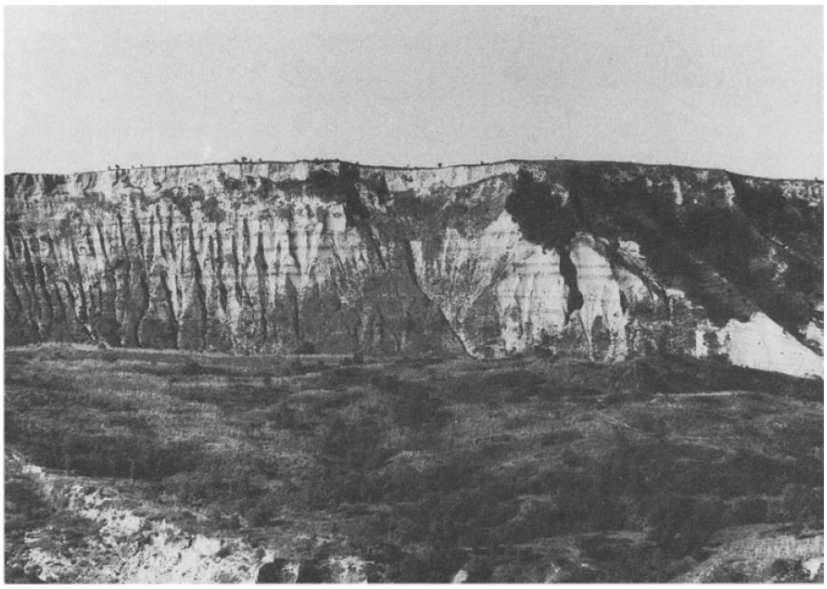

Figure 32 - This photo from Dodonov (1991) demonstrates the height of some loess sections in the foothill areas of Central Asia (in this example, from Khonako). It also shows how dramatic breaks in landscape in loessic areas can be, and how fertile an environment the loess can provide for greenery.

6.1.4 Climate Reconstruction from Central Asian Loess

The loess deposits of Central Asia stand out as one of the most important climate archives of arid areas, and of arid Inner Asia in particular (Dodonov & Baiguzina, 1995, p. 707). The combination of rapid accumulation of the sediments, generally good environmental preservation, and correlations with other global climate records make the loess sequences of Central Asia exceptionally valuable for environmental reconstruction. A variety of analyses can provide evidence for climate reconstruction. Magnetic susceptibility can reveal details of precipitation and temperature fluctuation throughout the Pleistocene, while sedimentological analyses can reveal the kinds of soils and probable floral communities.

Palynological evidence can provide more direct evidence of these floral communities. That being said, some forms of environmental data are badly preserved or absent from the loess record. For instance, the Lower Pleistocene faunal record of Central Asia is described as "poorly represented" (Ranov & Davis, 1979, p. 251), as can be seen in the exceptionally sparse faunal remains from Tajik Palaeolithic sites such as Lakhuti 1 and Kuldara. Furthermore, there is a noticeable paucity of gastropod evidence in humid palaeosols (Kukla, 1987, p. 204). Palynological remains are preserved, but complicated by the fact that loess, as an aeolian sediment, can incorporate large amounts of non-local pollen, and also because herbaceous pollen is also more likely to survive in these conditions than arboreal pollen. An exception to this, the sequence at Kairubak has provided unusually good data for palynological analysis, with very distinct palynological complexes identifiable (Dodonov & Baiguzina, 1995, p. 716). So while the loess sequences of Central Asia do provide an exceptional record of Pleistocene environmental change, this record is also not without limitations or challenges. As previously noted, loess deposits have accumulated predominantly in the piedmont regions of Central Asia, and consequentially these are the areas where Pleistocene environmental conditions are best understood. It does also happen that the piedmont regions are the most interesting, from the simple fact that these are the areas highlighted as possible *refugia* and as a part of the proposed IAMC.

Sedimentological & Palynological Evidence

Composition and properties of the sediments themselves, and the study of preserved pollen spectra, have provided some of the most informative lines of evidence for environmental reconstruction. The prevailing environmental conditions in Central Asia were dependent on the larger global system of air-mass dynamics, and it is these dynamics that influenced aeolian erosion and deposition within the study region in accordance with global glacial/interglacial stages, thereby affecting the formation of the sedimentological units and the floral community at any given period. The beginning of loess build up around 2.5-2mya is

an indication of the beginning of aridification in Central Asia, and it is the oscillation of humid-warm and arid-cold periods throughout the Pleistocene that is the source of the distinctive alternating deposits of loess units and the brown soil palaeosols or pedocomplexes (abbreviated to PC) see in deep sedimentological sequences. Sedimentological studies indicate that loess-forming glacial periods would have been relatively cold and dry, with increased aeolian activity, while the palaeosol-forming interglacial periods would have been comparatively more humid and warm, with reduced aeolian activity and reduced atmospheric dust (Ding, et al., 2002, p. 397). This can be seen in the rate of accumulation between glacial and interglacial conditions, such as at Karamaidan, where rate of sedimentation has been calculated for loess and pedocomplexes, showing that the substantially thicker loess deposits accumulated up to 2.5 times more rapidly than the pedocomplexes (Forster & Heller, 1994, p. 510).

Most piedmont areas of Central Asia would have been forested in the interglacials of the Lower-Middle Pleistocene (Ranov & Davis, 1979, p. 252); however, the horizons of loess formation represent an expansion of desert and desert-steppe into the piedmonts during arid glacial periods. During these glacial periods, the climate zones of mid-latitude Central Asia would shift southwards from their interglacial positions. In southern Central Asia, this would have meant an increase in summer precipitation and a decrease in winter precipitation during glacial periods, on top of an increasing southward trend of these climate zones from *c.* 850kya onwards (Yang & Ding, 2006, p. 336). It is notable that, unlike many other areas of the Pleistocene world, glacial periods in Central Asia are asynchronous with the expansion of glaciers within the region (particularly noticeable in the more arid Late Pleistocene (Abramowski, et al., 2006)). This is due in large part to the arid continental conditions that were exacerbated during glacial periods, because glaciers require moisture to grow. The loess horizons, as previously noted, have a tendency to preserve herbaceous pollen, whereas the soil horizons of the pedocomplexes show a higher frequency of arboreal

pollens (Dodonov & Baiguzina, 1995, p. 714). Preservation issues notwithstanding, this does also represent a change in the floral composition between the more desertified glacial periods and the more humid interglacials. The presence of plentiful carbonate formations in the loess-forming glacials also corroborate the aridity of these periods (Dodonov, et al., 1999, p. 590). The thickness and development of carbonate layers varies throughout the sequence, but there is a broad trend of increasing aridity throughout the Pleistocene (Dodonov, et al., 2006, p. 57). K values of magnetic susceptibility studies are also linked to temperature and precipitation. Dodonov et al. (1999, p. 587) note higher K values for modern soils, for instance, from the Tien Shan Piedmont, where average annual temperature is around 8-10 degrees C and precipitation reaches around 800-1000mm annually. Previous studies of magnetic susceptibility in Southern Tajikistan indicate high K values for brown soils in the PCs and low values for loess horizons, such as at the Darai Kalon sequence (Dodonov, et al., 2006, p. 55). During the Pliocene-early Pleistocene, it seems that precipitation was considerable enough that a forest environment was widespread throughout the piedmonts of the Tien Shan and the Pamirs, but is much reduced (probably in accordance with the decrease in precipitation) into the late Pleistocene (Dodonov, et al., 1999, p. 590).

The loess horizons that bracket the PCs vary in thickness throughout the sequence. Loess horizons below PC11, and also between PCs 9-8 and 6-5 are never more than 3-5m thick, while other loess levels vary between 7-12m in thickness (Dodonov, et al., 1999, p. 586). The general trend towards increasing thickness of loess deposits is in agreement with the trend of increasing aridification. The PCs between the loess deposits are not homogenous, but can often be divided into three kinds of brown soil. The upper and lower soils are commonly ‘xerophytic’ serozem soils, and carbonaceous in nature, reflecting a transition through relatively cool or temperate arid steppe environments with mixed shrubland compared to the central sections of the soil horizons (Dodonov, 1991, p. 188, Dodonov, et al., 2006, p.

57). These central sections have a tendency to be ferrous in composition, reflecting an increased temperature and humidity during their formation. Some of the PCs contain all three of the typical brown soils identified by Dodonov (1991), while others contain only two (Dodonov, et al., 1999, p. 584). The lowermost of these soils have a tendency to have formed under relatively humid conditions, perhaps suggesting that the transition to the typical brown soil begins with a relatively more humid environment. The transitions between loess units and PCs seems to have been gradual, implying that the environmental change was generally gradual as well. In particular this is interesting, as it suggests that hominins may have had time to adapt to environmental changes between interglacial and glacial stages, even if glacial extremes could be very harsh. Such gradual change may have allowed hominins to adapt their mobility patterns and resource-use in the landscape to take advantages of climatic *refugia*, such as the areas highlighted by the IAMC, or may have gradually forced hominins into adjacent territories, such as north-western China. The thickness of the PCs also increases upwards stratigraphically, particularly into the Late Pleistocene, suggesting that, while the glacial periods could be long and intense, the interglacials were concomitantly longer, in agreement with changes in the amplitude of orbital periodicity at this time.

So the broad trends for Pleistocene environment in Central Asia are for cooler arid shrubland environments with limited precipitation and increased aeolian dust activity during glacial periods, and for warmer humid arboreal environments with higher precipitation and decreased aeolian dust activity in interglacials. There is also a general trend for increasing aridification throughout the Pleistocene. However, there is some variation in the character of the individual PCs, and this variation, especially through palynological and sedimentoloigcal analysis, can indicate to some extent how the environment of individual PCs may have differed from the broad trends of Central Asian climate.

In the Lower Pleistocene, PC18 has been identified as a 'leached cinnamon soil' with clay illuviation, and is relatively humid with a well-developed forested environment (Dodonov, et al., 2006, p. 57). PCs 12-11 also seem to have been forested, containing a greater quantity of arboreal pollen than herbaceous pollen (Dodonov & Baiguzina, 1995, p. 714). *Cedrus* and *Pinus* seem to have dominated throughout PCs 12-10, with *Tilia* also reported from all three of periods. *Carya*, *Juglans*, *Pistacia*, and *Rhus* are also attested from PCs 12 and 11, PC10 has also provided evidence for *Platanus*, *Quercus*, and *Ulmus*, and *Ostrya* is also known from the early Pleistocene more generally. There is a significant component of herbaceous pollen, indicating some open woodland and xerophytic grassland environments. In spite of this, it seems that coniferous forests would have dominated, especially in the more humid times, such as in PC10, where the leached soils indicate that it was relatively more humid than other Pleistocene PCs (Dodonov, et al., 1999, p. 586). At Kairubak, Dodonov & Baiguzina (1995, p. 716) report that "…no palynological difference…" could be seen between PCs and loess horizons in the early Pleistocene deposits, suggesting that the floral community was remarkably consistent throughout. It should be noted, that hominin occupation at this time is evidenced by artefacts in PCs 12 and 11 at the site of Kuldara. Overall, the early Pleistocene of Central Asia seems to have been relatively humid and well-forested, possibly without much floral change between glacial and interglacial periods.

The Middle Pleistocene proves to be far more variable and diverse in its environments than the Lower Pleistocene. From PC10 up to the base of PC6 at Kairubak, arboreal pollen continues to dominate, while herbaceous pollen decreases (Dodonov & Baiguzina, 1995, p. 716). *Abies* appears for the first time during this interval, *Pinus* remains well-represented, while *Cedrus* decreases in representation. The thermophilic *Carya* and *Pterocarya* are also present throughout PC10 to PC6, as is *Ostrya* in the lower PCs. In the loess horizon between PC10-9, there is a decrease in arboreal pollen, and a large increase in herbaceous pollen, showing an expansion of grass and shrubland in stark contrast to the interglacials it is

bracketed by. This contrast in floral communities between glacial and interglacial periods at the beginning of the Middle Pleistocene is unlike the relative stability for floral communities reported on the basis of palynological evidence for the Lower Pleistocene deposits. PCs 9-8 do also see an expansion of steppe and forest-steppe environments, and higher carbonate deposits for these periods (especially in their lower layers) is an indicator that even these interglacials are relatively arid in comparison to other PCs (Dodonov, et al., 1999, pp. 586, 590), and PC8 sees the appearance of the well-developed brown soils that are regarded as typical for Pleistocene interglacials (Dodonov, 1991, p. 188). In the 8th PC, hominin occupation is again evidenced by stone tools, this time at Khonako II, and also for the first time in the record since occupation at Kul'dara The upper end of PC8 at Darai Kalon shows a gradual transition into increasing loess accumulation (Frenchen & Dodonov, 1998, p. 7). This loess deposit between PCs 8-7 sees a huge increase in the thickness of the loess deposited, indicating a harsher, more arid, glacial period with increased aeolian activity. After this harsh glacial period, PC7 shows relatively more humidity than PC9 or 8, appearing to indicate "damp" but also unusually "very cool" conditions (Dodonov & Baiguzina, 1995, p. 714), and a forest-steppe environment appears dominant (Dodonov, et al., 1999, p. 590). This is followed by another exceptionally thick deposition of loess between PCs 7-6, indicating another particularly harsh glacial period where the role of herbaceous pollen increases as arboreal pollen decreases (Dodonov & Baiguzina, 1995, p. 716). No artefacts are found in the Tajik loess between the 8th-6th PCs, and it might be suggested that the harsh glacials that bracket PC7 may have hampered the establishment or maintenance of hominin populations in the region, in spite of apparently mild conditions during the interglacial itself. PC6 is also relatively humid and exhibits a return to dominance of arboreal pollen, around 95% of the pollen content, indicating mixed woodland forests expanding the piedmonts with *Cedrus*, *Fraxinus*, *Juniperus*, *Pinus*, *Quercus*, and *Ulmus*. This would have been contemporary with the hominin occupation at Lakhuti and the two Obi-Mazar localities. The loess horizon

between PCs 6-5 is thinner than either the horizon between 7-6 or 5-4, indicating that there is a slight amelioration in the severity of this glacial period (Dodonov, et al., 1999, pp. 586, 590). This is particularly interesting, as this is the same glacial period that indicate as the glacial period from which artefacts have been found at Khonako I and Obi-Mazar Opolsen. PC5 exhibits a humid, forested environment similar to that of PC6 and populated with similar tree species. From PC5, artefacts have been found at Lakhuti, Obi-Mazar, and Obi-Mazar Opolsen. This is the PC that is also likely to be contemporary with the first occupations at the travertine sites of Koshkurgan and Shoktas. The loess between PCs 4-5 shows an increase in herbaceous pollen (Dodonov & Baiguzina, 1995, p. 716). PC4 has been identified as a leached cinnamon with features of clay illuviation, suggesting that this is a particularly humid and warm period that sees the development of extensive forest environments (Dodonov, et al., 2006, pp. 55, 57), although arboreal pollen content drops to around 72-73% and there is a suggestion of meadow environments mixed in. The arboreal pollen is mostly dominated by *Pinus* and *Tilia*; however, there is also a huge diversity of other species, such as *Acer*, *Betula*, *Carpinus*, *Carya*, *Corylus*, *Juglans*, *Platanus*, *Quercus*, and *Ulmus*. The arboreal component of the pollen in PC4 begins to reduce further towards the top of this unit. From PC4, artefacts have been found at Khonako II and III, as well as Obi Mazar. It's also possible that this PC coincides with occupation at the travertine sites. The loess unit between PCs 4-3 contains herbaceous pollen, but also some arboreal pollen of xerophytic species such as *Celtis*, *Rosacea*, *Rhus*, and *Tamarix*, confirming the aridification of this period, although *Ulmus* and *Fraxinus* is also represented (Dodonov & Baiguzina, 1995, p. 714). PC3 and subsequent PCs show a lighter soil, rather than the typical brown soils of earlier, more humid, interglacial periods (Dodonov, 1991, p. 188). The lower parts of PCs 3-1 exhibit leached carbonate soils, indicating that the onset of interglacial conditions were relatively more humid than the rest of the formation periods of these deposits (Dodonov, et al., 1999, p. 586). Further to this, it appears that the upper limits of PCs 3-1 also represent the most arid parts of interglacials. As

a whole though, PC3 exhibits a large arboreal component, including a dominance of *Betula*, an increasing role of *Platanus*, accompanied by *Alnus*, *Carpinus*, *Corylus*, *Fraxinus*, *Pinus*, *Quercus*, and *Ulmus*. From PC3, artefacts are known from Khonako III and Obi Mazar, and this also represents the likely final occupation at the travertine sites. The transition from PC3 to the overlying loess unit also contains *Quercus macranthera*, indicating arid and cool conditions. L3 contains a very low density of pollen, and the arboreal content is reduced to single grains of individual species, which probably indicates an arid, steppic environment, almost devoid of trees.

PC2 seems to have been relatively warm and humid, as evidence by the presence of broad-leaved trees such as *Alnus glutinosa*, *Juglans*, *Myrica*, *Ostrya*, *Pistacia*, and *Quercus* (Dodonov, et al., 2006, p. 55). Also present are, *Betula*, *Carpinus*, and *Pinus*. A loess layer divides PC2 into two halves, and this loess layer features a mixed forest-steppe environment with *Betula* predominating. From PC2, including the loess layer, artefacts are known from Khonako III. The transition from the upper half of PC2 into the overlying loess layer is dominated by *Betula* and *Pinus*, with all other arboreal species declining in number. Although L2 has a low density of pollen grains, it seems that some of the *Betula* and *Pinus* forests continue in the mountainous areas of Central Asia, even as an arid steppe environment expands. The beginning of PC1 is roughly contemporary with the occupation at the site of Sel'ungur.

To summarise for the Middle Pleistocene, the beginning of this period sees the onset of stronger environmental differentiation between glacial and interglacial periods than the preceding Lower Pleistocene. Glacials and interglacials see an increase in aridity and an expansion of desert-steppe and forest-steppe environments. The thick loess accumulations between PCs 8-7 and 7-6 indicate particularly harsh glacial periods. PC7 seems to be unusually cool for an interglacial period, while PCs 6 and 5 show relatively humid forest

environments that perhaps reach their apogee in the well-developed and diverse piedmont forests of PC4, and to a lesser extent PC3. The loess horizon between PCs 6-5 also shows an amelioration in the climate, so that it appears that the mid-Middle Pleistocene represents a less harsh environment than that in evidence in the early Middle Pleistocene, or the subsequent Late Pleistocene. The more humid PCs of the Middle Pleistocene saw a profusion of arboreal resources in the form of nuts, seeds, and berries, such as pine nuts, walnuts, hazelnuts, hickory nuts, pistachio, wingnuts, hophornbeam 'nutlets', seeds of plane and elm trees, and the berries of ash, juniper, and myrica. Furthermore, acorns may have been edible if hominins were able to process them, and the sap and sweet waters of maple and birch would also have been edible for hominins capable of gathering them. Even while more arid conditions probably saw a decrease in floral resources overall, they promoted the appearance of other valuable resources, such as edible rosehips, hackberries, and sumac in the loess unit between PCs 3-4. The presence of ash in this same loess unit also suggests the continuation of at least some arboreal resources in the more forested, sheltered areas of the foothills and piedmonts at this time.

The final two PCs show a shift towards more arid interglacials, and a decreasing arboreal component, suggesting a growing steppic environment. This tendency towards aridity continues into the Late Pleistocene, where PC1 sees the gradual decrease of arboreal pollen to herbaceous pollen content (Dodonov, et al., 2006, p. 57). The upper part of PC1 seems to reflect a serozem soil, and therefore a semi-arid steppic environment, which is overlain by a loess environment that also appears to be dominated by steppe and desert (Dodonov & Baiguzina, 1995, p. 714).

Vertebrate Fossil Evidence

As noted previously, the faunal evidence from Central Asia is not extensive, especially from the archaeological sites. Kuldara, the oldest archaeological site at just under 1mya, has

provided “almost negligible” faunal remains (Ranov, et al., 1992, p. 49), while the remains from the Lakhuti site at *c.* 500kya are described as “fragments” (Ranov, 1995, p. 738). Better preservation has been found at the so-called ‘travertine’ sites of Kazakhstan, Koshkurgan and Shoktas, as well as the cave site of Sel’ungur in Kyrgyzstan.

From the late Pliocene to the late Pleistocene in Central Asia, the overall trend from a relatively humid environment towards a more arid continental environment that is periodically warm and cool is evidenced by a transition in the faunal spectra. The late Pliocene includes savannah and open environment species with some forest species, while from the Middle Pleistocene onwards there is a gradual shift towards a steppic and forest spectrum with cold resistant species (Dodonov, et al., 1999, p. 589). At around 2.4-1.8mya, from Obi Garm and Karamaidan, we have evidence for some vertebrates (Dodonov, 1991, p. 186). *Protoryx laticeps, Gazella sinensis,* and *Equus stenonis*, may have provided possible prey for a nimble and entrepreneurial hominin, but are unlikely to have proven easy for a small-bodied hominin with a Mode 1 toolkit. *Dicerorhinus* would have provided a substantial challenge. The large-bodied and fast-moving *Acinonyx pardinensis* would have been an exceptionally dangerous encounter out in an open environment. The humid, wooded areas of the piedmonts may have provided more shelter and opportunities to ambush ungulates; however *Ursus etruscus* would have been a formidable encounter for unlucky small-bodied hominins in a wooded environment. As can be seen from Table 2, compiled by Ranov & Davis (1979), sites of subsequent date provide further evidence of the changing composition of the faunal complexes of Central Asia throughout the Pleistocene. In the earlier half of the Middle Pleistocene, at Koshkurgan (Kazakhstan) and Lakhuti (Tajikistan), the faunal remains suggest that megafauna such as *Palaeoloxodon antiquus* and *Dicerohinus etruscus, and D. kirchbergensis* were present in the landscape. Whether these were animals that could be exploited by Central Asian hominins at this time is unclear. Equids, cervids, and bovids are more likely to have been within the hunting competency of hominins around this time.

During the harsher glacial periods of the Middle Pleistocene, acquiring these animals for food could have been the difference between extinction and survival in the region. Felids, hyaenids, and canids in the record at this time are likely to present less of a predation risk to the more competent Middle Pleistocene hominins in groups, but nonetheless provide an element of risk. They are likely also to have been drawn to the camp and hunting activities of hominins, increasing the chances of encounters between these species in the landscape. Later in the Middle Pleistocene, as the piedmont forests diversify and the steppe environments begin to expand, a number of isolated finds from the Tajik Depression show that the faunal community was changing, albeit maintaining fairly similar kinds of fauna. Very large animals such as *Mammuthus trogontherii* and *Palaeoloxodon* would still have provided a substantial challenge to hominins, while *Equids* and *Bovinae* may have provided comparatively easier prey. *Marmota* appear in the record at this time, but might only have been caught opportunistically, or possibly more consistently by hominins that had mastered a form of trapping.

Absolute Age (in Millions of Years)	Standard Central Asian Stratigraphy	Southern Tadzhikistan Stratigraphy (Dodonov and Pen'kov 1977)	Correlation with Alpine Stratigraphy (Dodonov and Pen'kov 1977)	Faunal Complex	Comparable Eastern European Faunal Complex
0.2[b]	Tashkent, Ilyak complexes (Q_2), Middle Pleistocene	Ilyak complex (Q_2)	Riss	sp., *Bison priscus longicornis*, *Mammuthus trogontherii* (Pohl) (Aleshinskaya et al. 1971)	Hazar
		Vaksh complex (Q_1)	Mindel	Isolated finds, Tadzhik depression: *Palaeoloxodon* sp., *Marmota* sp., *Canis* (Thos.) *aureus fossilis* (?), *Bison* sp., *Equus* sp., Bovinae (Nikonov 1972)	Singil (?)
0.69[a]	Sokh (Nanay), Vaksh complexes (Q_1), Lower Pleistocene	Kayrubak suite, Eopleistocene	Günz	Lakhuti: *Equus caballus*, Bovinae, Cervidae (e.g. Megacerinae, e.g. Elaphinae), *Felis* sp., Hyaenidae, Canidae, *Microtus* sp., *Ellobius* sp. (Nikonov 1972)	
			Donau/Günz	Koshkurgan: *Palaeoloxodon antiquus*, *Paracamelus gigas*, *Equus sussenbornensis*, *E. caballus* cf. *mosbachensis*, *Dicerorhinus etruscus*, *D. kirchbergensis*, *Cervus elaphus* (Nesmeyanov 1971)	Tiraspol

Table 2 - Faunal complexes of Pleistocene Central Asia (Ranov & Davis, 1979)

Finally, at the end of the Middle Pleistocene, the site of Sel'ungur provides remains of *Capra sibirica*, Cervus *elaphus*, and *Ovis ammon*, all of which may have provided possible prey for the contemporary hominins who occupied the site (Davis & Ranov, 1999).

Summary: Environmental and Climate Evidence in CA Loess

The current section has examined in-depth the evidence for climate conditions in Central Asia throughout the Pleistocene. It began with an outline of the dominant weather systems, their evolution through time, and their general effect on regional climate. A more detailed consideration of the aeolian systems, the deposition of loess sediments, and the climate conditions inferred from palynological and sedimentological analysis allowed the conditions of individual glacial/interglacial stages to be more fully understood in relation to the general pattern of regional climate. Palynological evidence, and a brief consideration of the available faunal evidence, allowed for the highlighting of some of the resources that may have been available for hominins to exploit in these environments.

The Lower Pleistocene can be seen as a time of relatively mild climate. Although the beginning of loess deposition marks a turn towards growing aridity and strengthening aeolian processes in the region, the environmental fluctuations between glacials and interglacials are less extreme than subsequent periods. Hominins entering Central Asia at this time would have found extensive, well-developed forest environments in the piedmonts with plenty of plant resources such as seeds and nuts. Many of the arboreal species identified in the Lower Pleistocene PCs would have provided edible nuts, seeds, and 'nutlets', such as pine nuts, walnuts, hickory nuts, pistachio, plane and elm seeds, and others. Sumac (*rhus*) is still commonly eaten today in Asia, and would have provided an important concentration of nutrients that hominins could have exploited. Whether hominins would have been competent in making prey of some of the animals present in the faunal

composition at this time is unclear. It may rather have been the case that predation risk was of greater concern for them, especially in the open environments. We can perhaps imagine groups of small-bodied hominins generally avoiding the open environments, in favour of exploiting the plentiful plant resources of the forested foothills and piedmonts, and occasionally ambushing small herbivores opportunistically.

The Middle Pleistocene is a far more variable period, with more extreme climatic conditions, especially in the middle and towards the end. In spite of this, a well-developed, increasingly diverse forested environment during humid periods in the piedmont would have provided ample opportunities for the more competent hominins of the Middle Pleistocene. Harsh as conditions are likely to have been, artefacts have been found in every PC from 6 onwards, showing that hominins were present in the landscape. Whether they would have been able to thrive in the extreme glacial periods in the middle, or whether they would have become locally extinct at these times, is uncertain, but it remains possible that they retreated into *refugia* in the piedmont zones or adapted their behaviour during the apparently lengthy transitions into glacial conditions. The high likelihood that they represented a viable predator of larger animals that may have been beyond the competencies of Lower Pleistocene hominins may have provided a vital food source for them during harsher climatic conditions. We can perhaps imagine groups of larger-bodied hominins, competent hunters, possibly even, more speculatively, trappers. During harsh glacials and milder interglacials alike, they could have drawn on a varied spectrum of plant and animal resources, their camp often harassed by circling *canids* and *hyaenids*, from whom they may occasionally have scavenged or stolen carcasses.

But what were absolute conditions like for hominins in the piedmont areas of Central Asia? Artefacts are located mainly in the 'developed' optimal central sections of the palaeosols, although they are scattered throughout, including in one loess horizon, and very dense

cultural layers are entirely absent. Dodonov (1991, p. 189) suggests that this may reflect differential burial over time by aeolian processes (which were ongoing, if reduced, during interglacials) or repeated visits to locales leaving low densities of activity each time. The fact that loess accumulates so rapidly during glacial periods would suggest that, if hominins were present and discarding stone tools during these periods, then we would expect high-resolution records of their tool discard, which we do not have (with the previously noted exception). If glacial periods were complete apocalypse-style events for hominins, then Central Asia would be periodically uninhabitable for anywhere between 15-60ky at a time throughout the Pleistocene. However, the extremely low number of stratified sites investigated in loess areas, means that we cannot yet rule out taphonomic factors, or even simply changes in population density, in creating this patterning.

The gradual transition evident in the soil-forming processes between glacial and interglacial stages suggests that hominins would have had time to adapt behaviourally to such climatic changes, including relocation to piedmont *refugia*, or slow creeping migration forced by climatic downturn, such as through the gates of Dzhungar into north-western China. There are at least two possible scenarios, that may have been more or less the case in different areas of the study region, firstly, that Central Asia was periodically occupied mostly during interglacials, and secondly, that occupation of Central Asia remained possible, albeit probably difficult, in piedmont and foothill *refugia* from which populations could recolonise following the onset of interglacial conditions. The distinction between these two scenarios is less salient for the Lower Pleistocene, the most probable time for Central Asia's earliest occupation, when climate fluctuations between glacials and interglacials appear to have had less impact, and glacials themselves were less harsh, than at many points in the Middle Pleistocene.

Although the loess sequences represent some of the best terrestrial environmental records in Asia, from a modelling perspective it is difficult to use this information to place absolute values on environmental conditions at any one point in time. Even the substantial existing literature on reconstructing palaeoclimatic conditions rarely places any kind of absolute value on conditions during different stages of the Pleistocene, and rather couches observations in relative terms (e.g. wetter than the present, warmer than the Pliocene, drier than other glacial periods). This presents substantial difficulties for adapting this information to a spatial analysis, and even more so for producing a spatial analysis that is temporally sensitive. Ultimately, while an in-depth analysis of faunal and floral species with known or analogous existing species extents would be enormously valuable for the study of Pleistocene Central Asia, it is far beyond both the purview of the current project and the quality of the existing environmental evidence.

The Central Asian loess record provides some good environmental evidence for the Pleistocene climate of this region, enabling at least a detailed discussion of how the climate has evolved over the course of the Pleistocene. As was noted earlier, chronological control of this record has proven difficult in the past. It is primarily by correlation with other records of global climate, such as the well-studied loess sequences from neighbouring China, the environmental cores from Lake Baikal, and their correlation with the global Oxygen Isotope record, that the long durée of Central Asian climate has been best understood. These correlations are the subject of the next section.

6.2 Correlation with the Chinese Loess Sequence, Global Oxygen Isotope Stages, & Lake Baikal

6.2.1 Forcing Mechanisms and Geomorphology of The Chinese Loess Plateau

The loess coverage in China is the most extensive in the world by sheer area, up to 440,000 km^2 (Kukla, 1987, p. 191). It seems likely that winnowing processes deflating deposits in the desertified Tarim basin in western China provides a large proportion of the dust deposited in the Chinese loess plateau (Goudie, 2002, p. 304). However, Chinese conditions of dust accumulation do differ to Central Asian conditions in terms of their seasonal mechanism. While Central Asian dust storms occur predominantly during the arid summer months, and more or less disappear during the wetter winter months, in China it is the arid winter months (and winter monsoonal winds) that provide the chief mechanism for dust storm activity and loess deposition (Ding, et al., 2002, pp. 388, 397). In spite of this difference in mechanism, broad similarities in climate response to global forcing mechanisms can be seen throughout the Pleistocene, providing the basis for correlation. For instance, glacial periods in the Chinese Loess Plateau are also associated with higher and more variable rates of dust accumulation (Rost, 2000, Sun & An, 2005). Study of Pliocene-Pleistocene loess accumulation rates in China have implicated both the development of Northern Hemisphere ice sheets and the uplift of the Tibetan Plateau for increasing aridity, as has already been noted for Central Asia. Palynological study in the Qaidam Basin (Qinghai Province), confirms the importance of the uplift of the Tibetan Plateau for increasing aridity in both Central Asia and China throughout the Cenozoic (Wang, et al., 1999). Studies of the loess deposits around Beijing confirm the overall importance of the East Asian monsoon cycle in the accumulation of loess during glacial periods, above other forcing mechanisms (Tian, et al., 2017). The East Asian monsoon cycle is strengthened in response to a weakening of the Siberian-Mongolian high pressure system, and conversely the weakening of the East Asian Monsoonal system in

interglacial periods reflects a strengthening of the Siberian-Mongolian high. This mirrors the opposition in Central Asia, between the Siberian-Mongolian high and the loess-forming westerlies. Aeolian sediments are deposited in humid and arid phases, but as in modern day China, during humid phases the aeolian sediments deposited constitute a small enough amount that they can become incorporated into existing soils (Kukla, 1987, p. 204). During glacial phases, a reduction in floral and faunal species that could instigate this process, and a vast increase in the volume of aeolian dust deposited, lead to the accumulation of thick loess horizons. Isotopic analysis of speleothems from Kesang cave (western China) has suggested that precipitation is negatively correlated with increasing summer insolation in the region (Cheng, et al., 2012). Earlier, wetter periods showed lower summer insolation, the increase in precipitation probably caused by incursions of summer monsoonal rains.

6.2.2 Dating and Correlations with The Chinese Loess Plateau & global Oxygen Isotope Stages

The dating of the Chinese loess deposits was initially reliant on faunal dating, supplemented by TL and radiocarbon (Kukla, 1987, pp. 197-8). The introduction of palaeomagnetic techniques in the 1980s allowed a refinement of this dating. However, as with the Central Asian loess sequences, TL dates older than 100kya were found to be unreliable and significantly underestimated dates of sediments. Loess deposition in China appears to begin around 2.5 mya, as in Central Asia. This marks a shift in climate in central China from a warmer more humid environment, to a steppic environment that dominates periodically throughout the Pleistocene.

Correlations have been made between the Central Asian loess record and the Chinese loess sequences on the basis of magnetic susceptibility, grain size, and colour reflectance, (Ding, et al., 2002, Bronger, et al., 1998, Bronger, 2003, Kukla, 1987, p. 209). Ding et al. (2002, p. 397) goes further, and correlates Central Asian and Chinese loess records with the deep-sea Oxygen Isotope record, demonstrating that palaeosols and loess horizons in both areas

correspond to global interglacials and glacials respectively. Furthermore, Bronger et al. (2003) & Dodonov (2005) also demonstrate correspondence between the Central Asian, Chinese, and European records, showing that the forcing mechanisms of loess accumulation are global, even if they are prone to localised variation in dust source and intensity. Although pedocomplexes also are broadly comparable across Eurasia, some have more or fewer pedomembers, due either to erosion or local conditions of formation, and records from different regions of Eurasia demonstrate different levels of detail and completion. For instance, unlike the Central Asian record, the Plio-Pleistocene boundary is noticeably absent from the stratigraphic record of the Chinese loess Plateau (Kukla 1987). In some cases, the Tajik loess record is more detailed and complete than those of East Asia, as Bronger et al. (1998; 2003) demonstrate in their comparison of the Karamaidan and Chashmanigar sequences with that at the Chinese site of Luochuan. However, Ding et al. (2002: 388) point out that some stratigraphic features well represented in the Chinese sequence are "indistinct" in the Chashmanigar sequence. This difference of stratigraphic representation is most likely a reflection of the differing still regional variation in response to the forcing mechanisms behind the formation of these records.

However, the shift in climate cycle periodicity represented by the Middle Pleistocene Transition is well-evidenced in the Chinese loess record, and corresponds to the same shift in the global Oxygen Isotope record (Ding, et al., 2002, p. 398). Furthermore, a study of chemical weathering at the sequences of Chashmanigar (Tajikistan) and Lingtai (China) shows evidence for a substantial change around 850-600kya (Yang, et al., 2006), coinciding with the MPT. Yang et al. (2006) report a substantial decrease in the intensity of chemical weathering in dust source and deposition regions, which they link to ongoing uplift of mountains in high Asia, and possibly also an increase in northern hemisphere ice volume. The decrease in the intensity of chemical weathering may be due to the erosion of 'fresh' and 'less mature' clastic material at dust source locations, and cooler arid environments at

depositional locations, or likely a combination of both of these factors (Yang et al. 2006: 1707). Using the correlation between magnetic susceptibility in the Chinese loess record and the climate record of the deep sea ice cores as a starting point, Markovic et al. (2012) have also established a connection with the extensive loess record from Vojvodina, Serbia. Correlating these records makes clear the visibility of MPT affecting climate and environment, visible in records of magnetic susceptibility, rates of dust accumulation, and rates of pedogenesis. In the Early Pleistocene-early Middle Pleistocene, dust accumulation and soil formation in the Vojvodina locality is fairly uniform prior to the transition. Subsequent to the Middle Pleistocene transition, the pattern is less uniform, with sharp differences between glacial environments with high rates of dust accumulation and interglacial environments with low rates of soil development. Markovic et al. (2012) suggest that this represents the effects of a shared forcing mechanism for dust accumulation in Europe and interior Eurasia from the Early Pleistocene onwards.

In summary, Chinese and Tajik loess records seem to share global forcing mechanisms in their formation, although some specific regional factors also affect the intensity of accumulation and the nature of the sedimentation (such as coarser sediment accumulations at Chashmanigar subsequent to 650kya). Orogeny in Asia, such as the continued uplift of the Tibetan Plateau, is a possible candidate for remaking the boundaries of regional climate systems at this time. Ding et al. (2002, p. 398) have argued that the Chinese loess sequence remains more sensitive to global forcing mechanisms after this time. It might also be suggested that the Central Asian system, in comparison, becomes relatively more 'isolated', and, with an increase in the intensity of local aeolian forces, more dominated by regional forcing mechanisms.

6.2.3 Pleistocene Environment in the Chinese Loess Plateau: Similarities and Contrasts with Central Asia

Palynological studies of the Chinese loess sequence are complicated by some of the same factors as the Central Asian loess, including probable differential survival of herbaceous versus arboreal pollen, the difficulty of distinguishing local from non-local pollen, but also some disagreement with evidence provided by the carbonate content of the soils (Kukla 1987: 205). However, it can be broadly surmised from the available evidence that arid glacial periods generally resulted in low density vegetation in the form of restricted grassland and shrubland, while humid glacial periods generally resulted in woodland savannah landscapes with denser vegetation and a larger arboreal component (Kukla 1987: 204; 207). Palynological analysis of a core sequence that stretches from the Pliocene to the Holocene, taken from a terrestrial borehole in the Qaidam Basin, Tibet, shows a stepwise aridification of Chinese Central Asia and High Asia over this time period. 1.8-1.2 mya represents a relatively humid period (Cai, et al., 2012, p. 78), with significant drying events occurring at around 2.6, 1.2, 0.9, and 0.6mya, in agreement with other cores from the Qaidam Basin and the Chinese Loess Plateau. However, exact forcing mechanisms of this aridification are unknown, although it has been linked to the uplift of the Tibetan Plateau in conjunction with a trend towards global cooling throughout this period (for instance, Lu et al. (2010) prioritise global cooling, while Miao et al. (2012) stress the importance of uplift at least for Miocene China). Vertebrate fossils in the Chinese loess sequences also show an oscillation between cold arid environments analogous to present day interior North Asia, and warmer, humid environments composed of woodlands and grasslands that are similar to present day southern China (Kukla, 1987, p. 205). Steppe species begin to appear in greater frequency further up the sequences in both arid and humid phases. Study of lacustrine deposits in contemporary drylands of the Chinese Tarim Basin show that periods of greater humidity allowed rapid re-establishment of lake environments in areas that were sandy deserts during

periods of aridity (Yang, et al., 2011). Yang et al. (2011, p. 3231) describe these arid to semi-arid environments as “very sensitive systems”. On the basis of this rapid oscillating dynamic it seems that some formerly arid areas could demonstrate dramatic greening in periods of increased humidity, which might have allowed hominins to quickly reoccupy areas they had been gradually driven out of during transitions to glacial periods.

We can conclude that changes in loess accumulation were broadly similar between the Chinese Loess plateau and the areas of loess accumulation in the Central Asian piedmonts, even as the regional response to global forcing mechanisms differed slightly. This might suggest that any hominin adapted to the piedmont and foothill environments of Central Asia during interglacials would have potentially been reasonably well-adapted to exploit some contemporary environments in China. Whether these hominins would have been able to find viable *refugia* in either regions during glacial periods is still difficult to ascertain.

6.2.4 The Lake Baikal Environmental Record: Correlation with Orbital Forcing Mechanisms

Lake Baikal is a lake in southeastern Siberia that formed in a Miocene-aged rift, and represents the deepest and largest lake in the world (Lake Baikal Paleoclimate Project Members, 1992, p. 457). Being a high-latitude lake in a continental location, it is more sensitive to changes in northern hemisphere insolation, and also having remained uncovered by glaciation throughout the Pleistocene, Lake Baikal holds great potential as a palaeoclimate archive (Kashiwaya, et al., 2001). The sedimentary deposits of Lake Baikal have been estimated to be 7km thick, and to span approximately 15my, representing the longest duration archive of palaeoclimate information available (Lake Baikal Paleoclimate Project Members, 1992). The upper 1.5-1.7km of sedimentary strata alone represent roughly 2.5my of chronology (Kuzmin, et al., 2000). Possible sources of climate data from Lake Baikal sediments include magnetic and sedimentological analyses, biogenic silica and isotopic studies, and palynological studies.

Over the last few decades, a large number of sediment cores have been taken for study from a variety of different sedimentation environments within the lake, representing a variety of different palaeoclimate resolutions (Lake Baikal Paleoclimate Project Members, 1992). However, sediment disturbance by turbidity and tectonic activity mean that some areas of the lake provide poorer data for palaeoclimatic reconstruction than others (see Charlet et al. (2005)). Study has concentrated on the most potentially useful areas of the lake, especially the Selenga Delta and the Academician Ridge, and the best environmental data covers only the Late Pleistocene and Holocene, which is of less interest for the current study.

Sedimentological and magnetic analyses have provided a substantial amount of information about the sediment cores from the lake. Magnetic analysis of sediment cores from Academician Ridge has allowed the Lake Baikal sediment cores to be correlated with the Oxygen Isotope chronology, with which it provides a good match (Peck, et al., 1994). These cores cover a timeframe that extends from the present to approximately 250kya, and it allows the identification of the oscillation between glacial and interglacial stages, particularly in increased aeolian sediment input during glacial periods. In two cores taken from the Buguldeika Saddle in the bottom sediments of Lake Baikal, Kashiwaya et al. (1997) were capable of identifying sedimentary and magnetic traces of the glacial-interglacial succession. These cores extend back to an approximate age of 400kya, with interglacials showing input of coarse sediment and a high carbon:nitrogen ratio indicating increased ecological productivity, and glacials showing input of finer sediment and a low carbon:nitrogen ratio indicating reduced ecological productivity. Additional cores from the Academician ridge covering the last 2.5myr of climate, have shown that these records also reflect global changes in climate in their grain size and water content patterns (Kashiwaya, et al., 1998). Water content and grain size is higher for interglacials and lower for glacials. These patterns match well with the global oxygen isotope record, further demonstrating the importance of insolation and orbital forcing factors in the climate of continental Central Asia. Also from the

Academician Ridge is another core that dates *c.* 260kya at its bottom (Kashiwaya, et al., 1999). Sediment grain properties, water content, and the prevalence of biogenic silica (a proxy for aquatic productivity, which we be looked at in greater detail shortly) all reflect global patterns of climate change, including the interglacial-glacial cycles. A core from the Buguldeika River covering up to 600kya also reflects these global patterns of climate change in its clay composition (Yuretich, et al., 1999). Analysis of additional Lake Baikal sediment cores back to 780kya has shown a correlation between ratios of some elements and the increasing and decreasing prevalence of biogenic silica, both of which can be used as proxies of ecological productivity (Goldberg, et al., 2000). These ratios of elements also reflected the interglacial-glacial succession, and Milankovitch Cycles. Goldberg et al. (2000) have suggested that the Siberian climate is modulated by orbital forcing, and relies on these forcing mechanisms to a similar extent as global climate itself does, which agrees with the general impression of Lake Baikal as a 'sensitive' system. Palaeomagnetic studies have allowed for longer patterns of climate to be examined. Magnetic susceptibility analyses of cores demonstrate a pattern where Milankovitch forcing mechanisms dominate over the last 6.7mya in the sedimentation rates of Lake Baikal (Kravchinsky, et al., 2003). Magnetic, spectral, diatom, and mineralogical analysis has been used in combination for more detailed climatic reconstruction (Grygar, et al., 2007), suggesting that the period between OIS 8-5 is characterised by high seasonality and low humidity, which would coincide with the increasing aridity in Central Asia towards the Late Pleistocene. Palaeomagentic study of several cores from Lake Baikal, shows a cooling event around Lake Baikal region between OIS 6 and 7, which is coincident with sea surface cooling (from planktonic isotope studies) around the same time (Demory, et al., 2005).

Biogenic silica concentration can be taken as a proxy for bioproductivity, and therefore a proxy for palaeotemperature in the area around Lake Baikal. Correlation has already been briefly touched upon between the prevalence of biogenic silica and other measures of

environmental factors in the Lake Baikal cores. A core from the Buguldeika Saddle, that extends back to 200kya, demonstrates that the phytoplankton productivity of the lake follows patterns of the glacial-interglacial succession, and orbital forcing parameters (Edlund & Stoermer, 2000). Larger biogenic silica deposits are found during interglacials, because these represent increased ecological productivity. A study of cores that extend back as far as 800kya has also demonstrated these patterns of phytoplankton productivity, and correlated them with orbital forcing parameters, the glacial-interglacial succession, and oxygen isotope stages (Khursevich, et al., 2001a). Phytoplankton population and diversity expands massively during interglacials, followed by large extinction events during apparently rapid on-set glacial conditions (Khursevich, et al., 2001b). Using bulk sediment analysis to assess concentrations of biogenic silica and uranium in Lake Baikal sediment cores, Murakami et al. (2012) confirm that generally glacial periods were cold and dry, and interglacials were warmer and more humid, but further identify shifts between warm/dry and cold/wet climates within interglacials on a 10ky cycle that may be linked to ice rafting events and insolation. However, Prokopenko et al. (2006) report on a biogenic silica study covering the whole of the Pleistocene, demonstrating a time lag between insolation and the affect on phytoplankton in Lake Baikal, which they suggest is unrelated to global ice volume, and largely due to variation in amplitude of orbital forcing factors instead. This study also identified the Middle Pleistocene Transition, which of course relates to a shift in amplitude.

Palynological studies of Lake Baikal cores have provided some further insights into Siberian palaeoclimate. For instance, a combined palynological and sediment particle size analysis has shown that vegetational change in the Lake Baikal region has been synchronous with particle size changes in the sediments deposited (Shichi, et al., 2007). This suggests that the effects of climate visible in the sedimentary cores is directly related to vegetational change around the lake margins. Interglacials generally represent a forested environment of *Pinus* and *Picea* at Lake Baikal, while harsher glacial conditions represent cold desert and open

forest environments with a large *Artemisia* component. On the basis of Palynological analysis, Prokopenko et al. (2010) identify two cooling events in MIS 11, *c.* 411-10kya and *c.* 405-4kya, with the preceding period of MIS 11 considered a warm optimum for coniferous forest. The second of these may coincide with an abrupt cooling event around 390kya identified by Mackay et al. (2008) in an analysis of biogenic silica. In the piedmont of Central Asia, these cooling events would relate to PC4, which was a particularly warm and humid interglacial, with diverse and well-developed forests, perhaps suggesting that, although these environmental systems are broadly related through global climate factors, their responses to these factors are regionally idiosyncratic and asynchronous.

Key Points and Relevance of Lake Baikal Record to CA

Study of the Lake Baikal cores make explicit the impact of orbital forcing mechanisms on the climate of continental Asia. It can be seen that the dynamics of Central Asian environment and loess accumulation holds aspects in common not just with neighbouring loessic areas, but also more broadly in terms of global climate forcing mechanisms. However, the nature and timing of their response varies regionally. The changing nature of sedimentation reflects real vegetational change in the region around the lake, and also demonstrates increased aeolian input during glacial periods. Change in the local environment around the lake is rapid enough to cause extinction events for phytoplankton. Because Lake Baikal shares similarities in continental climate patterning and is affected in similar ways by the aeolian systems of interior Asia, it is possible to further develop our understanding of the climate of interior Asia with reference to it. However, because of their spatial separation, and especially the high latitude of Lake Baikal, it becomes impossible to deduce specifics from comparison with the record of Central Asia. At a minimum, the Lake Baikal record allows us to conclude that Central Asia is part of a much wider Asian climate system that is tied to global climate

changes over the Pleistocene, especially as regards the effects of northern hemisphere insolation, global ice volume, and cycles of orbital forcing.

6.3 Summary: The Pleistocene Environment of Central Asia, a Zone of Increased Evolutionary Pressures?

Throughout the Pleistocene, environmental conditions in the study region have varied between glacial and interglacials periods, linked to processes of loess formation, and ultimately to global climate forcing mechanisms. This chapter has highlighted aspects relevant to hominin occupation, and has considered what resources may have been available for hominins occupying these environments. The loess sequences of Central Asia are in some ways an exceptional environmental archive; however, there are some issues of preservation and coverage that limit their utility, and the data that they provide cannot be easily formulated into meaningful spatial datasets.

The Lower Pleistocene was a time of relatively stable floral communities between relatively mild glacials and interglacials. It was likely conducive to hominin occupation, especially because hominins of the Lower Pleistocene would have been smaller-bodied and probably had limited opportunities to exploit faunal resources or complex floral resources. The Middle Pleistocene has been shown to have been a time of increasing aridity and more variable climate between glacials and interglacials, with glacials becoming harsher, but also with interglacials demonstrating more diverse forest environments. This environment provided greater challenges, but also rich resources, which may or may not have been within the abilities of Middle Pleistocene hominins to exploit. But the open environments fostered by increasing aridity throughout the Middle Pleistocene may have provided rich resources for a hominin capable of hunting larger animals. A number of potential prey species were highlighted in the rather limited faunal evidence from the region, and as the example of the

Pleistocene Beringian tundra-steppe environment shows, a predominantly cold and arid environment dominated by herbaceous flora can support a very varied herbivore community (Yurtsev, 2001). Known as the “productivity paradox”, it has been argued that the key feature that makes it possible for such an environment to be highly productive for a herbivore community lies in the diversity of its herbaceous flora.

The correlation of the Central Asian loess sequence with the Chinese loess sequence provides dates for Central Asia, links its formation to global climate forcing mechanisms, but also highlights some variation in regional response (such as the seasonality of aeolian effects). Research on the evolution of arid environments in western China has also suggested that previously arid areas might be thought of as 'sensitive systems' that can recover rapidly during humid phases, with interesting implications for reoccupation by hominins.

Early occupation was most likely in, although not necessarily limited to, the piedmont and foothill regions of Central Asia. These regions would likely have been highly productive during interglacial periods, with multiple floral and faunal resources available, and may even have provided *refugia* during harsher glacial conditions. Perhaps we can characterise possible hominin movement through Central Asia as one of predominantly east-west/west-east direction, following the foothill and piedmont regions of the IAMC. However, whether hominins are first entering this region at its eastern or western edge cannot be known for certain, as chronological control within the region remains poor (see ‘Chapter 2. The Lower Palaeolithic of Central Asia’), and early dates in both Georgia and China provide competing scenarios (see ‘Chapter 3. The Lower Palaeolithic of Neighbouring Regions’).

It is, however, unclear how well hominins could have survived the glacial periods in Central Asia. Evidence for glacial occupation at Maliang in China *c.* 0.8mya, and from Khonako I and Obi-Mazar in Tajikistan *c.* 0.5mya suggest that hominins at this time might have been able at least to occupy the region periodically during these harsh conditions. If glacial periods in the

Lower Pleistocene were milder, if the onset of glaciations was gradual, and if arid environments had the possibility of rapid regreening at the end of glacial conditions, the possibility seems even greater that hominins could have adapted to these environmental conditions, and/or reoccupied rapidly from *refugia* and adjacent regions during the early Pleistocene as well. This leads to the possibility that Central Asia may have provided a very creative region from an evolutionary perspective, as has been suggested already in relation to the Variability Selection Hypothesis (see '4.2.2 Variability Selection Hypothesis'). The repeated separation into *refugia* during extreme environmental conditions and subsequent recombination of populations following climatic amelioration is known to have a creative effect in speciation that can be observed in studies of phylogeography (Stewart & Lister, 2001).

Chapter 7. Modelling Methods & Results

A substantial amount of background literature and synthesis feeds into the development of the models and interpretation of the results presented here. These models address topics of Lower-Middle Pleistocene dispersal and occupation in Central Asia, but are informed by contextual information from the archaeological records of neighbouring regions, consideration of the way discussions of hominin occupation and dispersal are structured and should be modelled, and a comprehensive understanding of the physical geography and Pleistocene climate of the region, all presented and summarised in the previous chapters. In particular, it has been emphasised that hominin occupation and dispersal needs to be considered as a process that is not only driven by environmental explanations. In particular, how hominin competency and adaptation factors into these models, and how a heterogenous landscape of resources is best modelled has been given serious consideration. The solution that has been arrived at draws on the concepts of the 'taskscape' and 'affordances', to produce novel 'amenability', 'accessibility', and 'entry-point' analyses that constitute the modelling component of this project. This chapter also briefly covers rejected modelling options in a section at the end.

7.1 Phase 1: Modelling Resources and Amenability to Occupation

7.1.1 Resources and Amenability Methodology

Phase 1 of the modelling consists of the spatial data collection for the project, the individual assessment of the datasets, and the combination of these datasets in a predictive surface model representing the amenability to hominin occupation throughout the study region. These steps aimed specifically to address the first of the three questions posed in the introduction:

Was Central Asia habitable during the Lower-Middle Pleistocene?

This question is addressed by modelling the different factors identified as important elements for hominin occupation in the 'Chapter 4. Hominin Dispersal and Occupation in the Lower Pleistocene'. This required a substantial data collection over several years of the project, focused on the different elements to be included in the model, and mapping those elements in relation to the known Lower-Middle Pleistocene sites. The end goal of Phase 1 was achieved in the combination of all these different mapped elements to produce a GIS of viable hominin occupation in Central Asia, or what is here referred to as an 'amenability to occupation' map, or simply 'amenability' map.

7.1.1.1 Data Collection and Formatting

Data Types/Decisions and Issues

During the data collection stage, several key issues had to be addressed to ensure that the data would be reliable and appropriate for the analysis. These included:

- Ensuring that data could be used in a way that did not perpetuate the discrete habitat concept (see Chapter 4. Hominin Dispersal and Occupation in the Lower Pleistocene);
- that use of environmental data avoids the risk of ED, by explicitly tackling human agency;
- that issues surrounding the use of Last Interglacial Climate data were understood and effectively mitigated;
- and that possible factors affecting the accuracy of Soviet-era mapping were understood and taken into account.

All four of these key areas are addressed in the next section.

As was highlighted in the section '4.3 Resources – A 'Variety of Elements' Approach', the discrete habitat approach to framing analyses and discussions of Pleistocene hominin occupation and dispersal is questionable in its value. Rather it has been argued that the prevalence of 'mosaic' habitat interpretations may reflect the poor fit of discrete habitats to hominin occupation. A preferable approach would focus on reconstructing a wider variety of individual elements of hominin subsistence in a continuous format.

Arguably, the focus on habitats and the prevalence of 'mosaic' habitats is a function of the traditional site-centred focus of archaeology. In his 'off-site archaeology' model, Foley (1981a, p. 2) has argued that "the archaeological record is spatially continuous". Sites themselves represent only a small part of the wider subsistence system, and therefore a site-centred focus in an analysis can be seen as an obstacle to the broader understanding of hominin subsistence in the landscape: "Prehistoric man operated over a landscape, and his survival depended on his ability to organise his activities over this landscape. His immediate dimension is also the one on which we should map our understanding of his behaviour" (1981b, p. 180). Foley's argument deals primarily with the mapping of artefacts and artefact clusters external to traditional sites, and as a result he does occasionally fall into the trap of assuming discrete habitats. However, the point made by Foley's 'off-site' archaeology model is equally applicable and necessary in the development of an 'off-site' subsistence ecology. When we view the wider landscape or the wider environment from within sites, rather than considering it in its spatial entirety independent of site placement, that is not adequate for reconstructing the past environment and behaviours of hominins: "traditional, site-based, archaeological methodology is inadequate for this, and alternatives must be developed" (Foley, 1981a, p. 13).

The current study aims to avoid site-centred, and discrete habitat methodologies, and instead attempt to develop and test alternative methods that aim to address the wider landscape, and the wider subsistence system of hominins in that landscape. This necessitated some important initial decisions at the level of data types to include, and also the manner in which those data were mapped. To avoid discrete habitat assumptions, it was necessary to use data that did not make these assumptions. For instance, the PRISM 3 BIOME land cover dataset is a large aggregate dataset, covering late Pliocene vegetation types across the whole world (Sohl, et al., 2009). However, it is very low resolution, with a very high possible error, and the categories it uses (e.g. “Grassland”, “Desert”, “Rainforest”) are not useful for breaking discrete habitats into continuous resources. The datasets used in the current study needed to fulfil several criteria:

- Provide consistent coverage over the whole study region (as opposed to, for instance, an individual dataset that had a high resolution for one area in Central Asia but not others).
- Have a high enough resolution and accuracy for the regional scale of the analysis.
- Be supported in the literature through their connection with hominin-driven occupation and dispersal factors (see the section entitled ‘4.3 Resources – A ‘Variety of Elements’ Approach’).
- Provide the ability to discriminate continuous resources rather than identifying broad ecological units (e.g. habitats, eco-zones, etc.).

By focusing on the impact of these theoretical issues and keeping a clear focus on the research questions during the data acquisition phase, it was possible to ensure that any data used helped to provide solutions to these issues rather than compound them.

As has already been alluded to several times, the use of predominantly environmental data in Paleolithic models and explanations runs the risk of reducing the role of human agency in our reconstructions of ancient hominin behaviour, a situation that has been termed environmental determinism (ED). Gaffney & van Leusen (1995, p. 368) have defined ED as: "…a theoretical approach to archaeology that regards past (and present) cultures as somehow functions of, or shaped by, environmental pressures. It relies to an extreme extent on the pre-eminence of human economic behaviour … This approach translates into the explicit and exclusive use of environmental variables in GIS models in order to explain patterns of past behaviour."

Because environmental data and explanation are such a key focus of Palaeolithic archaeology as a whole, ED is difficult to separate in our approaches, and also difficult to operationalise in our methods. It is suggested by van Leusen that ED in archaeological applications of GIS is an unintended consequence of the limited GI (Geographic Information) datasets available, combined with the limited functionality of a GIS, and so the use of a GIS-based methodology tends towards ED. While GI dataset availability has increased substantially since the publication of Gaffney & van Leusen (1995), data availability remains an issue for the current study region and scale of analysis.

For the purposes of this study, an undesirable situation of ED is understood to refer to a model, or interpretation of the results of a model, where environment divorced from hominin action provides the chief or only source of explanation for hominin behaviour and behavioural change. It is considered an undesirable situation because the Palaeolithic record is a result of hominin action and decisions taken over time, and it is understood that hominins are agents in their own adaptation, that "…so-called 'long-term changes' have to be conceptualised as accumulations of individual changes in behaviour and practice…"

(Gamble & Porr, 2005, p. 11). An understanding of ED may not change the results of a study, but it can and should be reflected in the framing of research questions, the building of the model, and the interpretation of the results.

The current study avoids ED where possible, and does not assume that environmental factors necessarily directly dictate patterns of dispersal or occupation. The study is specifically focused on looking for opportunities for hominin-environmental interaction, in the form of hominin-centred 'affordances' in a spatial 'taskscape' (see section '7.1.1.2 Amenability Analysis'). The data types used have been included on the basis that they provide affordances for hominin action. With literature support, I have argued for every environmental factor involved, and the method of its modelling, in terms of what it means to hominins and the hominin choices it facilitates in the landscape.

As an example, some types of data that could easily be incorporated and are often included as standard in spatial analysis, such as topography, have been rejected for use in the present model because they have no clear relation to the factors being investigated (further details in the section '7.4 Rejected Modelling Methods: Least-Cost and Visibility'). Topography in particular was rejected because it is unclear what role it would play at the spatio-temporal scale of the current analysis. Although, an index of 'roughness' could have been derived, as per King & Bailey (2006), it was argued previously in the section entitled '4.3.2 The 'Tectonic Landscape Model'', as well as by the authors themselves, that this index is really a proxy for a suite of environmental features attractive to hominins, which are ecologically linked to areas of topographic roughness.

The current study operates on a large spatio-temporal scale, and as a result it deals with large-scale accumulated probability, and aims to understand the long-term pattern that results from individual action over time. This is reflected in the way in which this analysis is

conceptualised (affordances), and in the way the results of this analysis are understood to relate to long-term patterns of dispersal and occupation.

The Use of LIG Climate Models

The use of datasets produced from Last Interglacial (LIG) climate models in the current analysis is potentially problematic, and must be specifically explained. The LIG itself only overlaps with the youngest securely-dated site under consideration (Sel'ungur, Kyrgyzstan, *c.* 126kya). Although the absolute values of the climate models certainly cannot be justifiably extended to apply to all of the Lower-Middle Pleistocene timespan of the current analysis, there are a number of reasons to suppose that the relative patterning of those climate systems remains broadly unchanged, at least on the scale relevant to the current analysis.

Tectonic uplift during the Quaternary has been previously reported for two of the major mountain chains in Central Asia, the Pamirs and Tien Shan (Fan, et al., 1994, Krestnikov, et al., 1984, Strecker, et al., 1995). However, a lack of good dating evidence has probably led to an over-estimation of the slip-rates for these mountain chains (Hetzel, et al., 2002). Furthermore, the timings of the three major deformation events identified in the orogenesis of the other major mountain chain, the Karatau mountain range in Kazakhstan, all take place prior to the Quaternary (Alexeiev, et al., 2009). Overall, Central Asia demonstrates a long-term preservation of its gross geomorphological features (Hetzel, et al., 2002, Neil & Houseman, 1997).

Orogenesis does occur in other parts of Asia during this time, and this does have an effect on Central Asia, for instance in the form of earthquakes recorded within the historical record (Hopkirk, 1993, p. 160). Substantial uplift of the Tibetan Plateau takes place during this time, which is known to have had substantial effects on precipitation and aridity in Central Asia, due in large part to its effect on the Asian Monsoon cycle (Abe, et al., 2005, Cheng, et al., 2012). There is an increase in the frequency of dust storms around 2-2.5mya, also linked to

glaciation, ice sheet volume, and the formation of loess deposits in Central Asia (Clark, et al., 2006, Ding, et al., 2002, Dodonov & Baiguzina, 1995, Machalett, et al., 2008). Dennell (2013a) has synthesised many of these factors, and outlines a link between the uplift of the Tibetan Plateau, the increased aridification of Central Asia during the Middle Pleistocene, and the exposure of deposits vulnerable to wind erosion and deposition as loess.

The most dramatic change in the region has been the deflation of the northern and western areas, and the aeolian deposition of those sediments in the south-eastern part of the study region. Although substantial, with loess deposits in excess of 100m in depth accruing in some locations, these are also unlikely to affect the overall geomorphology at the scale of the current analysis. The other datasets included in this analysis have error-ranges around or in excess of the depth of loess deposition in most areas of the region.

An assumption made in this study is that the uplift of the Tibetan Plateau intensifies, but does not completely change, the overall patterning of climate in the study region. Much of this patterning is dictated by the substantial complex mountainous topography present in the east and to the south-east of the study region, which has been shown to be largely stable during this timeframe (Hetzel, et al., 2002). The major orographic events that have taken place in Central Asia are on a timescale of tens of millions of years (Neil & Houseman, 1997, p. 573), so that while it is accurate to describe this geologically as a tectonically active region, on the timescale of the Quaternary these orogenic effects will be much less dramatic and not meaningfully impactful on the gross morphology of the landscape.

The way that this LIG climate data will be used in the current analysis, being first normalised and then combined with other data, means that the absolute values will not be preserved. So while the absolute values, which are almost certainly different to earlier conditions, will not be preserved, the patterning of relative climatic difference across the study area, which is argued to remain relatively stable, is what will be used in this analysis.

The reliability of Soviet archaeological information has already been briefly touched upon in a previous chapter (see '2.5 Archaeology in the Soviet Union'). A broader discussion is required due to the fact that this analysis also relies upon geographical and geological information produced during the period of the USSR, which is subject to several issues similar to those affecting the archaeological information, as well as several unique aspects that require consideration.

As has been highlighted in the discussion of Soviet Archaeology, Kohl (1984, p. 238) mentions three aspects of Soviet scholarship that are worth reiterating here. 1) a site-centred approach with limited regional studies, 2) low-quality and uninformative maps, and 3) censorship issues limiting dissemination of crucial spatial information.

The beginnings of academic geography in Russia lie within the reign of Peter the Great, whose sponsorship of geographical expeditions focused on assessing resources and providing maps to aid his militaristic endeavours (Hooson, 2001, p. 2). The foundation of the Russian Academy of Sciences during his reign was also of crucial importance for the burgeoning development of geography in Russia. Physical geography had a strong basis even in pre-revolutionary Russia, and Soviet scholars continued to build on this (Hooson, 1959, p. 74). Between this time and the Russian Revolution, the key aspects that would characterise subsequent Soviet geography were already in place, namely; a focus on physical conditions, especially of soils, as a result of a fully integrated bio-climatic system, a focus on the assessment of natural resources, and a separate geographical school of thought focused on the material and social conditions (including political conditions) of society (Hooson, 2001, p. 8). Early Soviet geography had something of a pioneer focus, comprising regional studies of the newly acquired territories, with an especial focus on mineral resources and soil quality (Komedchikov, 2000, p. 19). The effect of the Stalinist Period was to dampen interest in both

the overall concept of a totally integrated geography of physical processes and in the socio-economical political aspects of geography, in favour of a largely asocial specialised physical geography (Hooson, 2001, p. 9). Geographers took on a more tactical role during the Soviet participation in WWII, mapping infrastructure and landforms on both the European and Far Eastern fronts, and significantly increasing the mapping of national resources for use in the war effort in the Kazakh SSR (Komedchikov, 2000, p. 21).

During the period between 1950-1959, Soviet geography went from publications in a single All-Union periodical to a burgeoning scientific enterprise with tens of different publications for dissemination (Hooson, 1959, p. 73). Soviet geography generally was given a greater place of importance than in the U.S. or Great Britain, and was described as "more comprehensive" (Demko, 1965, p. 165). There was, however a heavy emphasis on the work of physical geographers above any other branch of geography (Demko, 1965, p. 166), and in particular a strong focus on describing physical processes (Hooson, 1959, p. 74). Physical geography constituted up to 90% of work published until 1952, and still constituted around some 50% a few years after this in 1957 (Hooson, 1959, p. 74). Grigoryev's (1955) report of the Congress of the USSR Geographical Society in 1955 shows an overwhelming focus on topics in physical and economic geography. Much of this work done by physical geographers can also be classified as data collection and inventorying of the physical resources of the USSR (Demko, 1965, p. 167). The work and products of physical geographers in the Soviet Union is described by many Western scholars as being of excellent quality (Hooson, 1959, p. 74, Demko, 1965, p. 166). The period between 1960-70 in particular is notable for the publication of a number of comprehensive atlases of great quality and scope (Komedchikov, 2000, p. 24), including Vinogradov's (1966-8) lithological atlas, which has been used in the current project.

Non-physical geographies tended to be lumped together as 'economic geography', reflecting to some extent the materialist and economic determinist themes in Marxist thought generally (Hooson, 1959, p. 74). Even economic geography tended to emphasis demographic topics, rather than social or political topics (Hooson, 1959, p. 75). This emphasis on physical geography, and relative neglect of economic geography led to a debate in Soviet geography between monists, who argued that a totally integrated geography was achievable and desirable, and dualists, who insisted on the necessity of the division between the physical and the economic geographies (Demko, 1965, p. 170). The issue of the "integral and inseparable character of the litho-atmo-hydro-biosphere" (Grigoryev, 1955, p. 434), was being discussed as a theoretical issue in Soviet geography from at least the mid-1950s onwards. What was perhaps lacking, however, was any real integration between these physical realms of geography and the socio-economic aspects of geography. Dualists in particular objected to integration, as they saw the development of an integrated geography as anti-Marxist, and for this reason it was reported that the "concept of a total geographical environment which includes both nature and society is unacceptable to them" (Demko, 1965, p. 170).

The work of non-Marxist Western geographers was initially poorly regarded by Soviet scholars, although in the mid-1960s this is reported as having been superseded by an atmosphere of communication and collaboration (Demko, 1965, p. 169). Likewise, Western researchers came to acknowledge the high standard of Soviet research through these opportunities for networking and collaboration (Demko, 1965, p. 169). An exchange visit between Soviet and Western researchers was reported as taking place in 1963, and as embodying "a general feeling of good will and mutual respect" (Chappell, 1963, p. 1). Although his Soviet colleagues criticised the quality of American cartography during their exchange visit, Chappell (1963) reports being refused access to topographic maps of the USSR during the Soviet leg of the visit, and he was therefore unable to comment on their

quality or compare them with contemporary American practice. Indeed, censorship and manipulation of map information is a known problem with many urban maps or economic geography maps, especially during the Cold War and the Era of Stagnation (Monmonier, 1996, pp. 115-8, Hooson, 2001, p. 13; Hooson, 1959).

It can be concluded, however, that the emphasis on high-quality physical geographical research and the separation of this research from economic geography renders the use of these products of Soviet cartography largely unproblematic, and of probable high reliability. The primary source of Soviet mapping for this project is Vingradov's (1966-8) lithological atlas, which appears to be exhaustive and of a very high standard.

Site Coordinates

A key aspect of this analysis relies on site location. Although site location has not been used to identify features for inductive predictive modelling, it has been used to understand the relationship between the distribution of known sites, their technology, and wider environmental variables subsequent to the production of the amenability surface. Describing and interrogating this relationship between sites and amenability was the ultimate goal of the first phase of analysis. Site coordinates are not a necessary component in building the amenability surface itself, but were necessary for investigating the relationship of the surface to the current Lower-Middle Pleistocene record in the region, as well as highlighting any deviation that would indicate a poor fit.

Most of the coordinates for the sites used in this analysis were reverse-engineered from the literature by digitising and geo-referencing several maps of site distribution, especially Vishnyatsky (1996). In this process, known locations of archaeological sites, major cities, or identifiable 'hard' features of maps (spatial features of known location that are not liable to relocate over time) are used to geo-reference a map containing features of unknown spatial location. The digitised maps differ in their methods of projection, and the process of geo-

referencing compensates for this by applying a number of methods of transformation to reduce the error between the known points. Coordinates created for sites through this technique are open to possible error, but the scale of such an error is acceptable for an analysis at a continental scale.

Several of the maps overlap in coverage, so an amount of redundancy between the different maps was also used to give an indication of problematic or erroneous coordinates. In judging between the different possible sets of coordinates, the maps were ranked in terms of the perceived reliability of the original map, but also by the residual error observable from the geo-referencing process. In terms of perceived reliability, several factors were taken into account, including date of publication, method of production (hand-drawn versus digital), line thickness and point size, and the reliability of other information within the publication. On larger-scale maps, there was also the possibility that groups of sites would be designated by an 'average' point somewhere in the middle of the cluster, or that highly-clustered groups of sites would be artificially separated for ease of visualisation. These sources of error would also have had a potential impact on the residual error produced during geo-referencing, but the scale or relationship of these errors is complex and impossible to gauge with absolute certainty. Occasionally, notes taken from the literature could be used to decide between different sets of coordinates when they described the site in relation to extant topographic and hydrological features, or in relation to modern urban areas. Overall, the site coordinates produced by geo-referencing maps from the literature cannot be regarded as providing exact locations for the sites in question, but should be regarded as broadly accurate enough for an analysis at the continental scale.

The only site that showed major disagreement between geo-referenced maps that were otherwise reliable was Sel'ungur, which provided at least three widely-separated clusters of coordinates. Two clusters to the south-east and the south-west of the Fergana Depression,

and one to the north in the middle of the depression. Part of this seemed to be due to perpetuated errors in the published literature, although it is quite likely that border disputes around the Fergana Depression both during and after the establishment and dissolution of the SSRs in this region may also have had a role in the confusion (Meorgan, 2012, pp. 471-3). This is why B. Viola, who has participated in several seasons of fieldwork at Sel'ungur, was contacted to provide accurate coordinates. The site of Mugodjari was excluded from the analysis, as co-ordinates could not be located for it.

Coordinates for several of the remaining sites that could not be found within the literature were provided by M. Glantz and colleagues at Colorado State University.

Geology

Based on the literature review, it should be clear that geology is considered to be a central feature of this analysis. As a result, high-quality geological data was essential, and a significant proportion of the time spent on collecting and preparing the datasets was spent on achieving this goal. Naturally there is always an element of averaging and interpretation between individual boreholes and exposures in the production of a geological map (Coe, et al., 2010, pp. 222-8, Dixon & Bernor, 1992, pp. 123-4). While acknowledging this, any errors resulting from geological field technique are likely to be at too small a scale to impact on the current study.

Geology is central to the current analysis in three major ways. Firstly, it is useful as an indication of the availability of knappable raw materials, and secondly as a proxy for groundwater. Groundwater is also necessary, as an indication of the ecological carrying capacity of different areas within the region, and therefore also as an indication of 'ecological richness'. Thirdly, geological data is necessary to assess Finalyson's (2014) 'rocky places', and their possible distribution within the study region. No individual source of

geological data was sufficient for these purposes, so it was necessary to draw on several sources of data to construct a useable dataset.

Firstly, a USGS energy resources dataset, covering the former USSR and in a vector format, was utilised to provide generalised geology, as well as size and extent of geological units. Reference to data hosted online by the OneGeology project (OneGeology, 2016) allowed designation of features by geological sub-period in some cases. Subsequent to this, a lithological atlas of the former USSR (Vinogradov, 1966-8) could be used to more accurately designate rock type to the different geological units. This lithological atlas could not be digitised due to restrictions placed on this material by the Bodleian library in which it was held, but instead detailed notes were taken on the atlas with the aid of the USGS dataset.

Because the types of data presented in the USGS dataset and the lithological atlas differ slightly, and the latter could not be digitised, there were significant obstacles to creating a composite dataset while maintaining the accuracy required for the analysis. Although the lithological atlas could provide more accurate rock type designations by sub-period, the USGS dataset only designated the spatial extent of geological units by period. However, the lithological atlas recorded the different proportions of rock types within units, which enabled a general estimate of the proportions of individual rock types in the units of the USGS dataset. The information on marine uplift and volcanic activity, also from the Russian lithological atlas, allowed a rough estimation of the chances and nature of metamorphism in the different units. This resulted in a spatial dataset, classified by period, and capable of producing a rough prediction of rock types across the study region (subsequently referred to here as the 'integrated geological dataset').

The chance of metamorphism of individual geological features was estimated as 'Low', 'Medium', or 'High', based on information derived from the lithological atlas. In principle, this three-tiered system equated Low with no metamorphism, Medium with cementation

and compaction, and High with recrystallization. The estimation was based on the age of original deposition of the geological feature, as well as the proximity to zones of volcanic activity and marine uplift identified in the Russian lithological atlas. It is difficult to assess the resulting precision of this dataset without access to more detailed geological data from the region, and the identification of specific rock types and absolute porosities is certain to differ. However, this dataset should preserve the scale of the differing values, if not the absolute values, which are determined in large part by a balance between antiquity and grain size.

The use of bedrock geology without surface geology is potentially problematic in the current study. It should be noted that the integrated geological dataset produced here is not a guarantee of outcrops of certain rock types being present in any one location, but is a general prediction of the rock types of outcrops that may exist in the region. This is more of an obstacle to stone tool raw material studies, but less of an obstacle to the groundwater hydrology. Surficial geology has been omitted, because it provides no information on the factors that are attempting to be modelled, and these deposits are sure to vary substantially throughout the Quaternary.

Use of the Integrated Geological Dataset

As previously noted, the geological data was necessary for assessing three separate aspects of the landscape relevant to hominin occupation and landscape use; groundwater potential, distribution of knappable raw materials, and rocky places. Groundwater potential is most relevant as a component of the hydrological and ecological mapping, and will be dealt with in subsequent sections. Raw material type is well-reported in very general terms for lithic assemblages in Central Asia, even though rigorous provenancing studies are rare, and therefore the identification of raw materials knapped during the Palaeolithic was made relatively easy. Although flint is reported from across the study region, non-flint raw

materials form a significant component of many assemblages. The raw materials reported from Central Asia commonly fall into a five different categories, and these categories are kept very broad here specifically to identify commonalities across the breadth of the study region:

1. Fine-grained materials with a siliceous composition and conchoidal or sub-conchoidal fracture (e.g. flint, other chalcedonies, and quartz)
2. Homogeneous high-grade metamorphic rocks (e.g. quartzite or hornfels)
3. Cemented sedimentary and low-grade metamorphic rocks (e.g. silicified limestones and cemented sandstones)
4. Volcanics of all chemistries and varying quality (e.g. felsite-porphyry and andesite)
5. Foliated and schistose metamorphic materials (e.g. schists and slates)

Raw material type 1 dominates the literature as a reported raw material in Central Asia, which is unsurprising as it corresponds to the most predictable facture and durable, fine-grained edge. Homogeneous high-grade metamorphics (raw material type 2) are probably the second-most reported raw material type, and account for the dominant raw material type at several of the Karatau Pebble Culture sites. While taking more physical energy to work, homogeneous high-grade metamorphics fracture fairly predictably and provide a sharp, durable edge. These features make them an adequate replacement when fine-grained siliceous rocks are rare or poor quality, but are likely to encourage fewer, simpler removals (as is seen in the Karatau Pebble Culture). The other three types of raw material are about as commonly reported as each other, but still make up a significant component of the raw material reported when combined. All three of these categories probably represent a compromise in raw material, as all will tend to fracture in unpredictable ways. Volcanics can be high-quality and homogeneous like high-grade metamorphics, but there may be other factors working against their selection and utilisation in Central Asia. With these raw

materials reported in the Central Asian literature, it will be possible to extract them from the integrated geological dataset to answer specific questions regarding raw material behaviour in Central Asia. Raw material will also feature as an element in the predictive map that is the final goal of Phase 1.

Finlayson's (2014) rocky places are also assessible using the integrated geological dataset. It has already been noted that the majority of cave sites with archaeological remains are found in limestone and dolomite karst systems (Hunt, et al., 2015). While it should be possible to extract limestone and dolomite from the integrated geological dataset, and predict the potential for karst formation in these areas using topographic relief, a specific dataset already exists for karst outcrops. This is the 'World Map of Carbonate Rock Outcrops v3.0', which was assembled by P. Williams and Y. T. Fong from a variety of geological sources, and is hosted online by The University of Auckland (Williams & Fong, 2010). Use of this karst dataset is preferred to formulating a derived dataset of the integrated geological dataset because the former has been assembled specifically for the purpose of identifying carbonate outcrops amenable to karstification, and has been included in the model for this reason.

Hydrology

It has been noted previously that Finlayson (2014) has argued the case for the importance of water distribution in human evolution, and that water is here regarded as a central element for hominin occupation of a region. The hydrological cycle describes in abstract the different states that water can occupy in an environmental system, and several of them are inaccessible as consumable drinking water to hominins (see Figure 33). The most easily accessible water-sources for hominins would have been in the form of overland runoff, or surface water. Groundwater would only be accessible where it fed into surface water through springs or similar exposures. Precipitation would only be periodically accessible to hominins, dependant on the frequency and duration of rainfall, but also on porosity and

saturation of the underlying soil and geology. Very high porosity or very high saturation would result in surface water, while very high porosity and low saturation (features of a sandy desert, for instance) results in rapid infiltration. High porosity and high saturation together defines a humid situation, which would provide good conditions for floral communities to thrive. While hominins themselves would have little to no direct access to water in the saturated soil zone of these areas, they would no doubt have benefitted from a productive floral environment in terms of plant foodstuffs (and possibly materials for organic technologies). Rich floral communities would also tend to be beneficial for faunal communities, which provide another potential resource for hominin subsistence. The combined effect of floral and faunal communities in high porosity-high saturation environments can be considered more broadly as a proxy measure of 'ecological richness'.

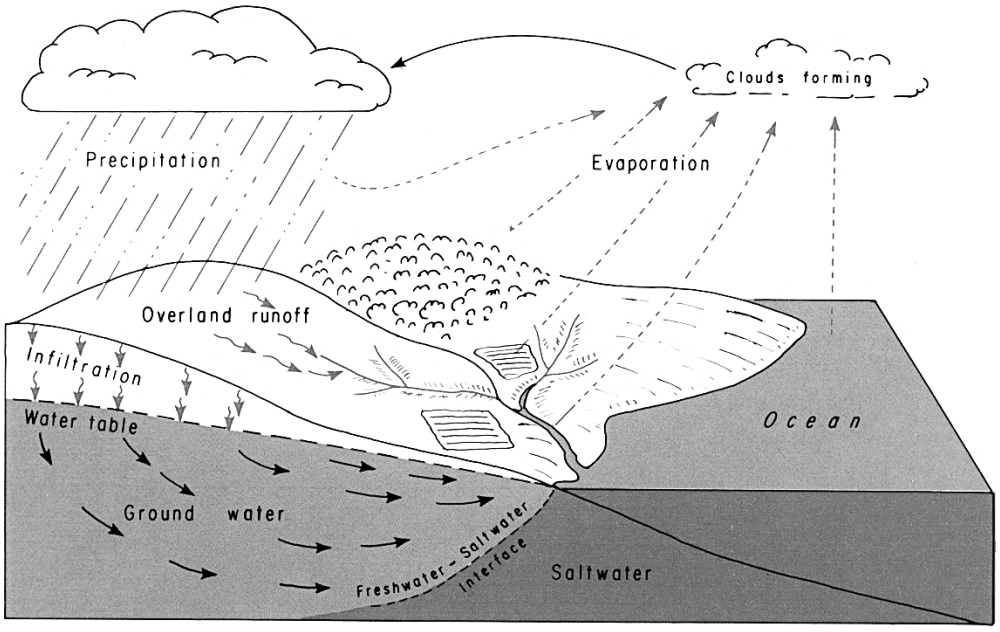

Figure 33 - The hydrological cycle has multiple interconnected stages, several of which render water inaccessible for hominin consumption. Figure from Heath (1983, p. 5).

Precipitation

The oldest available precipitation data dates to the Last Interglacial (*c.* 140-120 kya), and is hosted online by WorldClim and described as "downscaled climate data from simulations with Global Climate Models (GCMs)" (Hijmans, et al.). The original source for this data is

Otto-Bliesner et al. (2006). Although not ideal for characterising precipitation further back in the Middle Pleistocene or in the Lower Pleistocene, these data do overlap with the youngest site considered in this analysis (Sel'ungur at *c.* 126 kya). While the absolute quantities of rainfall almost certainly differ over such a protracted period, the pattern of relative rainfall across the region has been argued to be roughly similar throughout as the major sources of relief and rain-shadow in the region remain stable. The WorldClim data is broken down by month, and these were combined together and normalised to produce a surface representing average rainfall throughout the year.

Temperature

Much like precipitation, the temperature data used here has been derived from the WorldClim LIG dataset. An alternative to using this data would have been to create a linear graduated surface that uniformly decreased in value from south to north, to mimic the decrease in temperature from southerly to northerly latitudes. This was rejected, however, as gross landscape morphology is known to have a substantial influence on temperature in the study region, for instance near mountainous zones. WorldClim temperature has been included here with the same caveats that accompany the precipitation dataset.

Overland Runoff (Surface Water)

In a GIS, overland runoff can be calculated from topographic data in the form of a 'flow accumulation' (Conolly & Lake, 2006, p. 258). In a raster dataset, this essentially calculates the number of cells that 'drain' into each cell in the dataset, and is subsequently manipulated to produce linear vector data of individual streams. Modern topographical data from the Shuttle Radar Topography Mission (SRTM) is available online, hosted by The CGIAR Consortium for Spatial Information (2008). The Digital Elevation Model (DEM) that has been resampled to a resolution of 250m was preferred for the current analysis. As has been highlighted already, although this area has had a tectonically active past, little to no

significant gross morphological change has taken place between the Lower Pleistocene and the present day, and it can be considered to be broadly stable at this spatial scale over this (geologically) short timeframe (Hetzel, et al., 2002, Neil & Houseman, 1997, p. 573).

Tectogenesis in south Asia during this time does further isolate Central Asia from humid air circulation, beginning a phase of loess accumulation (Dodonov, 1991, p. 193). Significant deposits of loess have accumulated in some areas as a result, but this is restricted to a relatively small area of the study region. Loess deposition follows underlying relief (meaning that, although it smooths out the landscape and creates some steep cliffs, it is mostly uniformly distributed, representing the broad patterns of relief beneath (Dodonov & Baiguzina, 1995, p. 707). In particular, steep cliffs should not pose much of a problem because of the way in which DEMs are constructed, from estimated satellite readings.

In principle, it would also be possible to test any resulting hydrological data against known records of palaeo-rivers in the literature (Boomer, et al., 2000, pp. 1262-3). However, the Amu Darya and Syr Darya are known to have been very changeable in the past, even being said to have changed course after earthquakes in historical times (Hopkirk, 1993, p. 160), and there is good reason to believe that the courses of rivers has changed substantially over the Pleistocene (Davis & Ranov, 1999, p. 192), and may be impossible to reconstruct through spatial analysis alone.

Ultimately, just because river hydrology is simple to derive from topographical datasets, making them a standard component of many archaeological GIS analyses, this does not necessarily make them more accurate or useful. It is unclear exactly what such a river hydrology would mean at the scale of this analysis, considering the highly changeable nature of rivers in this region. It would also be impossible to verify the accuracy of such data without an extensive geomorphological survey of ancient river valleys within the study

region. For these reasons, it was decided not to derive river hydrology for use in this analysis.

Large Water-bodies (Surface Water)

As noted previously, the extent of the Caspian differs substantially in the early Pleistocene versus its modern extent. Around 2mya, the Caspian undergoes an expansion in extent known as the Apsheronian transgression, which lasts for several glacial cycles (Mitchell & Westaway, 1999, van Baak, et al., 2013). During this time, when dated sites in neighbouring regions suggest that initial dispersal into Central Asia is most likely to have occurred, the Apsheronian Caspian is limiting movement into and within the study region substantially. Just after the occupation at Kuldara, the similarly impactful early Baku transgression occurs around 0.89-0.85mya. A reconstructed, early Pleistocene Caspian extent was derived from the SRTM DEM by effectively 'flooding' the area immediately around the Caspian basin until it resembled the prehistoric extent. The extent was initially calibrated with reference to the Russian lithological atlas used to construct the integrated geological dataset (Vinogradov, 1966-8), but was further refined with reference to additional sources (Boomer, et al., 2000, Cristescu, et al., 2003, Zubakov, 2001). The Caspian and the Aral are combined during this phase, but similar reconstruction has not been attempted on the other waterbodies of Central Asia in this project. While the stratigraphy of the Caspian and the Aral are well-studied and published, these smaller waterbodies would prove much harder to reconstruct using the same techniques, especially as they would have been reliant on glacial ice dynamics, and therefore far more prone to variation. It should be noted, that large waterbodies themselves may provide resources that would potentially be useable by hominins. However, the evidence for exploitation of marine resources prior to the Late Pleistocene is extremely limited, and so it will not be included here.

As outlined above, groundwater would not be directly accessible to hominins, but has been considered here as a proxy measure of 'ecological richness'. Porosity is a measure of the amount of a rock's volume that is represented by voids, and as such is a measure of maximum groundwater storage potential. However, not all voids within a rock are connected, and groundwater is only capable of entering and moving through rocks with interconnected voids. The measure of possible fluid movement through a porous rock is referred as its permeability, but this is very difficult to gauge accurately except through field study of individual geological formations, due to the varying effects of primary and secondary openings (see Figure 34). Porosity is preferred as a measure of groundwater potential here because it can provide a measure of maximum fluid capacity, but is relatively easier to derive from existing datasets. This has been achieved by using average porosity values for specific rock types reported by several geo-hydrology sources (Bowen, 1980, Heath, 1983, Ward & Robinson, 2000). These porosity values have been assigned to rocks of the same types within the integrated geological dataset.

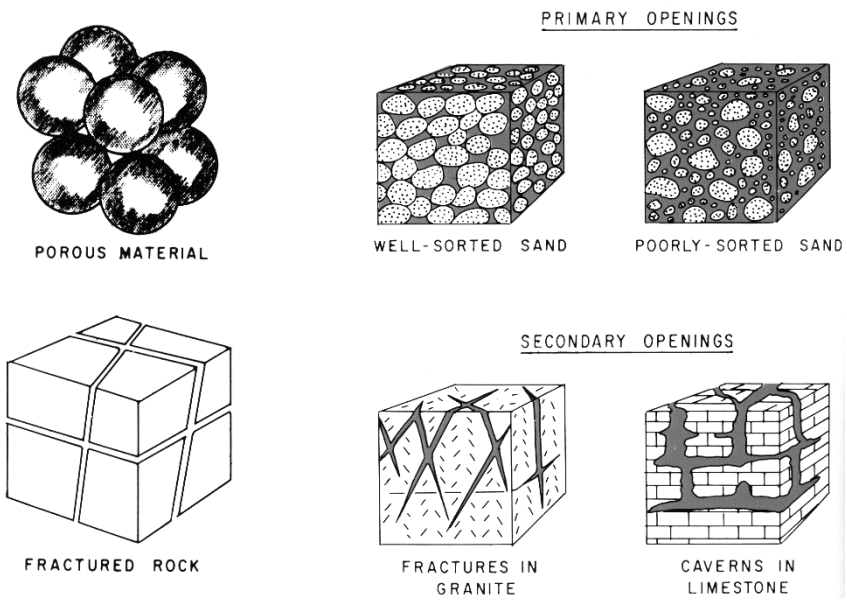

Figure 34 - The relationship between rock type and permeability, demonstrating some of the factors that affect both porosity and permeability. Figure from Heath (1983, p. 2)

7.1.1.2 Amenability Analysis

What is here referred to as the 'amenability analysis' is focused primarily on assessing the amenability of the environment in the study region to hominin occupation. As has been noted previously, amenability of the environment can mean a variety of different things, and has been considered through several different aspects of the palaeoanthropological record. Primarily this has tended to take the form of a discursive approach that takes into consideration only one or two key factors, and is often actualised through a discrete habitat concept when approached more systematically or spatially from a dispersal or occupation perspective. This amenability analysis seeks to combine multiple resources to produce a hominin-centred approach to the resources available to Pleistocene hominins in the study region. This hominin-centred approach is to be understood as being applied through the concept of 'affordances', which emphasises the combined nature of the resource patterning with increased or reduced ability for hominin action within the landscape.

Affordances and Predictive Modelling

Although the datasets that have been included in the amenability analysis have thus far been referred to as 'resources', it should be noted that, in reality, the amenability analysis model predicts resource patterning, and proxies for resource patterning, rather than resources themselves. When it comes to the subsequent accessibility in Phase 2 (see '7.2 Phase 2: Accessibility Analysis'), the issue of how these predicted resource proxies may inhibit or facilitate accessibility across the study region requires explicit examination of what these modelled resources actually constitute in the present amenability analysis. Rather than focusing on the role of predicted resources as physical entities and properties that exist static within the landscape, it is perhaps better to think of amenability and accessibility in this case as related to 'affordances', or opportunities for hominin action, in the wider environment.

Gibson (2015, p. 119) proposed the concept of affordances in the late 1960s, and has defined it thusly; "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill … I mean by it something that refers to both the environment and the animal … It implies the complementarity of the animal and the environment". This interaction between environment and animal is linked by Gibson to allied concepts such as that of the ecological niche (Gibson, 2015, p. 120), emphasising the adaptive nature of this interaction. For Gibson, humans fit within this scheme as well, with man-made artefacts also constituting an aspect of possible affordance, and the social world also.

The concept of affordances should not be misunderstood as environmental determinism, rather, the explicit focus on human-environment interaction should be seen as quite the reverse. Affordances differ from resources in that affordances represent "…the possibilities for action offered by objects…" (Ingold, 1992, p. 52), or the opportunity for action within the landscape. These opportunities are based on resources (and the wider environment), but are seen relative to the possibility of hominin action on those resources and in that landscape. Because the current analysis attempts to reconstruct a hominin-centred view of resources in the landscape of Central Asia, and because it represents the probability of resource density rather than actual or known resource density, it is more accurate to describe the amenability analysis as modelling affordances rather than resources.

With an affordances perspective, it becomes possible to see the amenability analysis as providing a map of possible opportunities of hominin action throughout the landscape of Central Asia. These affordances can be seen to facilitate or inhibit opportunities for hominin action through their presence and absence, and in this same way facilitating or inhibiting the success, expansion, and therefore potential to disperse of hominin populations in the region. In the subsequent accessibility analysis, this entails the use of predicted resources in the

landscape as affordances, and the lack of affordances as a cost against occupation, and therefore also a cost against facilitating wider dispersal through areas within the study region.

Such an approach is effectively using a movement-based analysis to study cost that is not directly associated with movement, but more broadly with aspects of subsistence behaviour and the affordances of the wider environment. It can be compared with approaches such as Whitley et al. (2010), who used estimated potential caloric return from territories surrounding their sites as a cost surface. The results produced by these analyses provide a view of the landscape that is centred on caloric acquisition, but through affordances provide avenues for examining wider-ranging behaviour across the landscape, and even engaging with issues of territory, exchange, and dominance (Whitley, et al., 2010, p. 390). In a sense, Whitley et al.'s (2010) model is a predictive model, but it uses a subsistence focus, argued and supported from a data-driven approach, to investigate the wider landscape factors that relate to site location and function, which is exactly the goal of the present project.

Gillings (2009) has similarly applied the concept of affordances in a geospatial context, but has instead applied it to view-shed analysis in the form of 'visual affordances'. By producing a model of aggregate sea-visibility across the island of Alderney, Gillings (2009) was able to consider monument placement on the island from the perspective of what the landscape visually 'affords'. With Gillings' (2009) focus being firstly on the landscape and its affordances as whole, with sites introduced and considered secondarily, it becomes possible to avoid the somewhat tautological reverse-engineering that hampers overly deterministic site placement and site prediction models. Such 'inductive' site location models tend to have a limited justification for the relevance of the data used. The primary determining factor in data choice tends to be the ease of data acquisition, while the logical basis of why particular factors might be relevant to occupation is rarely if at all understood (Ebert, 2000, p. 132).

Such an approach is necessarily tautological and environmentally deterministic. Ebert (2000, p. 130) has also argued that such inductive predictive models make a series of assumptions that are site-centred and fundamentally incompatible with a landscape-based approach.

Whitley et al. (2010) and Gillings (2009) both use affordances to study relevant features of the wider landscape, rather than relying on a site-centred perspective. These studies are both examples that show how an approach based on affordances can help break away from the assumptions made in bad predictive models. This focus on the landscape as a whole is an important one, if archaeologists wish to avoid an overly site-centred analysis of the record. Nowhere is this more important than in the current analysis, because the current distribution of sites in Central Asia is not well understood and is also prone to taphonomic and recovery biases. In terms of actualising Foley's (1981a, 1981b) 'off-site archaeology', it becomes necessary to challenge site-centred assumptions in our modelling.

In some sense, the 'landscape' over which Foley's (1981b, p. 180) prehistoric man organised spatially continuous activities does not truly exist, but it is perhaps better conceived as representing a kind of space defined primarily by the affordances and opportunities for hominin action. This would be something like Ingold's (1993) concept of the 'task-scape'. The 'task-scape' is not simply related to the physical landscape or the reality of resources and action in the landscape, but represents in some respects a totally separate 'landscape' of affordances comprising actions taken, potential to act, and the facilitating process of the available resources. This separation of the static, physical landscape from the organised activities and affordances of the 'task-scape' is necessary for actualising a truly off-site archaeology in geospatial analysis.

In looking at resources with reference to the concept of affordances, the current study aims to break away from the kinds of inductive predictive models that include vast numbers of attributes with limited or no behavioural or hominin-centred justification in a multi-factor

regression. The current study also attempts to avoid environmentally deterministic approaches that might emphasise broad-scale environmental variables at the expense of hominin agency through behavioural adaptation and interaction with known resources.

Creating the Amenability Analysis

The fulfilment of the objectives of the amenability analysis was done by creating an affordances surface. This surface represents a hominin-centred view of the affordances provided by the wider landscape and the resources distributed within it. The creation of this affordances surface required the combination of all of the individual resource datasets previously examined. These datasets exist in a variety of different formats and with mutually incompatible units of measurement, and so their combination required first that they be brought together into a commensurable format whereby they could then subsequently be combined together.

Conversion to Raster Format

The various datasets could be made mutually compatible by converting them all to the same data format, and then converting from absolute to relative units of measurement via a process of normalisation. The datasets could then be combined in such a way as would preserve the logic of the analysis and the relative patterns of resource abundance and scarcity.

It was decided to convert all of the datasets into raster format, and this decision was made for a number of reasons;

1. It would preserve much more of the data than the alternatives. So while some of the precision of a vector-based format is lost in conversion to raster, this is limited in comparison to the data loss when converting a raster format into something else, because while the former is a discrete data format, the latter is a continuous data format;

2. The alternatives to a raster format, especially when dealing with conversion from a raster format, would be unnecessarily unwieldy or result in a large loss of data;
3. The methods for combining the datasets are vastly simplified by the use of raster calculations, making this format far superior in terms of the ease of calculation;
4. Continuous datasets more accurately reflect the nature and logic of the real life phenomena being measured (continuous resources);
5. Also, a raster format for the final data product would be more convenient for the next phase of analysis, which requires a raster surface for its execution.

There are drawbacks to converting all of the datasets into a raster format. The issue of inevitable data loss has already been touched upon. It should also be considered that rasters, being built of square cells of different values, have a very different functional logic in comparison to point-based or vector-based data formats. The rendering of a vector-based object with raster cells necessarily 'pixelates' that object's geospatial relations, resulting in a loss of precision. Furthermore, although a vector object may be rendered in a continuous data format, it still functions as a discrete object within that dataset. The only way to counteract this discrete logic is through combination with other datasets to degrade the influence of the discrete dataset on the overall result, as has been done with the creation of the amenability surface.

Normalising and Combining Datasets

As well as being in a variety of different data formats, the datasets to be combined also include values in a variety of different absolute and relative units of measurement. These units are incommensurable, representing very distinct phenomena such as average temperature or precipitation in absolute terms, or relative bedrock porosity. The process referred to as normalisation serves to convert these values to relative measures that can then be combined with greater ease while preserving the order of patterning internal to

each dataset. There are several methods for achieving this process of normalising raster datasets via a raster calculation, such as dividing each raster by its maximum value, or dividing each raster by standard deviation. All of the raster datasets in the current analysis were normalised by dividing each raster by its maximum value. To achieve this, rasters with negative values had to be offset into positive values by adding the positive value equivalent of the lowest negative value to the entire dataset. A variety of options also existed for the combination of the normalised datasets, either by multiplying them together in one calculation, or by weighting the different datasets based on a variety of different logical criteria. The datasets used in the current analysis divide between those based on or representing overtly geological factors (raw material geology, karst outcrops), and those representing hydrological and climatic phenomena (predominantly precipitation and groundwater, but also including average temperature). The decision was made to combine the datasets nested within these groups. Therefore, the 'geological' datasets were first combined and then normalised to produce one raster dataset, and the 'non-geological' datasets were combined separately and then normalised to produce another, distinct raster dataset. These two rasters, representing geological versus non-geological datasets, could then be combined by multiplying the two together, and maintaining an equal weighting between the geological and non-geological datasets.

7.1.2 Resources and Amenability Results

This results section will firstly consider a comparison of the distribution of individual resources to archaeological site distribution, followed by the results of the amenability analysis.

7.1.2.1 Individual Resource Distribution

Raw Materials

The map in Figure 35 shows the distributions of several possible raw material sources in the study region, mapped against the distribution of sites. It should be noted that the extent of the different raw materials mapped here overlap to a large degree, and therefore the map is provided here only as a visual guide, while spatial analyses make use of the overlapping data that is not visible in the map. The raw materials included are siliceous rocks, metamorphics of various grades, and igneous rocks of all chemistries, because these are the rock types previously reported from Central Asian assemblages. Metamorphic rocks were the most complex rock type to predict, and the various grades are treated separately in the analysis itself. Sandstone, a low grade metamorphic would be predicted in areas where sand was deposited in a previous geological era, and which has subsequently received a moderate chance of low grade metamorphic activity such as cementation but not volcanic activity. Quartzite on the other hand would be expected in areas of high grade metamorphic activity, such as tectonic or volcanic activity. The information incorporated into the integrated geological dataset allowed specific geological units to be identified as potential metamorphics of various grades using just such criteria.

Several features are particularly notable in comparing the distribution of sites to the distribution of predicted raw materials. There is a noticeable lack of siliceous rocks in the vicinity of the Tajik loess sites. The majority of predicted raw materials in this region instead appears to be represented by metamorphics of various grades. The eastern Kazakhstan/Kazakh Altai area, in contrast, appears to have an abundance of siliceous rocks. The Kazakh Uplands in between appear very mixed, with an abundance of igneous and metamorphic rocks predicted, and sparse siliceous units. However, there appears to be almost nothing predicted in the west of the study region around the Mode 2 sites of the

Ustyurt Plateau. Aside from the western handaxe sites, the sites in the study region seem to show a good visual agreement with the mapped predicted outcrops. It might be suggested that this difference between the western Mode 2 sites and the other sites of the study region may represent a difference in subsistence strategy, including raw material sourcing strategy, and may also be indicative of a chronological difference. Perhaps diversity of raw material is less important, or less of an advantage, for producing Mode 2 technologies. By the advent of Mode 2 technologies in the study region, the greater distances traversed between sparse raw material sources in the western half of the study region might be less of a challenge and less of a disadvantage than for smaller-bodied hominins with an adaptable Mode 1 technology that can be successfully applied to a wide range of raw materials.

The table in Figure 36 compares the predicted raw materials within a 10km radius of each site with the raw materials actually reported from that site in the literature. 10km was chosen for the radius of the buffer because it represents the common upper limit of raw material distance transport for early Pleistocene hominins (see section '4.1.3 Hominin Ranging'). Many of the sites used in the modelling do not have raw materials published in the available literature, and these have been omitted from the table. At eight of the 25 sites with reported raw materials, one or more of the predicted raw materials are reported from the actual assemblage, but the assemblage itself contains additional raw materials that were not predicted in the mapping (highlighted in blue). At three of the 25 sites, the raw materials predicted within the 10km buffer account for all of the raw materials known from those sites, and so provide a perfect match. Considering the limited information available in the literature, and broad scale of the integrated geological dataset, this is argued to be an indication of a reasonably good fit. While these mapped raw material sources by themselves may not provide a precise, local landscape picture of the exact raw materials available in the vicinity of each site, they do give some idea of the diversity of raw materials available.

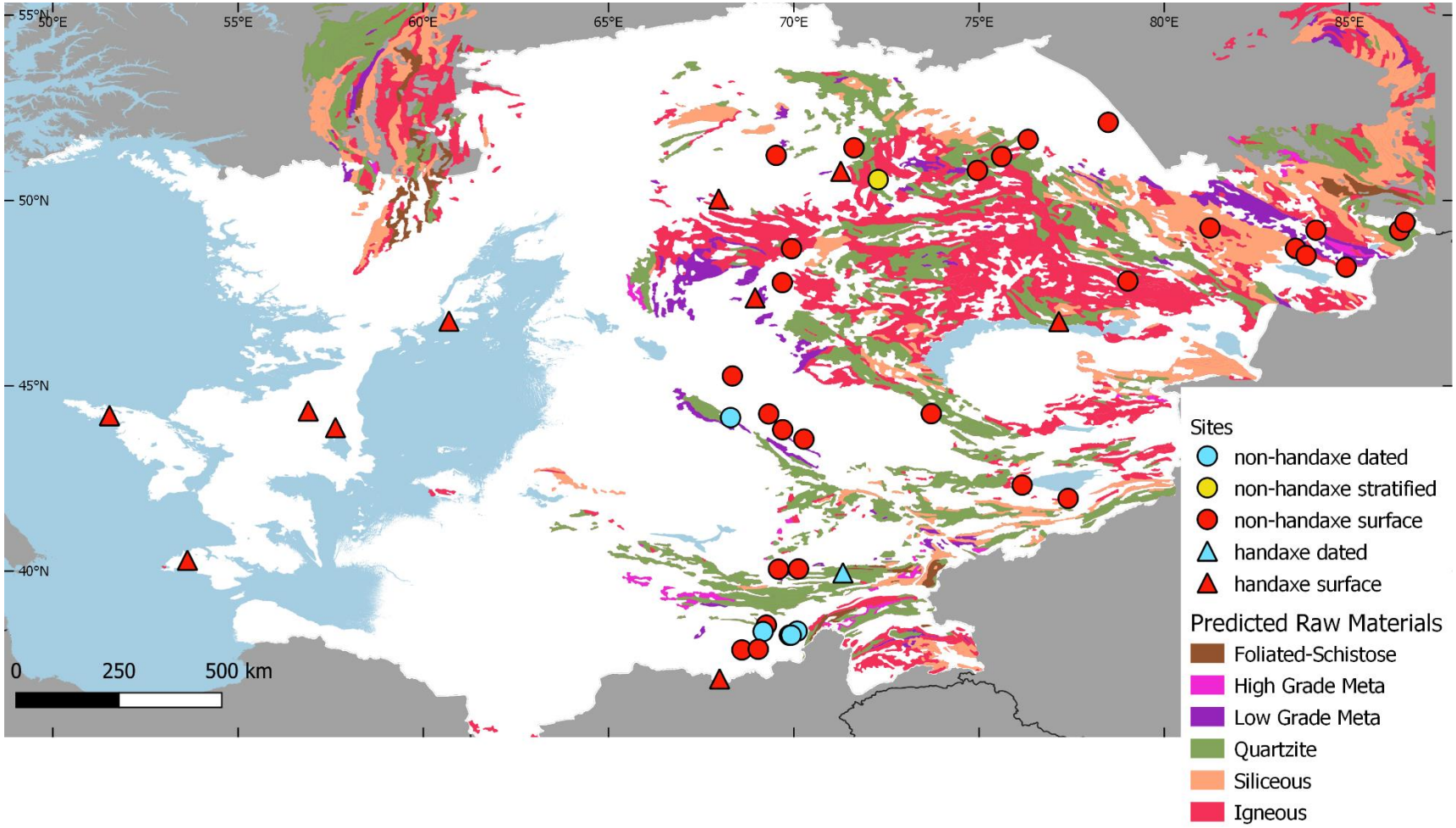

Figure 35 -The distribution of predicted raw material sources in the study region compared with the site distribution. The sites here are unnumbered for clarity. This map includes GADM, USGS, and site coordinate data, see 'Appendix 2. Spatial Data Sources' items 1, 2, and 6 for full references.

Sites	Context	Technology	Predicted Raw Material (10km buffer)	Reported Raw Material
Kemer	surface	mode 1	None	Siliceous
Karatau Range Sites	surface	mode 1	None	Siliceous
Koshkurgan1-3; Shoktas1-3	securely-dated	mode 1	low_grade_meta, quartzite, foliated_schistose	siliceous, quartz, sandstone
Kazangap	surface	mode 1	None	Siliceous
Khantau	surface	mode 1	quartzite, foliated_schistose	flint, porphyrite, alevrolite
Semizbugu	surface	mode 2	quartzite, foliated_schistose	flint, porphyrite, alevrolite
Chingiz	surface	mode 1	igneous, low_grade_meta	flint, porphyrite, alevrolite
Tokaly1-3; Zhanatas	surface	mode 1	None	Siliceous
Lakhuti; Obi-Mazar	securely-dated	mode 1	None	sandstone, metamorphics, siliceous
Karatau	securely-dated	mode 1	None	metamorphic, igneous, limestone, schist, quartzite
Yangadja	surface	mode 2	None	Flint
Esen 2	surface	mode 2	None	Chert
Karakuduk	surface	mode 2	None	Limestone
Zaisan Basin 1	surface	mode 1	igneous, siliceous	quartz, quartzite, jasper
Zaisan Basin 2	surface	mode 1	Igneous	quartz, quartzite, jasper
Zaisan Basin 3	surface	mode 1	Igneous	quartz, quartzite, jasper
Bolshoy Narym	surface	mode 1	igneous, low_grade_meta	quartz, quartzite, jasper
Camp Lake Site	surface	mode 1	igneous, siliceous, low_grade_meta	schist, fluvial pebbles
Dzhambul	surface	mode 1	quartzite, foliated_schistose	granite, schist, quartzite
Berel'	surface	mode 1	quartzite, foliated_schistose	schist, siliceous
Kuldara	securely-dated	mode 1	None	quartzite, igneous, schist, limestone, flint
Batpak; Mizar	stratified	mode 1	quartzite, igneous, low_grade_meta	sandstone, quartzite, pelitic, conglomerate
Muzbel; Obalisan	surface	mode 1	quartzite, igneous, foliated_schistose	Quartzite
Zhaman Aibat	surface	mode 2	low_grade_meta	Sandstone

Sel'ungur	securely-dated	mode 2	quartzite, foliated_schistose	siliceous, igneous, pelitic, schist

Figure 36 -This table compares predicted raw materials found within a 10km buffer of each site with the actual reported raw materials from the assemblage. Sites highlighted in blue have at least one reported raw material identified by the integrated geological dataset, while sites highlighted in green represent a perfect match between the raw materials reported and the raw materials predicted.

Precipitation

The map in Figure 37 shows the WorldClim Last Interglacial precipitation data, combined to provide a composite of precipitation patterning averaged over the course of a year. The rain shadows in the study region are immediately obvious, and caused by the substantial topography of the mountains in the southeast. All of the dated sites fall within or close to the areas of highest precipitation in the region. The large scatter of surface sites around the north and east of the study region are mostly within areas of moderate, but not high, precipitation, except for those of the eastern Kazakhstan/Kazakh Altai area. The westernmost surface sites find themselves in an area of presumed water duress, with very little annual precipitation, especially in the southeast of Turkmenistan (near the modern Karakum desert). Certainly this agrees with the repeated evaporation and transgression of waterbodies in this part of the study region over this time period, oscillating between substantial 'salt deserts' of evaporite minerals and saline waterbodies.

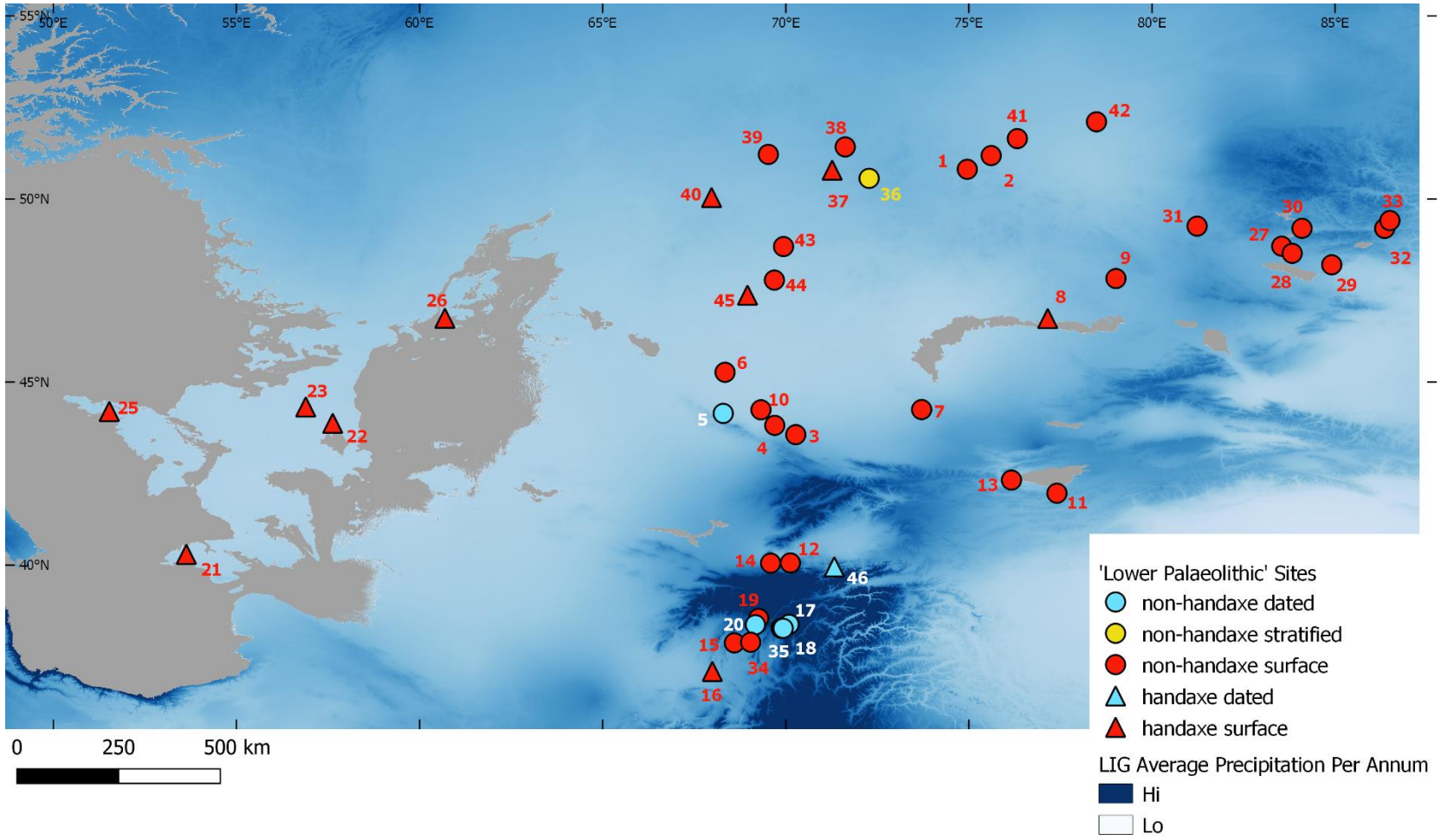

Figure 37 -Average annual precipitation, derived from Last Interglacial (LIG) climate models. The major orography of the south-east of the study region has a noticeable effect on the distribution of precipitation. This map contains site coordinate and WorldClim data, see 'Appendix 2. Spatial Data Sources' items 1 and 4 for full references.

Temperature

The map in Figure 38 shows the site distribution over the WorldClim LIG temperature data, again averaged to provide a measure of annual temperature. It can be seen how the areas near the mountains of the Pamirs, the Karatau range, the Tien Shan, and the eastern Kazakhstan/Kazakh Altai are all influenced by the proximity of these mountain features. The slow decrease in average temperature towards the north, particularly marked in the Kazakh uplands is also notable. Eastern Turkmenistan, in contrast, has a very high average annual temperature, with the area of the Ustyurt Plateau being similarly high. It is extremely difficult to ascertain what absolute values may have been at this time, but consulting estimates of recent global Pleistocene (Snyder, 2016), we might provisionally suggest that, during interglacials around the beginning of the Pleistocene temperatures may have been an average of +3.5°C warmer. By the advent of the Middle Pleistocene this would have dropped to around only +0.3°C, so very close to current temperatures. To put this in terms of the modern day temperatures discussed for the study region in the section '5.2.1 Temperature', this would have little impact on the mean temperature of the summer in Central Asia, which currently ranges from 30°C-20°C, or in the high mountains which would have been have probably remained with a mean annual temperature below 0°C. However, in some environments this difference would have had a potentially huge impact. Mean annual temperature around intra-montane lake basins in the Tien Shan might have been something like 5°C in the early Pleistocene, and closer to only 1.8°C in the Middle Pleistocene (1.5°C modern value), which may have made them much more amenable to occupation in the early Pleistocene. Some areas of Uzbekistan and Turkmenistan currently reach highs of 5°C in the winter. If this was increased to winter temperatures of 8.3°C in the early Pleistocene and

6.3°C in the Middle Pleistocene, this would also have made these tough environments much more amenable to hominin occupation during the winter.

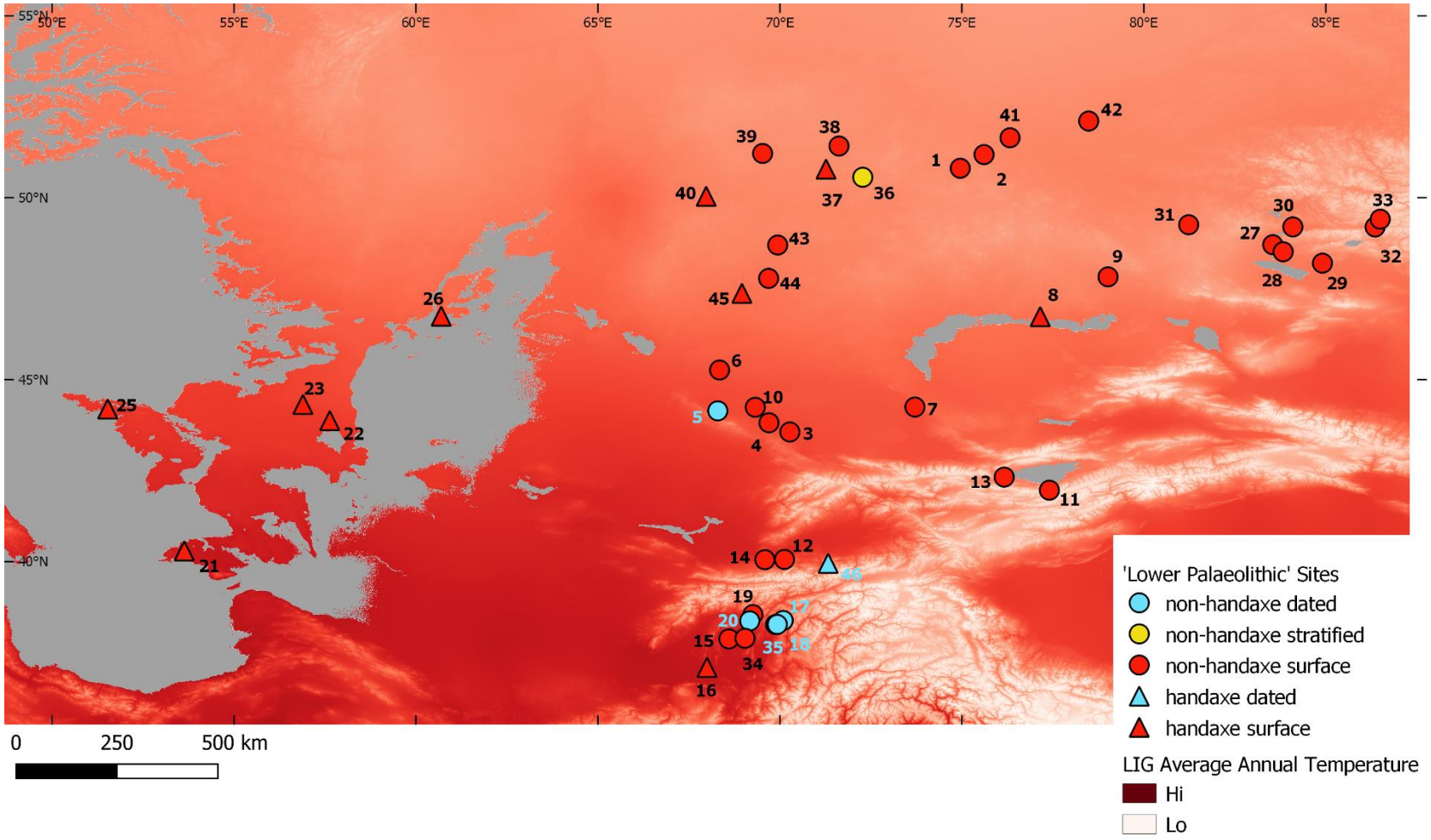

Figure 38 - Average annual temperature, derived from Last Interglacial (LIG) climate models. As with precipitation, the mountainous regions in the study region have an obvious impact on the distribution of average temperature. This map contains site coordinate and WorldClim data, see 'Appendix 2. Spatial Data Sources' items 1 and 4 for full references

7.1.2.2 Amenability Analysis Results

The resulting combined resource affordances amenability mapping in Figure 39 shows some good visual correspondence between the sites and areas of high resource affordance. In particular, modern-day Tajikistan and the surrounding area are well-represented in the amenability mapping as having high affordance values. This is the area in the study region where the majority of the stratified sites currently known are located. While this cannot be assumed to be causally related, it does at least provide circumstantial evidence for a relationship between the rich Tajik record and the possibility of a high resource availability during the Pleistocene. This mitigates to some extent the other factors that may be involved in the site distribution, such as differential preservation or differential coverage of archaeological investigation.

Perhaps surprisingly, considering their northerly position, the Kazakh Uplands rank quite highly in the amenability analysis, suggesting that they localise a lot of the resources that hominins need. The high values in this area are on a par with the loessic foothills and valleys of Tajikistan and Kyrgyzstan, and possibly the lack of dated sites in this region has led researchers to underestimate the value of this area for hominin occupation, which might rival the IAMC for resource density.

While areas immediately surrounding the mountains, show relatively high amenability values, it is interesting to note the mountainous areas themselves and major intra-montane basins (such as around lake Issyk Kul) rank very poorly in amenability score.

Several areas in the east of the study region also exhibit very high affordance values in the amenability mapping. These high values might suggest that if these areas were accessible in the Lower-Middle Pleistocene that they may also have been productive areas for hominin occupation. This corroborates some of the early sites that have been claimed for this part of the study region, and makes their proposed dates and locations seem more feasible. These

areas and sites also raise the potential of hominin dispersal into north-western China, and also suggests that these areas would comprise a part of the most likely route if such dispersals were to have occurred.

There is an anomalous area of extremely high values just around the southern tip of the Urals, in the centre-north of the study region. This area is anomalous in that, unlike all of the other areas, it has no stratified or surface sites included in the model. It is possible that this region may be too far north for occupation, although this seems unlikely when compared to some of the areas with sites in eastern Kazakhstan. It is also possible that it may be too disconnected from other areas with high affordance values to prove accessible to hominins. However, it is also very likely that one site, which has not been included in the model because coordinates or a map could not be located for it, might be around this area. The Mugodjari mountains are very close to this location, and if the surface sites reported under this name were indeed located around here, then it would provide multiple examples of Mode 2 technology. This area could be considered as a high-amenability stepping stone towards occupation in the resource-sparse western areas for Mode 2 using hominins.

Along the southern border of the study region, a large differential is apparent in the provisioning of affordance values in the amenability mapping. The eastern section of Turkmenistan along the western half of the border closest to the flooded Caspian-Aral basin registers as very low in affordances. In comparison, Tajikistan is seen to exhibit much higher affordance values, suggesting that this latter area would be much more likely to support occupation, and therefore also represents a stronger contender for an entry-point into the study region. It should be noted that the eastern half of Tajikistan, although registering high in the affordances mapping, is probably too mountainous for sustained hominin occupation, and should be only provisionally considered alongside the more westerly half of Tajikistan as a possible entry-point.

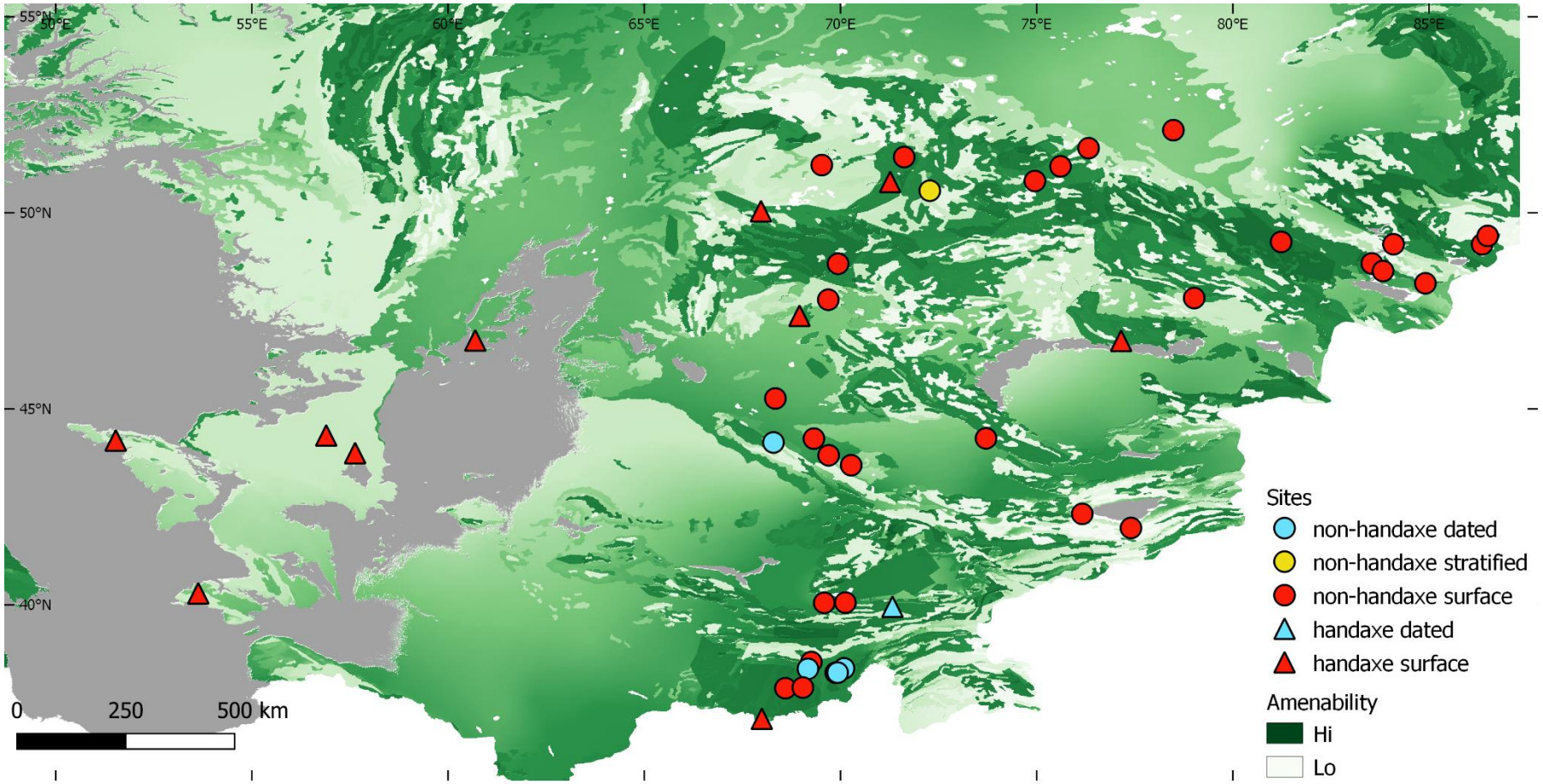

Figure 39 - Results of the amenability analysis. This surface represents the predicted availability of affordances for hominin occupation throughout the study region. A higher value represents an area high in affordances, and therefore more amenable to hominin occupation. Areas that stand out as areas of high amenability include the Tajik loess/Fergana depression area, the Kazakh uplands, and the eastern Kazakhstan/Kazakh Altai area. In contrast, the Ustyurt Plateau is seen to be extremely low in predicted amenability value. This map includes site coordinate data, and data derived from WorldClim, USGS, and the World map of carbonate outcrops, see 'Appendix 2. Spatial Data Sources' items 1, 4, 6, and 7 for full references.

Finally, the Mode 2 surface sites in the western half of the study region, on the coastline of the flooded Caspian-Aral basins, are interesting in that they emerge as grouping distinctly from the more easterly sites in the study region. The western area, largely isolated by the joining of these basins, is also extremely low in affordance values when compared to the other areas of the study region, and especially when compared with the areas immediately around the other sites in the study region. At the very least this probably signifies that these sites reference a very different pattern of occupation in their location in the landscape, and quite possibly represent a later time period than many of the easterly Mode 1 sites.

Overall the results of the amenability analysis, conducted by means of probabilistic mapping of hominin-landscape affordances, appears to indicate a good fit with the site distribution data. The table in Figure 40 ranks all of the sites in the analysis by mean amenability score taken from a 10km radius around that site. The mean of these 10km buffer values (0.306320253) is above the mean value of the overall populations of raster cells (0.289255948), suggesting that the 10km areas around each site are situated in above average areas of the amenability raster surface. The sites in Tajikistan are even higher, with a mean of 0.356241862.

In Figure 40, sites above the population mean are coloured green, and sites below are coloured blue. To demonstrate this relationship statistically, a one sample t test was used to compare the mean of the 10km site buffer areas to the mean of the overall raster population. The results of the one sample t test satisfy with a 95% (0.05 alpha) confidence that the sample of 46 sites are located in above average areas of the amenability surface, meaning that they represent a mean value higher than would be likely to be achieved in a comparable but random sample of 46 areas.

This confirms many of the observations made above. The Tajik loess and Fergana depression sites all rank above the halfway mark of the table, as do several of the sites from the eastern Kazakhstan/Kazakh Altai area. These results suggest that the resources combined to create the amenability model do in fact have an impact on site location, especially as site location was not used in the generation of the amenability surface. This is a strong indicator that the model identifies features important for hominin occupation and dispersal at this scale of analysis.

Sites	Context	Combined_buff
Camp Lake Site	surface	0.474941188
Muzbel; Obalisan	surface	0.40879967
Kuhi-Pioz	surface	0.397546789
Ak-Koshkar	surface	0.396099223
Kizyl-Kala	surface	0.391179729
Zaisan Basin 1	surface	0.388770831
Kajragach	surface	0.382742462
Sel'ungur	securely-dated	0.372178462
Khonako	securely-dated	0.361562703
Lakhuti; Obi-Mazar	securely-dated	0.35906725
Kuldara	securely-dated	0.358971468
Vishnëvka	surface	0.347572225
Volgolonovka	surface	0.343400458
Semizbugu	surface	0.334021507
Karamaidan	surface	0.330880764
Koyki-Tau	surface	0.327265047
Angrensor	surface	0.327107867
Khantau	surface	0.326119758
Karatau	securely-dated	0.323461142
Khodzha-Bakirgan	surface	0.322257847
Zaisan Basin 2	surface	0.310271417
Zaisan Basin 3	surface	0.304664725
Karatau Range Sites	surface	0.303357156
Zhaman Aibat	surface	0.300963145
Tokaly1-3; Zhanatas	surface	0.293980864
Batpak; Mizar	Stratified	0.293168048
Kazangap	surface	0.291525529
Aralsk	surface	0.289591997
Kemer	surface	0.285568425
Koshkurgan1-3; Shoktas1-3	securely-dated	0.28422377
Dzhambul	surface	0.283393251
Maraldi	surface	0.278267817

Bech-Barmak	surface	0.266396587
Kudaikol	surface	0.26511826
Yangadja	surface	0.264633734
Aidarli	surface	0.263603886
Kamenka	surface	0.262770714
Bolshoy Narym	surface	0.261759827
Esen 2	surface	0.261177265
Karakuduk	surface	0.26012871
Shakhbagata	surface	0.2360285
Kumuktepe	surface	0.2360285
Chingiz	surface	0.230989182
Taskuduk	surface	0.203300386
Berel'	surface	0.173288039
On-Archa	surface	0.112585506
Sample Mean (46 sites)		0.306320253
Population Mean (amenability surface)		0.289255947

Figure 40 -This table ranks all of the sites in the analysis by predicted amenability value, averaged in a 10km radius around each site. Rows coloured green are records above the mean value of the complete amenability surface, and rows coloured blue are records below that same mean.

7.2 Phase 2: Accessibility Analysis

7.2.1 Accessibility Analysis Methodology

The key question that structured Phase 2 of the analysis was:

What were the probabilistic routes for hominins through Central Asia?

This question was addressed using a version of accessibility analysis. Accessibility analysis refers to any form of spatial analysis that is primarily focused on assessing the ease of access of a given spatial unit from other areas. In principle, accessibility is a matter of assessing the connection of spatial units to wider spatial datasets. The technique used here is one that uses cost-distance analysis in its execution, similar to least-cost pathways, but it differs from them in a number of fundamental ways.

Accessibility in spatial analysis is often associated with studies of modern urban environments and services, and is often applied as a measure of network structure that

relies on the topological relationships between and within vector datasets. It is this kind of approach that Conolly & Lake (2006, p. 241) reference when they define 'local accessibility' as providing: "information about how readily a node may be reached from further afield." Some studies of accessibility do rely on raster datasets, and these studies use accessibility in a sense that is closer to that of the current study, by assessing the aggregate costs of accessing an individual origin point from every cell in a raster dataset.

The method used here for assessing accessibility across the region used a number of cost distance rasters produced using origin points along the southern Tajik-Afghan border. This border area has been previously highlighted as the most likely entry point into the study region, and was chosen for this reason. As with least-cost pathway analysis, the raster dataset used in this instance is referred to as a 'cost surface', where each cell is allocated a value based on the perceived cost of movement through it. In traditional analyses these costs can be based on factors such as slope and distance derived from a DEM, which are inappropriate or have an unclear relationship at the spatio-temporal scale of the current study (see '7.4 Rejected Modelling Methods: Least-Cost and Visibility' and also the next section). However, the results of the amenability assessment discussed earlier have provided an appropriate solution for a cost surface. The amenability assessment provides a raster surface where areas rich in resources are given high values, and areas poor in resources are given low values. By simply inverting this dataset, so that rich areas present low values, and areas with a paucity of resources present high values, it can be used as a cost surface that penalises movement through resource-poor areas.

7.2.1.1 Problems and Limitations of Least-Cost Pathways

Although this analysis had originally been conceived as a least-cost pathway analysis, multiple factors led to the decision to abandon least-cost pathways and to focus on a method of analysis based on accessibility instead.

Least-cost pathway analysis is by its very nature a linear form of analysis. While useful for analysing directed movement between known origin and destination points, this has the potential to render it inappropriate for situations where the direction of movement is ambiguous, or the behaviour that is being analysed represents aggregate movement with substantial time-averaging. Both of these are relevant weaknesses for the current analysis.

This time-averaged, aggregate behaviour also potentially introduces a lack of clarity on the side of the behavioural interpretation. It is not exactly clear what, behaviourally, a least-cost path would represent on the geological timescale of the current analysis. It would have to be adapted to be a more meaningful form of analysis, and with the uncertainty as to what it would map to behaviourally, it might not be the most appropriate way of understanding the data.

On top of the effects previously discussed, least-cost pathway analysis is also disproportionately affected by the differences between discrete and continuous data. In the current analysis, least-cost pathways may not be useful or meaningful due to errors introduced by the nature of discrete data, largely due to the 'step-wise' logic of the cost distance calculation. The errors introduced are similar in form to those introduced by the discrete habitat concept, as discussed earlier, in that they emerge from an artificially pronounced disparity in the dataset. These disparities do also affect the cost-distance component of accessibility analysis, but the 'step-wise' process of a least-cost pathway analysis make the latter far more susceptible to not only perpetuating the errors, but exacerbating them. Combining data types can serve to smooth out some of the errors that are introduced by discrete datasets, but they do not eliminate them entirely.

This discussion serves to illustrate the differences between least-cost pathway analysis and accessibility analysis, and in particular to highlight some of the methodological issues surrounding the former technique. The next section will consider the accessibility analysis in

more depth, and some of these themes will be further addressed in the section '7.4 Rejected Modelling Methods: Least-Cost and Visibility'. It has already been considered exactly what features of the dataset and the real world record are being measured in this situation, and also how it maps to meaningful hominin behaviour on the spatio-temporal scale of the current analysis.

7.2.1.2 Accessibility Analysis

As mentioned previously, the resultant raster from the amenability analysis, where high values accord to high resource availability, is inappropriate in its final form for cost-distance analysis. Cost-distance analysis requires a raster known as a 'cost surface', where high values represent high cost of movement, and low values represent low cost of movement. The process of inverting the values of the amenability analysis so they can be used as a cost surface is a relatively simple procedure of raster calculation.

The next step was to designate source features for the analysis. As previously argued, the current analysis proposes that the southern Tajik-Afghan border represents the most likely entry point into Central Asia during the early Pleistocene. 1000 points (the maximum number that it was possible to process given computational limitations) were distributed evenly along the length of this border, from the reconstructed Apsheronian Sea in the west to the mountains in the east. These points were used to provide source features for the analysis. Cost-distance analysis was used to calculate the distance from each of these border source points to every other cell in the cost surface raster. This analysis resulted in a separate raster surface for each border point, representing the cost of accessing each cell in the raster, calculated using the original cost surface. These separate rasters were then summed together to produce a raster that represented the cumulative accessibility across the entire study area from all of the 1000 border points. This raster could then be mapped to show the ease of accessibility of different areas of the study region, with cost based on

potential resource availability at different areas in the landscape. The results of this accessibility analysis were then applied backwards to the border source points to map the border points in terms of access to the known sites and assess the likelihood of different entry points into the study region (addressed separately in the later section '7.3 Phase 3: Entry-Point Analysis').

7.2.2 Accessibility Analysis Results

In the results of the accessibility analysis, one of the clearest patterns that emerges is the large divide in accessibility between the eastern and western sites in the study region (see Figure 41). This corroborates the overall visual impression of isolation given by the flooded basins of the Caspian and the Aral, as well as the very low scores that this region receives in the resource affordances mapping. The western sites are so isolated in the accessibility analysis that some of them come out as being less accessible from the southern border than sites in the north-east and far east of the study region, on the border with north-west China. The western half of the study region is scarce in affordances for hominin occupation and subsistence, except in the vicinity of the Mugodjari mountains, and these western sites are poorly connected in terms of accessibility to the rest of the study region due to that overall scarcity. The effect of the high resources in the Kazakh Uplands and eastern Kazakhstan can be seen in the slightly lower cost of travelling through these regions. The high affordance scores of the proposed IAMC seems also to facilitate accessibility towards the east of the study region.

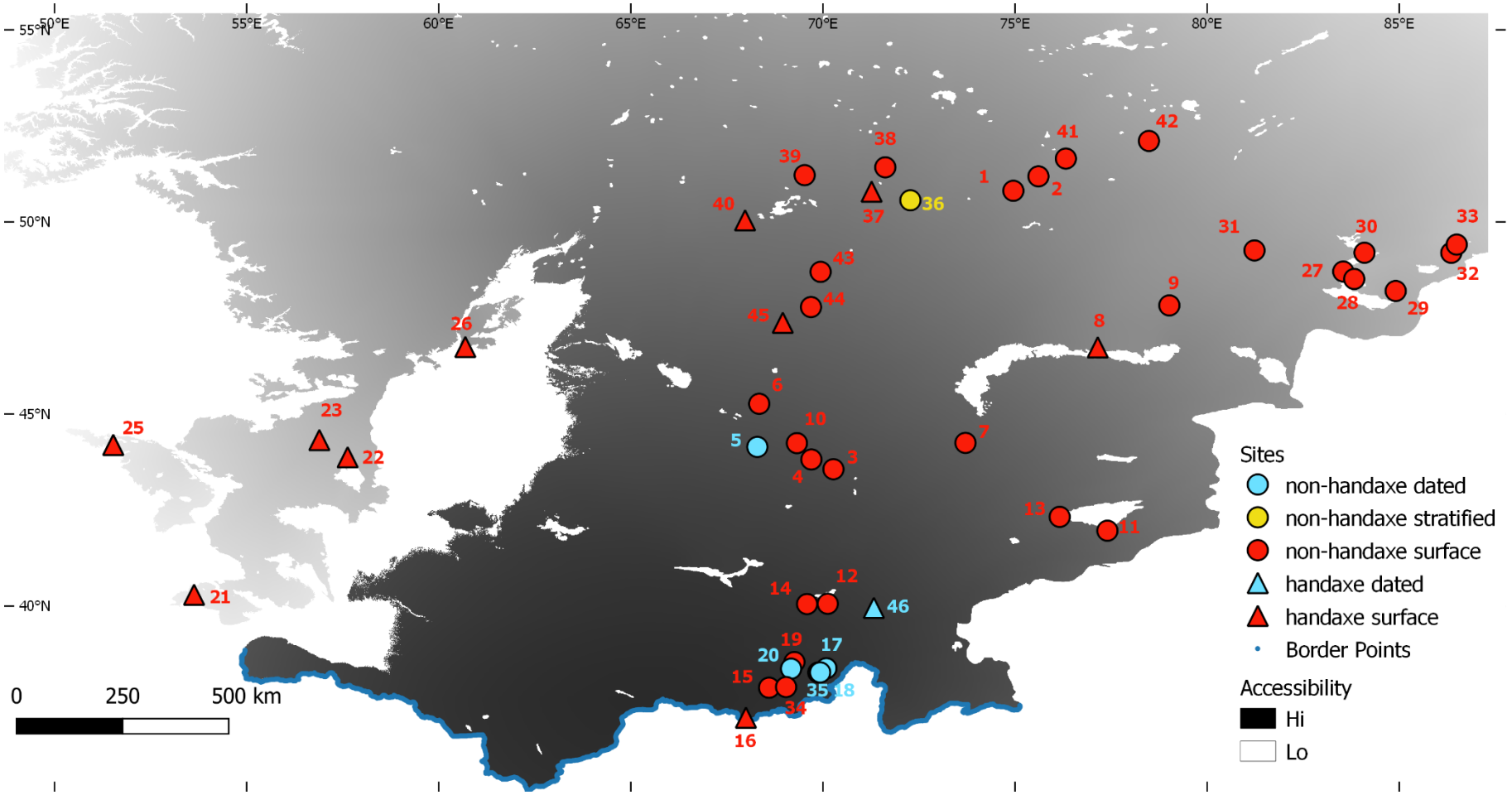

Figure 41 -This map shows the predicted accessibility surface, generated from 1000 source points along the southern border of the study region. This analysis used the amenability results from Phase 1 as a cost surface to achieve a form of accessibility analysis using cost distance based on predicted affordance values in the landscape. This map uses site coordinate data from multiple sources, see 'Appendix 2. Spatial Data Sources' item 1 for full references.

Based on histogram breaks in the accessibility values, we can define six groups of sites based on increasing accessibility cost from the southern border (see Figure 42). These groups should be thought of as increasing cost to access these locations from the southern border based on the amenability of the environments traversed in order to reach them, but it also remains possible that these groups can be interpreted as six 'phases' of dispersal based on environmental cost distance from the southern border.

Group 1 contains almost all of the dated sites from the region, based in the river valleys in the loessic foothills of Tajikistan and Kyrgyzstan, including the oldest site (Kuldara). Group 2 includes the only other dated sites, Koshkurgan and Shoktas, which lie in a more open, plains environment in close proximity to the more complex topography of the Karatau Range. A very speculative chronological interpretation would be to suggest that Group 1 represents the area occupied by hominins from *c.* 1mya, and Group 2 the area occupied by hominins from *c.* 500kya. Because of the low number of dated sites, perhaps it is most cautious to say not that the groups represent a chronological pattern of dispersal into the region, but that they at least do not contradict such a pattern. Aside from the youngest site at Sel'ungur, Groups 1 and 2 contain no Mode 2 sites.

Groups 3-6 do not contain dated sites, and are therefore difficult to interpret chronologically, except perhaps in relative terms. Group 3 includes sites at the westernmost extent of the Kazakh Uplands (4 sites), on the peripheries of the Tien Shan (1 site), within intra-montane depressions of the Tien Shan (2 sites), showing that these areas have a similar accessibility cost from the southern border, in spite of the fact that the Kazakh Upland sites in Group 3 are almost double the linear distance from the nearest southern border point than the intra-montane sites. The intra-montane areas rank poorly in the amenability surface, and the resultant increased cost to traverse these areas is what results in them being ranked in Group 3 along with the westernmost Kazakh upland sites. Two of the seven

sites in Group 3 demonstrate a mode 2 technology, and both of these are from the group of sites at the westernmost end of the Kazakh uplands. It might be cautiously suggested that mode 2 technologies may not have been necessary for hominin dispersal into the intra-montane zones.

Group 4 consists primarily of sites that span the Kazakh Uplands and the area around Lake Balkhash (10 sites). Among the Group 4 Kazakh Uplands sites, only two exhibit a Mode 2 technology, again suggesting that a Mode 1 toolkit may have been sufficient for occupying this area. From east-west, the upland sites of Group 4 span 800km, perhaps indicating that a rapid dispersal would have been possible through this resource-rich region once it was accessed. Group 4 also includes the Aralsk site north of the Aral sea, the first of the western handaxe sites. Aralsk's accessibility cost is slightly lower than the two easternmost (Camp Lake Site) and northernmost (Maraldi) upland sites in Group 4, placing it above most of the Kazakh Upland sites in terms of cost.

Group 5 contains the Mode 1 sites of the Kazakh Altai, and also two of the trans-Caspian handaxe sites, again indicating a roughly similar accessibility cost between these two regions from the southern border, in spite of a vastly different linear distance from the nearest southern border point for each. Much of this difference is necessarily due to the combined extent of the Caspian and the Aral, where this area may have been more accessible later in the Pleistocene (excluding the early Baku transgression), and it is notable that all of these western sites demonstrate a Mode 2 technology, perhaps, again, indicating that they do relate to a later Mode 2-enabled dispersal. The final group, Group 6, contains only the westernmost handaxe sites, and further underlines this pattern.

It might be suggested that, on the basis of an admittedly very small sample of dated sites, the loessic foothills and river valleys of Tajikistan and Kyrgyzstan might represent a core area of hominin occupation that spans at least *c.* 1-0.126mya. Furthermore, while hominins may

have found the transition to plains areas adjacent to foothills and mountainous regions possible by at least *c.* 500kya, and possibly with only a Mode 1 toolkit, the transition to interior uplands and intra-montane areas may have taken longer. Once in upland areas, hominin expansion may have proceeded relatively rapidly through these resource-rich areas. The progress of hominin dispersal into the more arid and open environments between the Caspian and the Aral may have been slower, and may have necessitated a Mode 2 toolkit.

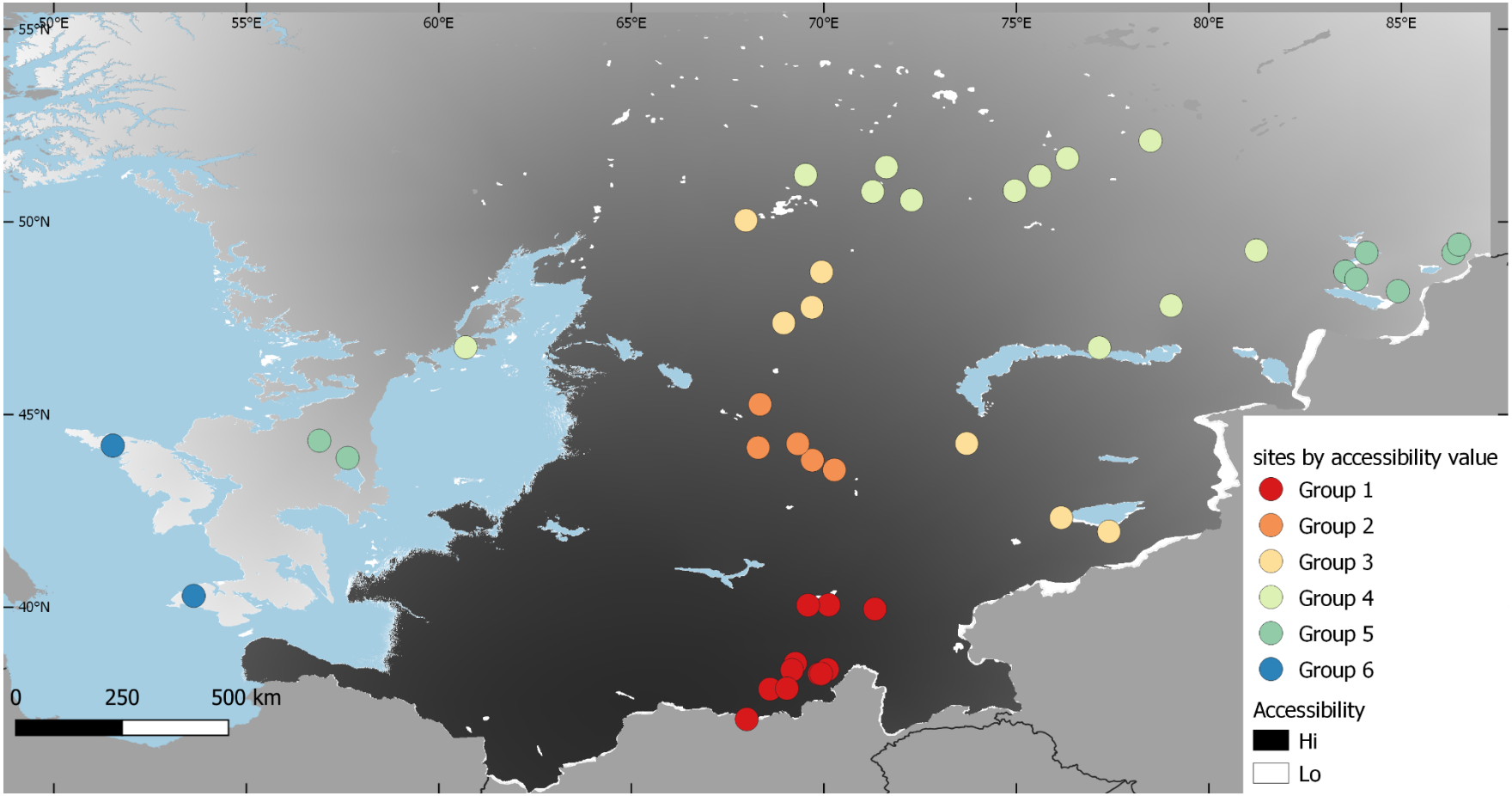

Figure 42 – Sites grouped by accessibility into six groups based on natural breaks in the histogram of accessibility score. This map uses site coordinate data from multiple sources, see 'Appendix 2. Spatial Data Sources' item 1 for full references.

7.3 Phase 3: Entry-Point Analysis

7.3.1 Entry-Point Analysis Methodology

Phase 3 of the study was structured around answering the question:

What was the most likely entry point for Lower-Middle Pleistocene hominins into Central Asia?

Using the results from the previous accessibility analysis, it was possible to map the different border source points in terms of accessibility to sites within the study region. The aim of this was to ascertain, based on the current site distribution and modelled environmental factors, where the most likely point of entry along the southern boundary of the study region would be by reversing the accessibility scores. The feasibility of this analysis is vastly increased by arguments against an early Pleistocene entry point north of the Caspian Basin (as indicated in (Holmes, 2007)), limiting the analysis to the southern border of the study region.

Effectively using the sites as destination features, it was possible to extract multiple values from the accessibility rasters to the individual border points, which could then be mean averaged for each border point. This provided each border point with a value that represented its accessibility to all of the known sites in the study region. It was then possible to identify the border point with the lowest mean value of cumulative cost, and therefore the lowest cost to access all of the sites in the study region (the highest accessibility to those sites), and also to identify the border point with the highest cost to access. It was also possible to map the border points by mean cost value, and in this way visualise the accessibility from all border points to all known sites. Such an analysis would potentially demonstrate a bias of central tendency, but the pattern visible in the results of this analysis do not appear to be overly influenced by this tendency.

7.3.2 Entry-Point Analysis Results

The results of the entry-point analysis seen in Figure 43 show that the border point with the lowest mean cost to access is very close to the middle of Tajikistan, and in close proximity to the cluster of Tajik loess Palaeolithic sites. As might be expected, the border point that shows the highest cost to access is at the western end of the southern border. It is also possible to map all of the border points by average cost, showing the distribution of cost for accessing the sites from the different border points. This highlights most of the border in western and central Tajikistan as having the lowest affordance cost for accessing the sites in the study region. This pattern in both analyses appears to outweigh the bias towards central tendency, although there may be some small influence from the irregularity of the border. The cluster of Tajik loess Palaeolithic sites no doubt influences the positions of the highest and lowest mean cost to access border points; however, it should be stressed that this is not an 'unintended consequence' of the model, but rather it is a demonstration of the relationship that this model is intended to highlight. It has been shown in the results of the amenability analysis that the sites show a demonstrated preference for above average areas on the amenability surface, and this is especially true for the Tajik loess sites. It is not unexpected that we find no sites near the western, desertified section of the southern border, and also that we find a profusion of sites in the higher amenability eastern section of the southern border.

Both of these analyses suggest several things, foremost of which is that south-western Tajikistan represents the most likely entry point for early dispersal into Central Asia based on the current available data. Although topography does not constitute a part of the cost for the accessibility analysis, most of eastern Tajikistan is probably too high altitude or mountainous for hominin occupation at this time. Of great interest, then, is the fact that the analysis highlights an area of peri-mountainous foothills between the river valleys of western Tajikistan and the mountains of eastern Tajikistan. This appears to reinforce the theory

proposed earlier that such peri-mountainous foothill zones represent a rich overlap of the resources mapped as affordances in the analyses for this project.

From this entry-point, the eastern side of the study region appears far more accessible than the western side of the study region. The western handaxe sites, again, appear very isolated and inaccessible from this entry-point. It is important to bear in mind that what is being measured and represented here is distance modified by cost. In terms of determining the most likely entry-point into Central Asia along the southern border, this area of Tajikistan in the eastern side of the southern border is suggested, both by the distribution of sites themselves, the reconstructed amenability surface, and the cost to access entry point analysis which combines both site distribution with amenability.

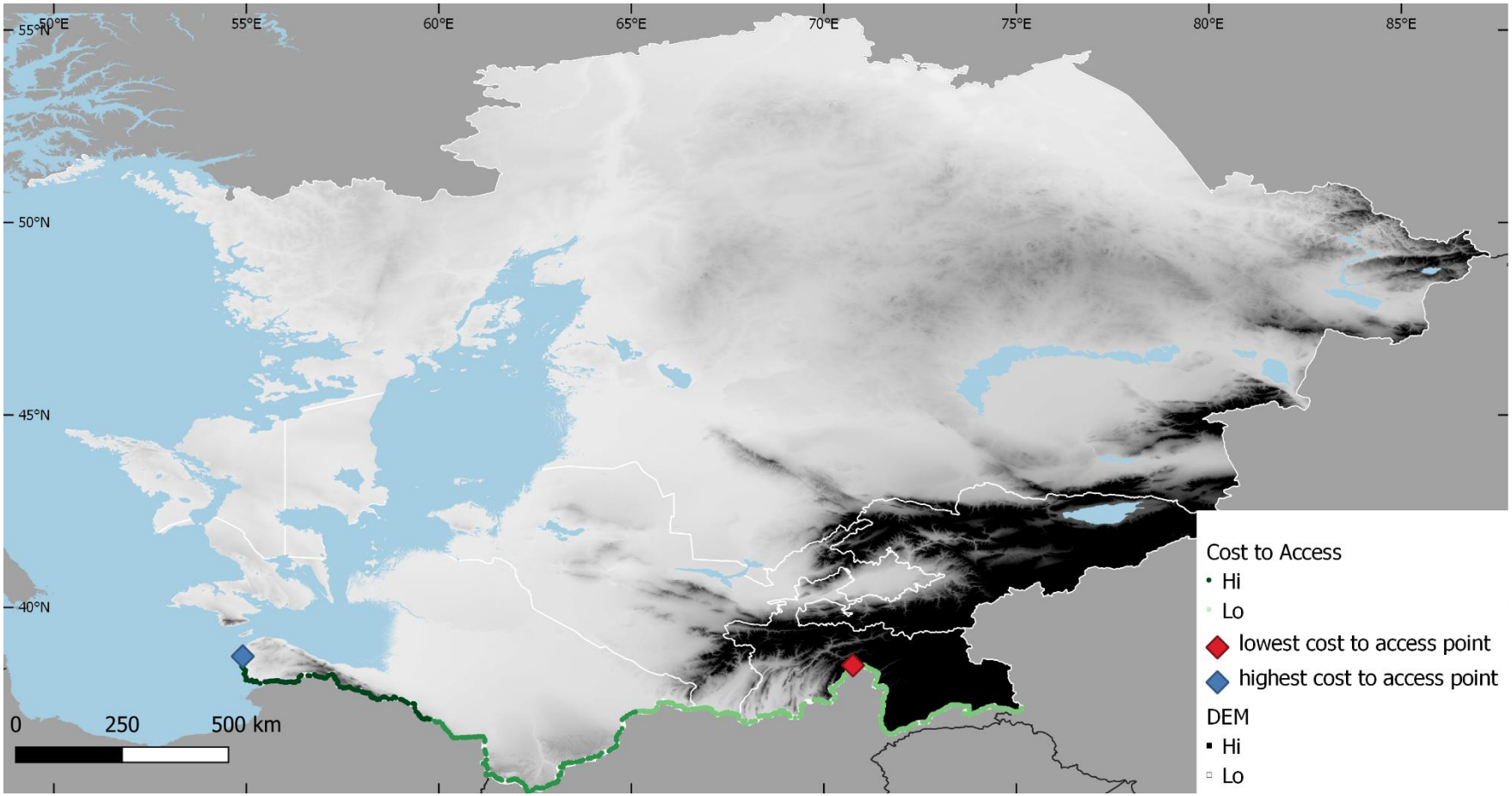

Figure 43 – This map shows the results of the entry-point analysis. Each of the 1000 border points along the southern border is coloured relative to the cost required to access all of the sites used in the analysis. The darker green the border point, the less the cost to access all of the sites, with the exception of the very lowest cost border point, which has been marked by a red diamond. The highest cost border point has been marked with a blue diamond. The results highlight western Tajikistan as a key point for possible entry into the study region. This map uses data from GADM and naturalearth.com , and data derived from SRTM data, see 'Appendix 2. Spatial Data Sources' items 2, 3, and 5 for full references.

7.4 Rejected Modelling Methods: Least-Cost and Visibility

Although topographic least-cost and visibility analyses are widely used in archaeological applications of GIS, especially in later prehistory and historical periods, there are several reasons why these analyses have been judged unsuitable for inclusion here. Resources and analyses have been included here on the basis of reasoned argument from the literature, with at least a proposed understanding of how these resources would have been meaningful for hominins at Pleistocene timescales, and what modelling results might meaningfully represent at such timescales.

Topographic least-cost analyses are commonly used and easily applied, and have even been used at continental scales for questions of Pleistocene dispersal (e.g. (Field & Lahr, 2005, Field, et al., 2007)). However, it is unclear why topographic movement cost would be meaningful at such scales. Firstly, the cell sizes of continental models is extremely large, and therefore removed from individual cost decisions made during the course of individual journeys. If one $1km^2$ cell of a landscape has a higher elevation than another, this would be judged as an increase in cost to move to that cell from a third cell of lower elevation. It seems unlikely that cost decisions are meaningful at this scale.

Topographic least-cost analyses are adapted forms of hydrological analysis, meaning that at their most basic, they assume hominin movement mirrors that of overland runoff and responds to increases in effort in similar ways. To some extent, hominins may follow or be tethered to water features, especially early in the Pleistocene, and topographic least-cost analysis might approach this pattern, but it does so for the wrong reasons. It would also have us assume that hominins avoided upland areas, and dispersed only through low-lying valleys towards the sea or inland lakes, both of which are false. Many topographic least-cost analyses also avoid modelling the increased costs of low-lying flooded areas, exactly because it is difficult to balance the cost of soil saturation against the cost of degrees of hillslope in

any simple way. Undoubtedly, we can imagine that there must be some upper limit to the altitude that hominins could occupy, as they are unlikely to have possessed the adaptations required to occupy extremely high altitude areas, but this limit is difficult to deduce from the existing record. This is also why no upper limit has been artificially added to any of the models developed here.

Visibility or viewshed analyses for continental Pleistocene models share any of the same deficits of topographic least-cost models. Once again, it is difficult to identify the sense in which visibility is intended to model something 'meaningful' in either hominin behaviour, the Pleistocene landscape, or in the interaction between the two. Visibility is liable to change dramatically for individual locations based on vegetational factors that are impossible to accurately reconstruct. It also requires much more detailed topographic information than is typical for continental scale analyses. Highly detailed topographic data is rarely used for Pleistocene analyses, because it is likewise almost impossible to reconstruct at the detailed landscape level. The growth of alluvial fans, the deposition of metres of loess and colluvium, the erosion of softer sediments away from hard fluvial deposits leaving negatives that snake across open floodplains. As soon as we step below the very generalised, coarse-scale topography necessary for continental analysis, we have to contend with substantial geomorphological change that is otherwise considered negligible at a continental scale.

Furthermore, it is not clear in what sense visibility would be meaningful for Pleistocene hominins. For instance, is it more important to be able to see over the landscape, or is it more important not to be seen? Does landscape visibility meaningfully impact the exploitation of resources over a generational timescale? Even assuming that resources might be consistently accessible and consistently visible throughout the course of the Pleistocene, do we know that hominins do not find and exploit relatively low-visibility resources over generational timescales? Visibility analysis also requires an assumed 'height' calculated for

the observer position, and we know average hominin stature is likely to change over the Pleistocene. A workaround could be arrived at by combining multiple heights of visibility to provide a 'fuzzy' visibility index, but without even a basic understanding of what visibility means in the Pleistocene such a speculative undertaking is of very limited value.

If there is no reasoned argument why a particular model provides a valuable or meaningful view of the Pleistocene record, it is inadmissible to simply include it without understanding what it attempts to model or what modelling results could meaningfully represent. For these reasons, and the more specific negatives listed above, topographic least-cost analysis and visibility analyses have been rejected for inclusion in the models presented here.

Chapter 8. Discussion: Technology, Dispersal, and Occupation in the Lower-Middle Pleistocene of Central Asia

This project used an in-depth literature approach spanning multiple disciplines to understand what is known and what can reasonably be deduced about the hominins of Lower-Middle Pleistocene Central Asia, the environments they would have been contemporary with, and to examine their relationship to those environments based on the known record. This has informed a continental-scale landscape model that was developed from a novel 'Variety of Elements' approach based on affordances. The issues addressed by these analyses impact on two related aspects of the Central Asian record and its place in the wider Palaeolithic of Asia: issues of stone tool technological behaviour and change, and issues of dispersal and occupation.

8.1 Stone Tool Technology in Central Asia

The role of technology in the dispersal into and occupation of Central Asia during the Lower-Middle Pleistocene is complicated by the partial chronology and lack of overall coverage in the region. Only the area around the Tajik Loess Palaeolithic sites is really rich enough to provide a relatively detailed sequence of technologies, allowing the definition of the Karatau Pebble Culture in that region.

8.1.1 Mode 1 Technology and The Karatau Pebble Culture

In Chapter 2 it was highlighted that the majority of dated Lower-Middle Pleistocene sites in Central Asia can be classified as Mode 1 core and flake assemblages. In Chapter 3, it was established that Mode 1 technologies are widespread in Lower Pleistocene Asia. The predominance of Mode 1, especially in this early period, is not surprising, but several aspects of this technology provide interesting points for discussion in relation to the current analyses.

The Mode 1 technologies found throughout Central Asia are most easily understood in relation to the Tajik loess sites and their Karatau Pebble Culture, because the sites from this area form the only relatively complete chronology for the region. This area is especially important if, as suggested by the accessibility analysis, it seems likely to have provided a consistent 'core area' of hominin occupation throughout the Pleistocene, and possibly also the most likely point of entry for early hominins. The identification of western Tajikistan as the most likely entry point into Central Asia does support the use of this detailed record as a key to understanding the wider Central Asian record. At the very least, it can inform us to some extent of the technological behaviours and skills such hominins are likely to have possessed, and these seem to agree broadly with those we see in neighbouring Georgia and China during the Lower Pleistocene. However, the lack of a detailed chronology elsewhere in Central Asia hampers any definite understanding of how core and flake technologies may vary either temporally or spatially. What we can say is that the techniques of pebble-working in evidence at the Central Asian sites run the full period of the Lower-Middle Pleistocene, and that surface sites also suggest that this technology may have been prevalent over most of the study region. The exception to this is perhaps in the isolated, desertified west.

It has been suggested here that many of the distinctive features of the Mode 1 assemblages in Central Asia may relate to raw material factors. More specifically, it is the regular reduction of pebbles, and also the harder to work igneous and metamorphic materials, which probably result in behavioural techniques that are used to maximise simple cutting edges from pebble clasts, widespread throughout Asia almost a million years before the earliest site in Central Asia. It was seen from the raw materials mapping in the section '7.1.2.1 Individual Resource Distribution', that Mode 1 assemblages in the region are all located within areas of relatively higher raw material diversity. This fits well with the idea that this is a simple but adaptable technology, which can be modified and applied in a variety of environmental situations and on a range of raw materials. In terms of technology

and raw material availability alone, there seems to be no obvious reason that hominins could not be expected to occupy at least the southern portions of Central Asia prior to the current age of Kuldara. Harder to explore is how the relationship between the technology and the contingencies of adaptation in the landscape may develop over time.

Perhaps it is the widespread use in Central Asia of bipolar percussion methods of knapping cores on anvils, especially pebbles and cobbles, that provides the key to why Mode 1 technologies in Central Asia can be adaptable on a wide range of raw materials. These bipolar techniques are also well known in the records of the regions neighbouring Central Asia. Across all regions it seems to be an adaptation for expedient flaking of poor quality raw material on awkward or small clasts, requiring minimal skill. It also provides an interesting connection between the Central Asian and the Chinese record, due to its noticeable absence from the Lower-Middle Pleistocene South Asian context. Bipolar core reduction is known from the Indian record, but only in a Late Pleistocene context where it is identified as a Middle Palaeolithic technology (Petraglia, et al., 2007, p. 115, Clarkson, et al., 2012, p. 169, Blinkhorn, et al., 2013, Jones & Pal, 2009, p. 337). The chopper industry in the Siwaliks of Northern India may be associated with a bipolar reduction technique, but there are no secure dates for this, and the technology is interpreted as Middle Palaeolithic (Chauhan, 2007, p. 416). Specifically Chauhan (2007, p. 435) rejects any similarity to older Mode 1 assemblages from Pakistan, Central Asia, or China. Although there is certainly an important raw material factor in the use of bipolar techniques in China and Central Asia, the use of bipolar in Middle Palaeolithic industries in India suggests that some of the raw material factors that provide the impetus for the use of such a technique might also exist there at this time.

Another interesting connection between the Mode 1 assemblages of Central Asia and China, is the development of Lower Palaeolithic ‘microlithic’ or ‘small flake’ industries. In the

Central Asian and Chinese record, this can be seen as a behavioural tactic that represents an intensification of raw material reduction, which is also associated with the use of bipolar core reduction. This may imply a periodic connection between these populations, but alternatively, these technological similarities could be seen as an example of convergence, as autochthonous developments of a simple technology, mitigating some of the restrictions of difficult raw materials. Nonetheless, it is interesting to consider that they might represent similar adaptations to raw material, an intensification of raw material exploitation, in similarly challenging high-latitude environments.

8.1.2 Mode 2 in Central Asia and the Movius Line

LCTs are present in Central Asia from a variety of surface locations, but are still rare overall in the region. The fact that the majority of LCTs are from surface assemblages makes them particularly problematic, as it becomes almost impossible to say anything concrete about the dating of this technology, or how it interacts with the comparatively better-dated Mode 1 technologies. Although LCTs are known from the Caucasus *c.* 800-600kya, and from East Asia *c.* 400kya, a lack of dating for the Iranian assemblages (and complete absence of evidence from Afghanistan) south of Central Asia compounds our difficulties in arriving at a reasonable chronology for Mode 2 in the region. The biface and cleavers at Sel'ungur may represent the only stratified Mode 2 technology in Central Asia, but they arrive extremely late in the chronology compared to other areas of Asia. Whether the biface at Sel'ungur constitutes a 'true handaxe' is probably irrelevant. Such a distinction is dubious at its most basic level, as it also appears to confuse the discussion around LCTs and the Movius Line in East Asia (see '3.4.4 Large Cutting Tools in China').

The presence of LCTs in Central Asia, even in a surface context, shows the fallacy of the Movius Line in its *sensu stricto* formulation. The replacement of this 'monothetic' approach by a 'polythetic' *sensu lato* approach based on frequency and density is no less problematic

(Dennell, 2016, p. 17). To some extent, the problem is inherent within the definition of Mode 2 technologies as predicated on the absence or presence of bifaces, which has a unique dimension for surface sites where LCTs are likely to be concentrated in aggregate, time-averaged assemblages and more easily identified during survey. In China, as in Central Asia, there are numerous LCTs in a surface context, but only a few stratified examples. The only occasional appearance of LCTs in the sequences of China and Central Asia suggest that these tools are in fact used less frequently in time than Mode 1 technologies, but appear prominently in surface collections. It is therefore appropriate to suggest that Mode 1 surface assemblages without LCTs in Central Asia (as well as China) demonstrate that Mode 1 technologies without LCTs remain an important behavioural component of hominin adaptation throughout the Lower-Middle Pleistocene. This agrees with the known chronology of the Tajik loess Palaeolithic, and also raises interesting questions about the western half of the study region, where no Mode 1 assemblages without LCTs have yet been identified. Ultimately, rather than adding explanatory value, the Movius Line concept instead acts to obscure "…the diversity and richness of hominid behaviours at local scales" (Li, et al., 2014a). LCT frequency varies widely throughout Asian Pleistocene assemblages, and in no small part may be due to functional or behavioural issues, and especially to the fact that behaviour is distributed across the landscape. Even a discrete assemblage cannot be viewed in isolation, because it represents one facet of a spatially-distributed behavioural system.

The analyses presented here suggest that we can think of at least two groups of Mode 2 assemblages in Central Asia, those which overlap with the eastern extent of the Mode 1 assemblages in the study region (and therefore may share their relationship to geological and raw material diversity), and those that exist in the western, desertified extreme of the study region. However, whether this pattern should be considered to be chiefly a chronological or a behavioural pattern is more difficult to ascertain. If the earliest Mode 2

assemblages of the Caucasus do coincide with the early Baku transgression of the Caspian and Aral, then this represents the earliest point at which Mode 2 technologies would have been present in the neighbouring regions of Central Asia, and therefore available to be brought in by dispersing hominin populations. If hominins using a Mode 2 technology entered into Central Asia at this time, they would have found the Caspian and Aral joined together, as in the Apsheronian, blocking their route into trans-Caspia, and reinforcing the isolation of the western half of the study region, as observed in the results of the accessibility analysis. The isolation of the western handaxe sites in Central Asia seems to be a genuine pattern, and may relate to the use of this technology in dispersing into and occupying the resource-poor western lowlands, which rank very low in the amenability analysis

It is difficult to say for certain whether Mode 2 technologies enable dispersal into areas of sparser resources in the west of the study region, because the hominins of the Middle Pleistocene are different to the earliest Mode 1 using hominins in a whole constellation of inter-related physiological and behavioural traits. The continuity of Mode 1 technologies throughout the Lower-Middle Pleistocene in the south, however, suggest that the undated examples of Mode 1 and Mode 2 technologies in a surface context in the eastern and northern areas of the study region may be the result of a coexistence of these technologies over some period of time. There is no reason to expect pebble and bipolar core and flake technologies not to continue contemporaneously with Mode 2 technologies in the region, as is the case in the Chinese record. In spite of this overlap in eastern and northern areas of the study region, it is Mode 2 technologies that dominate in the western half of the study region, which does also imply that it is Mode 2 technology using hominins who could occupy this area, whether it is the technology itself or a constellation of traits that enables it. It can only be provisionally suggested that Mode 2 technologies arrived late into Central Asia, possibly during the Middle Pleistocene, and to speculate that they may have enabled

occupation in the more extreme environments where we do not find Mode 1 assemblages without LCTs, such as the west of the study region.

8.2 Occupation & Dispersal: Northern Routes, Tectonic Mountain Corridors, and Savannahstan

Issues of reconstructing hominin occupation and dispersal in Central Asia have formed a large part of the focus of this project, and the process of examining these issues has involved consideration of a number of models and hypotheses. Dispersal has been defined here as a large-scale, aggregate process, emerging from the continuous process of hominin occupation of amenable environments over time. In trying to understand the factors that are most central to this occupation, this project has drawn on a wide range of literature, and considered in depth the environments that hominins were likely to face in Central Asia during the Lower-Middle Pleistocene. The amenability analysis captures a hominin-centred view of these environments. In terms of dispersal, the project has specifically focused on the viability of a Lower Pleistocene 'Northern Route' model, but has also looked at the feasibility of primarily environmentally-driven models such as Savannahstan. The Complex Topography Hypothesis has independently suggested a number of the key contentions of the Variety of Elements approach that has been adopted here to structure these analyses. The Variability Selection Hypothesis has also been drawn on to highlight the possibility that these areas at the northerly extent of the hominin range may have provided especially creative areas in evolutionary and adaptive terms. All of these models overlap to some degree in their consideration of the nature and driving mechanisms of hominin dispersal, and provide opportunities to consider these issues specifically in relation to the Central Asian record. The results of the analyses presented here allow a furthering of the discussion of the nature of hominin occupation and dispersal in Lower-Middle Pleistocene Central Asia.

8.2.2 Occupation in Lower-Middle Pleistocene Central Asia

It has been argued here that, in spite of the relatively late date of the earliest Lower Pleistocene site in Central Asia, the opportunity existed for hominins to have dispersed into and occupied areas within Central Asia from the beginning of the Pleistocene. These earliest hominins were likely to have been small-bodied and small-brained, akin to the Dmanisi hominins (see Figure 44). They are likely to have utilised a simple and adaptable Mode 1 technology that especially included the production of simple flakes from pebbles and cobbles using bipolar percussion on an anvil. It has been suggested that their group sizes might have been smaller than Middle Pleistocene hominins, and that they may have been capable only of hunting small game and scavenging the kills and leftovers of specialised carnivores. Evidence from Dmanisi and the Nihewan basin suggests that early Pleistocene hominins were targeting the rich resources of woodland and wetland areas, and possibly some of the resources of nearby grasslands. It seems most likely that the early hominins of Central Asia would therefore have been attracted to the extremely rich foothill and valley environments of Tajikistan, where they would have had access to fruit, flowers, seeds, and nuts. The results of the present analyses suggest that this area would also have provided their most likely entry point into the study region. Through repeated reoccupation, dispersal would tend to be through these foothill zones over time, the IAMC, while expansion into the exposed grasslands and open environments is likely to have taken longer.

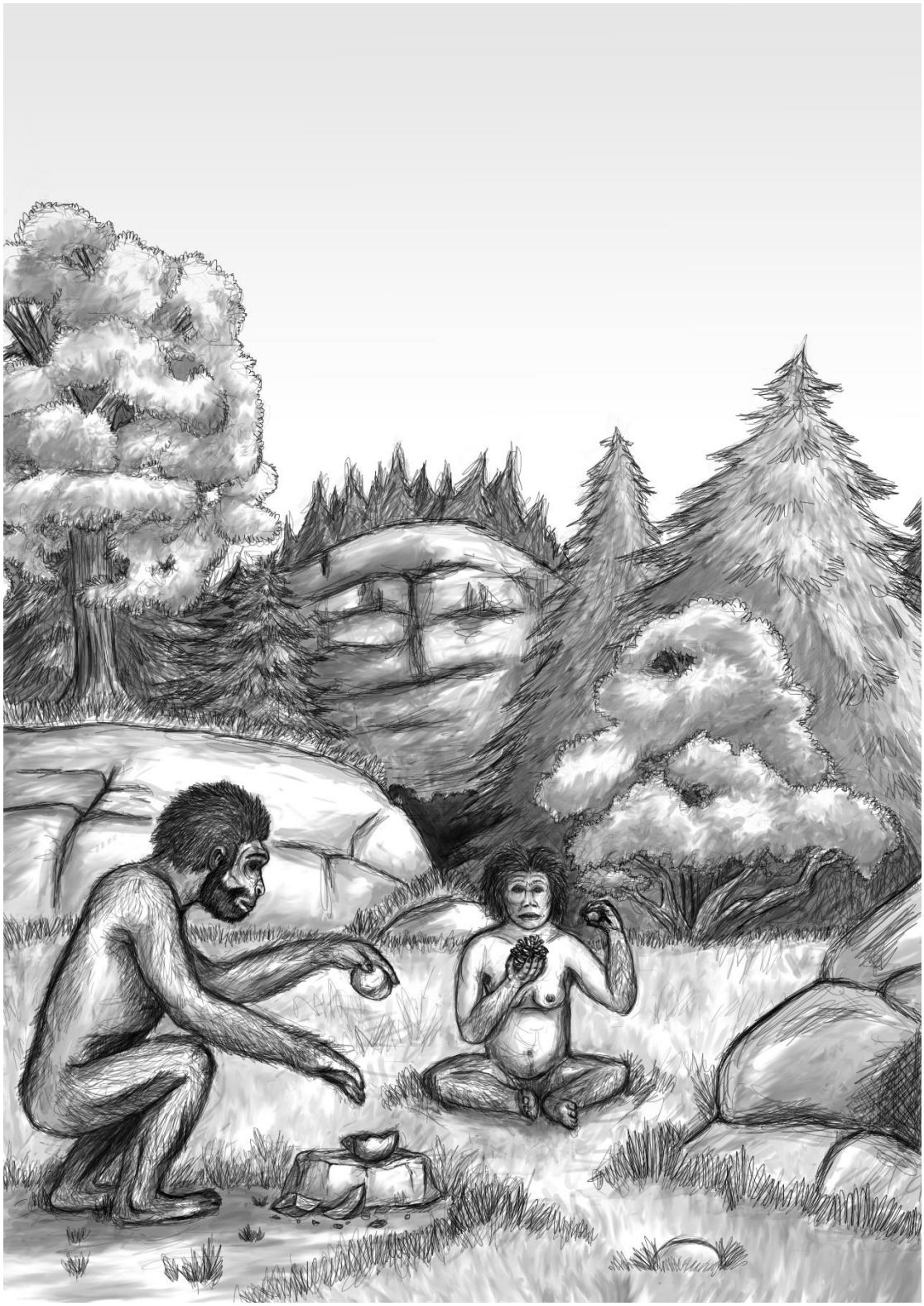

Figure 44 - The earliest occupants of Central Asia are likely to have been small-bodied hominins using a Mode 1 technology. In this interpretive reconstuction, two hominins take advantage of the sheltered environment provided by the wooded foothills in order to knap with a bipolar percussion method, and process pine cones for seeds to eat. ©William Snyder 2020, used with permission under a creative commons (CC) license.

Their simple technology does not appear to have provided a limit on their ability to occupy other environments of Central Asia, as the same technology is found in intra-montane basins of the Tien Shan, across vast areas of the Kazakh Uplands, and far into the north and east, in the environmentally-rich but cold areas of the Kazakh Altai. Occupation of these environments is likely to have taken some time from the first occupations in the south, and perhaps it could be suggested rather that it is the development of behavioural adaptations to the harsher, more exposed conditions of open environments that provides the primary obstacle to be overcome in the slow development of occupation in these regions, rather than the development of technology. Larger-bodied Middle Pleistocene hominins are likely to have been more capable than earlier hominins in these kinds of environments, able to range over larger distances, making better use of the sparsely-distributed resources, and possible hunting their own prey (see Figure 45).

It is difficult to know how the conditions of occupation may have differed between glacials and interglacials throughout the Pleistocene, even as it is possible to identify the generally deteriorating conditions over this timespan. The rich foothills of the IAMC do seem likely to have provided *refugia*, core areas of occupation from which hominins could begin to reoccupy other areas following the end of a glacial epoch. We should, however, stress a key distinction between these foothill zones and the intra-montane basins, which are much less amenable to occupation due to the paucity of resources coupled with punishingly low glacial and winter temperatures. From the perspective of sheltered and rocky places, it is also interesting to note that cave occupation from Central Asia has only been dated at the youngest site considered here, and perhaps caves and the areas around them in Central Asia did not provide an attractive enough environment for earlier hominins. However, I can say from my own experience surveying in the study region that Pleistocene deposits in caves in

Kazakhstan, at least, are extremely rare, and a lack of research on this topic may underlie the lack of evidence for cave occupation during the Lower-Middle Pleistocene. We might consider the travertine sites to be intermediary between foothill and open environments, but because of the age ranges provided for these sites, we do not necessarily know how occupation would have been split between interglacials or glacials. They may have provided a regular fixture for hominin land-use strategies in both glacial and interglacial conditions, and perhaps hominins were present during even harsh glacial periods. Their populations could have been extremely low, or their land-use patterns extremely widespread, both of which could be suggested as possible responses to these harsh environmental conditions. Or perhaps they were mostly occupied during interglacials, and not amenable at all during harsh climatic downturns. The change in open landscapes between glacials and interglacials is likely to have been the most extreme in the study region, and it seems probable that even Middle Pleistocene hominins would have struggled to occupy these areas in the deteriorating environment following the MPT.

We must assume that hominins were highly mobile and had complex, distributed networks of land-use across resources in several kinds of environments. The archaeological evidence is not such that we can fully reconstruct these, however, it has been possible to deduce some basic parameters. These have been outlined in the literature of Lower-Middle Pleistocene Central Asia and neighbouring regions, and supplemented and extended by the analyses presented in the present study. It has been possible to outline some basic expectations for hominin occupation in this period, and to discuss how these may have changed throughout the Lower-Middle Pleistocene, and further to that, consider how these relate to issues of long-term dispersal in the region.

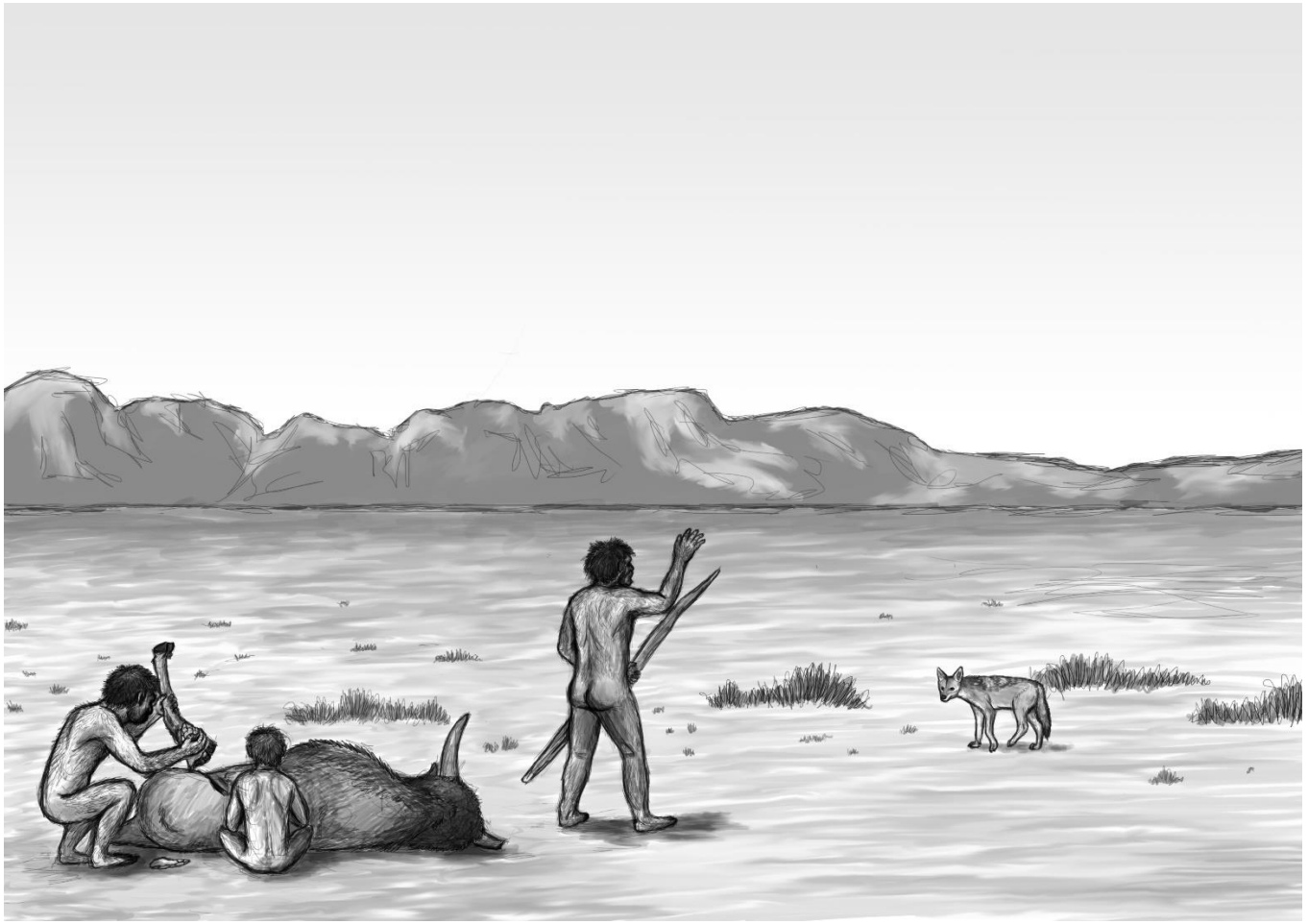

Figure 45 – Larger-bodied hominins of the Middle Pleistocene might have been better able to withstand the pressures of open environments with sparse resources. In this interpretive reconstruction, a group of hominins butcher a juvenile bison with large core tools, which they may have hunted themselves or acquired by driving off carnivores from a kill. A jackal circles the kill, hoping for leftovers. ©William Snyder 2020, used with permission under a creative commons (CC) license.

8.2.1 Dispersal: Northern Routes, Tectonic Mountain Corridors, and Savannahstan

The viability of the 'Northern Route', with which this project began, is contingent on whether hominins could have occupied latitudes as far north as would be required to allow dispersal between Central Asia and China, and whether the resources present would make such an occupation viable in Central Asia. The most northerly extent required for dispersal through the Northern Route is slightly further north than the most northerly occupation known in the Lower Pleistocene of the Asian record. Middle Pleistocene occupation in Central Asia is known as far north as 44°N, and this is the same latitude that occupation is known from in the Lower Pleistocene at Dmanisi. Access to east Asia would have required hominin occupation of areas up to and around 48°N, slightly higher than either of these. Temperature is likely to have been the main environmental factor limiting high-altitude occupation at this time. Temperature was used as a factor in the resource affordances analysis, and despite decreasing average temperatures between 44°N-48°N, the areas of eastern Kazakhstan that border China still emerge from the analysis as areas high in resources. If a barrier exists to dispersal between Central Asia and China, it is likely that this barrier exists in the desertified regions on the Chinese side of this border and the difficulty of occupying inter-montane basins, rather than in a lack of attractive environments on the Central Asian side. However, the opportunity for dispersal between these regions is even further reduced when it is considered that many of these easterly and northerly areas of Central Asia are likely to have gone unoccupied during glacial periods due to sub-zero, freezing winters. Ultimately, it seems that it was possible for hominins to occupy many areas of Central Asia, sometimes probably even up to the altitudes and into the areas necessary for possible access to the Chinese border. However, the actual opportunities for dispersal across this border seem to be so limited that it perhaps doesn't make sense to refer to

Central Asia as a northern 'route' to East Asia. Rather it appears to represent another extreme high-latitude area, analogous to the situation in northern China.

Further to this, the Variability Selection Hypothesis has also suggested an important role for high-latitude adaptation during this period. Although the Variability Selection Hypothesis sought originally to explain the impact of climatic fluctuations on hominin evolution in Africa, many of the features it describes appear to be relevant to the high-latitude Asian environment in the Lower-Middle Pleistocene. China and Central Asia might be seen as creative regions of variability and repeated reoccupation and adaptation, as both are high-latitude areas where climatic fluctuations would have had a pronounced impact on local populations of hominins. However, this needs to be balanced against the very real possibility that the diverse microclimates of the IAMC would have played a dynamic role in relation to these processes, offering areas *refugia* during periods of climatic deterioration.

The Savannah Hypothesis, in the form of 'Savannahstan', can also be reassessed based on the results of these analyses. It has been argued that the use of grasslands in theories of hominin evolution and dispersal should be tempered with a more nuanced approach, acknowledging that the discussion is not one of habitat alone. More recently, authors have come to acknowledge the important role that other environments and resources play in hominin lifeways during the early Pleistocene, with grasslands and open environments representing only one facet of an adaptive system of landscape use. Once broken down into an individual variety of elements, the homogeneous grasslands of 'Savannahstan' are seen to provide too simplistic a view of hominin occupation. The results of the amenability analysis in Central Asia demonstrate that the picture is far more complex than the expansion and contraction of a largescale biome or discrete habitat. The amenability analysis shows that not all grasslands are equal. In fact, in an area with a continental climate such as Central Asia, the most homogenous lowland environments appear the least rich in resource

affordances and amenability to occupation. The areas that have previously been identified as peri-montainous foothills, and to a lesser extent the 'broken' uplands, appear to concentrate resources and provide a heterogeneous mix of hominin-environment affordances. Grasslands alone are poor determinants of good environments amenable to hominin occupation. Rather, a combination of geological, hydrological, and climate variables have here been shown to be more important.

The concept of the 'tectonic trail' or the 'complex topography hypothesis' was also introduced in 'Chapter 4. Hominin Dispersal and Occupation in the Lower Pleistocene'. It has been argued that this concept is commensurable with the Variety of Elements approach put forward in this analysis, and the amenability analysis has served to reinforce this argument. By mapping those resources independent of King & Bailey's 'roughness index' this study has supported their hypothesis that topographically complex areas localise resources.

Hominin populations at the northernmost extent of their range in Eurasia may have been subject to a number of environmental and geographical factors that could have fed back into their evolutionary and adaptive systems in a variety of ways. Broadly east-west movement seems likely through most of the study region, with perhaps limited, slow dispersal into the harshest and more peripheral environments of the study region. Perhaps at some points during the Pleistocene, hominin populations could have moved between the modern territories of Central Asia and China, but the opportunities for this appear to have been few, and of limited duration.

Chapter 9. Conclusion

The present study has taken a landscape-based approach to the problem of hominin dispersal and occupation in Central Asia. It has provided a broad synthesis of the Central Asian Lower-Middle Pleistocene record, including its major themes and problems, and situated this within the broader context of its neighbouring regions. A series of spatial analyses address three major questions relating to hominin dispersal and occupation in the region. The results of these analyses have contributed new data for dispersal discussions, and enabled a re-examination of the of Central Asian record, and now provide also a framework for future study.

At the beginning of this project, the three key questions used to structure the approach to the Lower-Middle Pleistocene Central Asian record were as follows:

1. Was Central Asia habitable during the Lower-Middle Pleistocene?
2. What were the most likely hominin dispersal trajectories through Central Asia?
3. What was the most likely entry point for Lower-Middle Pleistocene hominins into Central Asia?

Answering these questions has required a broad approach covering a wide range of theoretical, archaeological, and geospatial literature and methods. These analyses have been able to provide a much more detailed examination of occupation and dispersal in Lower-Middle Pleistocene Central Asia than has previously been possible. In the process of answering these questions, this thesis has examined a number of different topics related to the Central Asian Lower-Middle Pleistocene record. In particular, it has discussed and presented a synthesis of Central Asian Lower Palaeolithic archaeology that is the most complete so far compiled in English. It has also placed the Central Asian record in a much wider context through a lengthy examination of the archaeology of neighbouring regions and how these records relate to the Central Asian record.

Sites in the study region are highly concentrated, many are undated or undatable, and only the area of the Tajik loess Palaeolithic provides enough dated sites for a reasonably detailed chronology. The very general technological features of Central Asian Mode 1 technologies, and the widespread distribution of similar technologies in Asia throughout the Lower-Middle Pleistocene preclude the need for an 'origin point' for these industries, and cannot help us to narrow down an entry point on that basis alone. Techno-typological arguments for the earliest industries are untenable, and the technology appears everywhere in Central Asia where sufficiently diverse raw materials are available. The result is that Mode 1 technologies seem to have proven sufficient for hominins to occupy most areas of Central Asia, with the possible exception of the western deserts. A lack of dated Mode 2 technologies means that it is difficult to determine when and how these technologies may have been brought into the region, and Central Asia has previously been placed on the non-handaxe side of the Movius Line. Neighbouring regions such as Iran provide a similar condition. Although the only dated Mode 2 site in Central Asia at Sel'ungur suggests a late advent of Mode 2 technology, finds from the Caucasus and China suggest the presence of Mode 2 technologies in the surrounding areas of Asia around the beginning of the Middle Pleistocene. These technologies are unknown from the easternmost extent of Central Asia, but are found alongside Mode 1 assemblages in areas of diverse raw materials in the south and centre, and in the affordance-sparse environments of the west. We must conclude that, if a pattern exists within Central Asia in the opposition of Mode 1 and Mode 2 technologies, then it may relate to raw material availability, or to the subsistence strategy that underpins the use of particular technologies in the landscape.

This study has also proposed and demonstrated the utility of a novel 'Variety of Elements' approach. This approach was defined on the basis of Finlayson's (2014) arguments that a "variety of elements", i.e. resources in a landscape, is a truer representation of the factors affecting hominin occupation than discrete habitats alone. This approach was set in contrast

to the mosaic environment concept or Savannah Hypothesis, and it was shown how this novel approach could, in combination with the concepts of affordances and taskscapes, be used to inform a geospatial methodology with implications for how we discuss and understand hominin dispersal. The current study has identified and mapped key resource affordances ('amenability') as environmental proxies through Central Asia during the Lower-Middle Pleistocene, providing a predictive model for more detailed resource mapping at continental scales during the Pleistocene. It has highlighted especially the importance of raw material mapping studies, which are rarely done over an entire landscape, and tend instead towards a site-centred approach. It has also highlighted the importance of water resources in hominin evolution. In the process of modelling resources, this study has also supported many of the resource-based proposals associated with the Complex Topography Hypothesis.

On the basis of mapped amenability, which has combined geological, hydrological, and climate factors from a hominin-centred affordances perspective, the richest and most diverse environments for hominin affordances seem to have followed areas peripheral to the mountains, the IAMC. The location of the sites, which was not used in the production of the amenability surface, agrees with this assessment, in that known sites are located in areas of above average environmental richness in the surface. Even with declining temperatures into the north of the study region, the high amenability score of the north-eastern area from the Tien Shan up to the Altai indicates that hominin occupation during the Lower-Middle Pleistocene may have been possible here. This adds an extra line of evidence to bolster the claims for an early Mode 1 technology in the Zaisan Basin, and the possibility of dispersal into East Asia via a 'Northern Route'. This must be set against the likelihood that this was a very challenging environment during glacial periods, and also that the attractive environments on the Central Asian side of the border may not be mirrored with equally attractive environments on the Chinese side. We can conclude that these areas of the IAMC,

and to a lesser extent some areas of the Kazakh Uplands, were comparatively richer in resources than the lowland and plains areas during the Lower-Middle Pleistocene.

On account of this richness, they are likely to have provided a core area of hominin occupation and also the earliest entry point into the study region. Dispersal is likely to have followed these rich areas through the study region, even providing *refugia* during glacial periods. The accessibility analysis has shown how this comparative richness, and the obstacle provided by the repeated transgressions of the Caspian and Aral seas, is likely to have affected hominin dispersal into Central Asia. From the current analysis, we can conclude that the area of the IAMC and the Kazakh Uplands are likely to have been occupied earlier than the area of Ustyurt Plateau, from at least 500kya. Areas of the Zaisan Basin and Ustyurt Plateau are likely to have taken longer. The Kazkh Upland sites in particular are roughly as accessible as some of the intra-montane basin sites, in spite of being approximately twice the linear distance from the nearest southern border point. This is a demonstration of how the richness of the Uplands are likely to have facilitated movement through them, while intra-montane environments may have been surprisingly difficult to penetrate in comparison. Turning this accessibility analysis around in the entry-point analysis, it can be concluded that southwestern Tajikistan provides the most likely early entry point, in terms of both amenability richness and accessibility to the sites within study region.

These analyses agree with the Complex Topography Hypothesis and suggests that Finlayson's 'Variety of Elements' is perhaps more important in understanding early hominin occupation and dispersal than any possible role played by the 'discrete' habitats of open environments, as in the Savannah Hypothesis and adapted versions of the theory such as Savannahstan. Considering both technology and environment, we can conclude from these analyses that hominin dispersal into and occupation of Central Asia is likely to have

happened much earlier than the current oldest site in the region. The vastness of the region, the limited amount of study, and the opposition between deflated areas and areas of net deposition, are all likely to have contributed to the lack of datable Lower-Middle Pleistocene finds. These analyses suggest that further research focused on the area of the IAMC, and perhaps also on the area of the Kazakh Uplands, is likely to be the most productive in the search for Lower-Middle Pleistocene sites.

9.1 Future Directions

This project has provided a framework for further study in an area that has great potential but has received little attention from western scholars. Central Asia lies at a crucial point in Asia for understanding wider dispersal patterns, and continued study in this region should develop our understanding not just of the region, and not just of the hominin occupation of Asia, but also of hominin dispersal and adaptability in variable environments generally.

A number of future directions exist for developing the Central Asian Lower-Middle Pleistocene record. A better chronology would benefit overall understanding of the region immeasurably, and more securely-dated sites in particular would be central to this. A better chronology is necessary to really understand the timings, interactions, and developments of the different stone tool technologies in Central Asia. Further Lower-Middle Pleistocene hominin fossil sites would also be of great value, as it is still basically unknown what hominins may or may not have occupied Central Asia. This area is well known as an area through which, historically, great population movements and trade networks have flourished, and in the late Pleistocene it has a possible place in the mysterious topic of Denisovan dispersal. Despite this, Central Asia's connectivity to neighbouring regions during the early Pleistocene remains very much a mystery.

Some aspects of the hominin niche could also be better studied to further understanding of them. In particular, our understanding of the water acquisition behaviour of hominins could

benefit from further study, as it has rarely been considered in any depth but is likely to hold a central place in hominin subsistence patterns. Palaeolithic archaeology could also be benefitted by a push away from site-centred archaeology, which would probably have to prioritise spatial studies. Palaeolithic spatial studies should focus on building new research agendas, methodologies, and techniques, rather than addressing the concerns of traditional site-based Palaeolithic archaeology. To achieve this, there has to be a move towards producing better theoretical underpinnings, methodologies, and datasets for Palaeolithic spatial analysis.

Appendix 1. Gazetteer of Central Asian Sites

This gazetteer is intended to provide additional information on some of the sites used in this analysis where such information exists. Unless otherwise specified, coordinates have been reverse-engineered from georeferenced maps, and compared between sources where possible. This results in a coordinate that will be accurate at a broadscale appropriate for the present analysis, but cannot be considered accurate for locating these sites on the ground.

Ak-Koshkar (Kazakhstan)

67.973400, 50.040334

Date: Lower Palaeolithic (?, Vishnyatsky, 1999, p. 103).

Site Type: Surface site with bifaces.

Situation: Found by quarrying, south-west of Lake Tengiz (Moloney, et al., 2001, p. 139).

Technology: Several thousand artefacts are reported (Vishnyatsky, 1999, p. 103).

The 'oldest' artefacts are regarded as Lower Palaeolithic by Vishnyatsky (1999, p. 103), and are probably the most eroded.

The artefacts are described as "large bifaces" (Vishnyatsky, 1999, p. 103), "large choppers, picks, or trihedrals, massive irregular flakes, pointed tools and biconical cores" (Moloney, et al., 2001, p. 139).

The lithics are made on quartzite and porphyrite (Vishnyatsky, 1999, p. 103).

Taphonomy: The artefacts are described as "highly eroded" (Moloney, et al., 2001, p. 139) and "multi-period" (Vishnyatsky, 1999, p. 103). Moloney *et al.* (2001, p. 139) seem to imply that the material is a deflated, surface assemblage, revealed by wind ablation of loess deposits.

Dating: Typological

Batpak Valley (Kazakhstan)

72.275599, 50.562957

Localities: 20 localities (Moloney, et al., 2001, p. 139).

Date: 1-0.78 mya (Upper Aktasy formation, Moloney, et al., 2001, p. 140)

Site Type: Stratified and surface sites.

Situation: The Batpak Valley is located approximately 120 km south-east of Astana, in the Aktastinsky Highlands, in the Nura-Ishim watershed (Moloney, et al., 2001, p. 139).

Technology: Artefacts have been claimed from three major formations in the stratigraphic sequence, the Lower Aktasy formation, the Upper Aktasy formation, and the Batpak formation. The artefacts claimed by Voloshin in the Lower Aktasy formation are regarded as unmodified rocks by Moloney and Olsen (Moloney, et al., 2001, p. 140).

Artefacts from the Upper Aktasy formation are not explicitly discussed by Moloney et al. (2001). However, artefacts described as Lower Palaeolithic are mentioned from the Batpak Valley localities, and the sequence is said to stretch "from Lower Palaeolithic at the base to Upper Palaeolithic at the top", suggesting that stratified Lower Palaeolithic artefacts were identified here.

The artefacts from the Batpak formation are considered Mousterian (Moloney, et al., 2001, p. 140).

The Lower and Middle Palaeolithic artefacts, from excavated and surface localities, are described as comprising a wide range of raw materials (Moloney, et al., 2001, p. 141). The more homogenous materials present, such as the indurated sandstone and siltstone, are thought to be easier to work, while the quartzite, poor-quality metamorphic rocks, and

conglomerates that were utilised may have been more challenging to work (Moloney, et al., 2001, p. 141).

The raw materials exploited by Lower and Middle Palaeolithic hominins has been described as “primarily local” (Moloney, et al., 2001, p. 141).

A biface has also been recovered from a locality, Batpak 7, possibly from a Pleistocene context (Vishnyatsky, 1996, p. 146).

The locality of Mizar in the Batpak Valley also contains Palaeolithic remains, possibly including Lower Palaeolithic (Vishnyatsky, 1999, p. 103)

Faunal Remains: (From the entire sequence): *Mimomys*, *Marmota*, *Equus*, *Elasmotherium*, *Mammuthus*, *Bison*, *Saiga*, *Cervus*, *Rangifer*, rhinoceros, camel, and an unidentifiable carnivore (Moloney, et al., 2001, p. 140).

Research History: Moloney et al. (2001, p. 139) report that Voloshin had surveyed and excavated in this area (Central Kazakhstan) for over 30 years as of 2001. Of the 20 localities identified in the Batpak Valley, Voloshin had test-pitted some and excavated others. Voloshin invited a team led by Olsen to study the Batpak Valley in 2000, during which this team had recourse to study the geography of the valley, the on-going excavations, and the collected lithic assemblages (Moloney, et al., 2001, p. 140).

Taphonomy: Substantial ice-wedge damage is present in several areas of the sequence, which may potentially have caused sediment mixing (Moloney, et al., 2001, p. 140). This would be particularly problematic for the composite stratigraphy.

Dating: Composite stratigraphy of Pleistocene alluvium and loess containing evidence for multiple palaeomagnetic reversals (Moloney, et al., 2001, p. 140).

Additional Notes: Pleistocene deposits range between 30-45 m in depth, spanning Lower Palaeolithic to Upper Palaeolithic (Moloney, et al., 2001, p. 140).

Esen 2 (Uzbekistan)

57.628997, 43.872550

Date: Lower Palaeolithic (?).

Site Type: Surface site with bifaces.

Situation: Surface scatter near chert outcrops in the southern half of the Barsakelmes depression on the Ustyurt Plateau, southwest of the Aral Sea in western Kazakhstan (Dennell, 2009, p. 332, Vishnyatsky, 1999, p. 74).

Technology: 60 bifaces and 150 flakes and chips found in a 90 by 40 m scatter near chert outcrops (Vishnyatsky, 1999, p. 74). A third of the bifaces are described as being "in the initial stages of preparation" (Dennell, 2009, p. 332), while the rest are finished or near-finished but often fragmentary (Vishnyatsky, 1999, p. 74). 'True' cores and retouched flakes are absent (Vishnyatsky, 1999, p. 74).

Vishnyatsky (1999, pp. 74-6) infers from the finished and near-finished bifaces that: "their makers sought to produce thin, but wide and rather long ... (no less than 10- to 12-cm) tools with pointed ends and sharp edges." Vishnyatsky (1999, p. 76) suggests that the reduction process was achieved by "... detaching large, flat removals ...", (biface thinning?), "... sometimes followed by the retouching of parts of the edge" (biface finishing?).

Interpretation: Vishnyatsky (1999, p. 76) interprets Esen 2 as a biface workshop.

Dating: Typological

Jaman Aibat 4 (Kazakhstan)

68.955100, 47.374677

Date: Lower Palaeolithic (?)

Site Type: Surface scatter with bifaces (Vishnyatsky, 1999, p. 103).

Situation: 150 km southeast of Djezkazgan (Vishnyatsky, 1999, p. 103).

Technology: Over 800 artefacts made on sandstone, including handaxes measuring 10-14 cm and made on flakes and nodules (Vishnyatsky, 1999, p. 103). Dennell (2009, p. 332) refers to the handaxes from this site as "possibly late Acheulean", which agrees with Klapchuk (1976; cited in (Vishnyatsky, 1999)).

Interpretation: Dennell (2009, p. 332) interprets the surface assemblages of Jaman Aibat and Vishnëvka 3 to "indicate that groups using Acheulean bifaces may have been foraging over much of the region".

Dating: Typological

Karakuduk (Uzbekistan)

56.892792, 44.320840

Date: Lower Palaeolithic (?, Vishnyatsky, 1999, p. 76)

Site Type: Surface site with bifaces.

Situation: Situated on the northern slope of the Barsakelmes depression (Vishnyatsky, 1999, p. 76).

Technology: The assemblage from Karakuduk consists of over 900 lithics made on nodules of silicified limestone (Vishnyatsky, 1999, p. 76). The majority of this assemblage is composed of tested nodules with only a single removal and corresponding primary flakes (Vishnyatsky, 1999, p. 76). There are also 12 bifaces in various stages of manufacture, although none are considered 'finished' (Vishnyatsky, 1999, p. 76).

Interpretation: Vishnyatsky (1999, p. 76) interprets Karakuduk as a biface workshop.

Taphonomy: Possible admixture with later periods.

Dating: Typological

Karatau I (Tajikistan)

69.170221, 38.370215

Date: *c.* 620-570 kya (Dennell, 2009, p. 326).

Site Type: Stratified 'Pebble culture' site.

Situation: "on the watershed of the Yavansky Karatau range, 54 km southeast of Dushanbe, at a height of 1700 m asl" (Vishnyatsky, 1999, p. 89). 80 km west of Lakhuti I.

Technology: Dennell (2009, p. 327) reports almost 1,000 artefacts from Karatau I; however, Vishnyatsky (1999, p. 89) and Glantz (2010, p. 104) both report the number as more than 600. This confusion probably stems from Ranov (1995, p. 737), where 931 'finds' are reported, 616 of which are described as 'artifacts'. Ranov (1995, p. 737) gives the following breakdown:

- 319 debris (34.2%)
- 211 flakes (22.6%)
- 165 debris with scars (17.7%)
- 34 wedges (36%)
- 30 choppers (3.2%)
- 39 'quarter d'orange' (slices, 4.1%)
- 16 scrapers (1.7%)
- 29 debris with retouching (3.1%)
- 21 cores and core-like pieces (2.2%)
- 5 denticulates (0.5%)
- 15 notched tools (1.6%)
- 4 points (0.4%)
- 2 blades (0.2%)

- 9 side scrapers (0.9%)
- 6 unifaces (0.6%)
- 25 pebbles with scars (0.7%)
- 1 hammer (0.1%)

Dennell (2009, p. 329) estimates the density of finds at 1.9 per m^2. Karatau I is attributed to the 'Karatau Pebble Culture' (Davis & Ranov, 1999, p. 187, Vishnyatsky, 1999, p. 90), and Glantz (2010, p. 104) regards it as "very similar" to the technology in evidence at Lakhuti I.

The assemblage represents an industry focused on the reduction of pebbles producing tools and débitage, which Ranov (1995, p. 737) has referred to as the "pebble technique ... for stone débitage" (see entry for Kuldara). The assemblage is dominated by "chips, fragments, and crude flakes" (Vishnyatsky, 1999, p. 89), including several citrus slices (Ranov, 1995, p. 737), while prepared cores and bifaces are absent (Vishnyatsky, 1999, p. 90), although some bifacially flaked pieces are in evidence (Ranov, et al., 1979, p. 255). In terms of stone tools, Vishnyatsky (1999, p. 90) records "several tens of choppers, a dozen scrapers on massive pebble flakes, and various irregularly retouched pieces and fragments". Some cores not made on pebbles are present, but they do not demonstrate a consistent flaking technique, but are described as "cubic and multiplatform types", which represent less than 1% of the total assemblage (Ranov, 1995, p. 737).

18% of the flaked artefacts from Karatau I were between 2-3 cm in length, and around 70% exhibited removals < 5 cm in length (Dennell, 2009, p. 328). The flakes are described as primary or "half-primary" (Ranov, 1995, p. 737). The flake platforms are mostly 'smooth' (plain?) or cortical, and the cores themselves do not exhibit prepared platforms (Davis & Ranov, 1999, p. 187, Vishnyatsky, 1999, p. 90). The presence of several 'citrus slices', probably produced through the *zitron* or *quartier d'orange* technique (Ranov, et al., 1979, p.

255), as well as the prevalence of cortical platforms, has been taken to suggest a preference for this form of pebble reduction (Davis & Ranov, 1999, p. 187).

The raw materials at the Karatau I site are variously described as “metamorphic river pebbles and cobbles” (Ranov, et al., 1979, p. 255, Vishnyatsky, 1999, p. 89), “mainly ... volcanic raw materials” (Ranov, et al., 1995, p. 338), or primarily “fragile magmatic rocks ...” and, “... to a lesser extent silicified limestone, schist, and quartzite” (Ranov, 1995, p. 737).

Ranov (1995, p. 733) has summarised the technology at Karatau I as: “Local pebble tools technology without systematic flaking”. Ranov has suggested that several of the larger flakes (> 10 cm) in the assemblage are reminiscent of the Clactonian industry in Britain (Ranov, 1995, p. 738, Ranov, et al., 1995, p. 338), and has compared the Karatau assemblage generally with non-biface assemblages in Europe, “Acheulean without bifaces” (Ranov, et al., 1995, p. 338), such as Bilzingsleben and Vértesszölös. Ranov (Ranov, 1995, p. 738) has also compared the Karatau assemblage to that found in layers 6-10 at Zhoukoudian. However, Ranov (1995, p. 740) caveats his use of the terms Clactonian and Tayacian in regards to non-biface assemblages and the Karatau assemblage: “The term ‘Tayacian’ has long outgrown the framework of its initial reference and indicates, as does the term ‘Clactonian’, only general ideas about a local Palaeolithic culture with a ‘non-classical’ line of evolution--without bifaces, Levallois blades or Levallois technology.”

Interpretation: Ranov et al. (1995) suggest that the remains at Karatau I represent “temporary occupations”.

Taphonomy: Ranov et al. (1979, p. 252) interpret the site as being *in situ*, but the result of multiple occupation episodes. Ranov (1995, p. 737) reports that the patination and weathering on the artefacts is highly variable. However, the edges are described as “never

rounded" (Ranov, 1995, p. 737), and the variability has been attributed to the nature of the raw materials.

Dating: Correlated with the North Chinese loess and marine isotope sequences, which are considered to be more accurate than previous thermoluminescence dates (Dennell, 2009, p. 327). These earlier TL dates appear to have significantly underestimated the age of the site (Dennell, 2009, p. 327), placing it at *c.* 200 kya (Glantz, 2010, p. 104).

Additional Notes: One of the Tajik 'loess Palaeolithic' sites (Dennell, 2009, p. 326), Karatau I is located in the 6th pedocomplex (PC6, Ranov, et al., 1979, p. 252). The excavation area is reported as 500m^2 (Ranov, 1995, p. 736).

Karatau Range Surface Sites (Kazakhstan)

Karatau Range 69.698730, 43.815308 (from M. Glantz)

Tokaly & Zhanatas 69.322327, 44.241089 (from M. Glantz)

Localities: Akkol, Borykazgan, Kazangap, Kemer I, II, & III, Tanirkazgan, Tokaly I, II, & III, and Zhanatas

Date: Lower Palaeolithic (?, Glantz, 2010, p. 104).

Site Type: Surface sites.

Situation: Listed by Vishnyatsky (1999, p. 101) as surface sites in the Karatau Range, southern Kazakhstan.

Technology: These surface sites are described as producing over 6,000 lithic artefacts in total (Glantz, 2010, p. 104), and "tens or hundreds of lithics" each (Vishnyatsky, 1999, p. 101).

Alpysbaev has interpreted these surface finds as representing a Lower Palaeolithic industry. Glantz (2010, p. 104) describes Alpysbaev's proposed industry as "characterized by irregular orthogonal cores, 'citron' spalls, massive *racloir*-like tools, and large cutting tools." These large cutting tools were apparently argued by Alpysbaev to be representative of Acheulean and Mousterian technologies (Vishnyatsky, 1999, p. 101).

Vishnyatsky (1999, p. 101) has argued that the assemblages could be either Middle or Lower Palaeolithic, asserting that they lack true handaxes or typical flake tools. Instead, he identifies "precores, cores, flakes (often large and massive), and choppers" as key assemblage components (Vishnyatsky, 1999, p. 101).

More recently, researchers such as Shunkov have drawn comparisons between these collections and the assemblage at Kuldara (Glantz, 2010, p. 104). However, Glantz has reanalysed the collection made by Alpysbaev, and disagrees with the descriptions of other

authors (e.g. (Vishnyatsky, 1999); Shunkov 2005). She argues that the assemblage is best characterised by the dominance of discoidal cores, fan cores, and modified flakes, and that it also contains tool types most associated with Middle Palaeolithic technologies (Glantz, 2010, p. 104).

The raw materials are described as similar across the various sites, as "boulders of a Lower Carboniferous siliceous rock" (Vishnyatsky, 1999, p. 101).

Interpretation: The large percentage of flakes with natural platforms (>50% at most sites) leads Vishnyatsky (1999, p. 101) to interpret these sites as workshops where local raw materials were reduced. Taimagambetov *et al.* (2013, p. 689) confirm this interpretation, asserting that the artefacts "are the products of primary cleavage", with few implements in evidence.

Research History: Sites identified by Alpysbaev during two seasons of surface surveys (1958-1959, Glantz, 2010, p. 104).

Taphonomy: The assemblages appear to be multi-period and admixed, probably formed through deflation (Glantz, 2010, p. 104, Vishnyatsky, 1999, p. 101).

Dating: Typological.

Additional Notes: Alpysbaev also identified Darbaza III, Daurenbek, Degerez, and Suleymensay I & IV, which are also Karatau Range surface sites. Alpysbaev apparently designated these sites as "Acheulean-Mousterian", but Taimagambetov *et al.* (2013, p. 690) interpret them as Middle Palaeolithic.

Khonako (Tajikistan)

70.089407, 38.381351

Localities: Khonako I, II, III

Date: Khonako II: 725-740 kya (???), Khonako I: 530-570 kya (???), Khonako III: 360-430 kya (???, Dennell, 2009, p. 328, These represent the oldest dates reported for each Khonako locality).

Site Type: Unknown

Technology: The 3rd palaeosol at Khonako II has provided "a small collection" (Ranov, 1995, p. 743) of artefacts described by Ranov (1995, p. 733) as "flake debris pebble tools technology", which he places temporally between Mousterian and Upper Palaeolithic assemblages, reporting a date of 40 kya (Ranov, 1995, p. 743, It should be noted that Ranov places '(?)' after the site name, and Dennell does not include Khonako II in the 3rd palaeosol. If these artefacts are genuinely from the 3rd palaeosol it would date them between 300-335 kya according to Dennell's Figure 8.33).

Ranov et al. (1995, p. 339) attribute artefactual remains at Khonako to 'palaeosoil' 9, reporting a date of 0.5 mya.

Taphonomy: Some apparent confusion over which palaeosols artefacts are to be attributed to, although this confusion may be an artefact of perpetuated errors in the literature.

Dating: Unknown, some confusion. Apparently young dates are probably due to (discredited) TL dating. Dates reported by Dennell (2009, p. 328) most likely come from correlation with north Chinese loess.

Koshkurgan (Kazakhstan)

68.291870, 44.142273 (from M. Glantz)

Localities: Koshkurgan I, II, III

Date: 500-170 kya (Glantz, 2010, p. 104)

Site Type: Stratified Lower Palaeolithic site

Situation: In the Karatau range, near Alpysbaev's surface sites (Glantz, 2010, p. 104)

Technology: In the assemblage from Koshkurgan I, most of the artefacts are not larger than 4-5cm, and several retouched tools are present, including sidescrapers, denticulates, and a few points (Vishnyatsky, 1999, p. 101). Early analysis by Artyukhova and Voloshin concluded that 3000 artefacts from Koshkurgan I represented a typical Mousterian assemblage with some unique elements (Vishnyatsky, 1999, p. 101).

A large variety of raw materials are in evidence in the assemblage from Koshkurgan I, primarily in the form of pebbles, including "jasper, flint, chalcedony, quartz, sandstone" (Vishnyatsky, 1999, p. 101).

The industry from the Koshkurgan localities is described as "small tool" or "micro" (Glantz, 2010, p. 104, Vishnyatsky, 1999, p. 102). Along with the nearby Shoktas localities, this industry is compared with Vértesszölös and Bilzingsleben in the European record (Vishnyatsky, 1999, p. 102).

Faunal Remains: Artefacts at Koshkurgan are described as being associated with the Lower-Middle Pleistocene Koshkurgan Faunal Complex (Vishnyatsky, 1999, p. 101), which supports an ESR date of 500 kya (Moloney, et al., 2001, p. 139).

Taphonomy: Vishnyatsky (1999, p. 101) questions the geological age of the artefacts, and their association with a Lower-Middle Pleistocene faunal assemblage. However, this scepticism probably predates the series of ESR dates mentioned by subsequent authors.

Dating: Glantz (2010, pp. 104-5) reports that ESR dating on travertine deposits at the Koshkurgan localities has provided a date range of 500-170 kya. Taimagambetov et al. (2013, p. 689) report an ESR date range for both Koshkurgan I and Shoktas I as 500-300 kya.

Kul'bulak (Uzbekistan)

Not included in the modelling. Included here for supplementary information.

Date: Lower Palaeolithic lower layers?

Site Type: Stratified open air site with potential for Lower Palaeolithic remains (Flas, et al., 2010).

Situation: Located in the north-western region of the Tien Shan, on the south-western slope of the Chatkal mountain range, north of the Fergana depression (Vishnyatsky, 1999, p. 96).

Technology: As of 1999, around 70,000 artefacts were recovered from all the cultural layers at Kul'bulak, the majority made using flint (Vishnyatsky, 1999, p. 96). Several other locally available raw materials were used as well as flint, including siliceous limestone, chalcedony, quartzite, and quartz (Vishnyatsky, 1999, p. 96).

Vishnyatsky (1999, p. 97) finds two features of the assemblage particularly notable. Firstly, the assemblage includes a very high proportion of retouched pieces. Secondly, there are a large number of notches and denticulates.

Kasymov identified the lowermost 22 layers at the site as Acheulean, but the presence of an Acheulean component at the site is not uncontroversial (Vishnyatsky, 1999, p. 98).

Flas et al. (2010) have identified no Lower Palaeolithic or Acheulean elements in the earlier layers, but argue that these earlier artefacts are Middle Palaeolithic and comparable with the lithic industry from Obi-Rakhmat

Faunal Remains: Faunal remains are in evidence, but scarce, and do not allow for an age estimation (Vishnyatsky, 1999, p. 96). Vishnyatsky (1999, p. 96) lists several species identified in the lower layers: "The animal bones from the lower layers (45-12a) are said to

be horse (*Equus* sp.), deer (*Cervus elaphus*), ox (*Bos primigenius*), wild goat (*Capra sibirica*), wild boar (*Sus scrofa*), and hare (*Lepus tolai*)."

Research History: The original excavator, Kasymov, identified 49 separate cultural layers at Kul'bulak, although some of these are evidenced by very few stone tools (usually somewhere in the region of 20-30, but occasionally less, Vishnyatsky, 1999, p. 96). Kasymov is said to have identified 22 Lower Palaeolithic levels, 24 Middle Palaeolithic levels, and 3 Upper Palaeolithic levels (Kolobova, et al., 2012, p. 13).

Between 1962 and the early 1990s, more than 600 m^2 of surface had been exposed at the site, with a maximum sequence depth of 19 m in one of the test pits (Flas, et al., 2010, Vishnyatsky, 1999, p. 96). In 1999, Vishnyatsky (1999, p. 96) speculated that further, earlier, archaeological material could exist in the unexcavated lower levels of the site.

Taphonomy: The complex stratigraphy at this site appears to show some undisturbed levels, although much of the material may have been re-deposited (Vishnyatsky, 1999, p. 96). Ranov & Nesmeyanov have argued, on the basis patination and wear on lithics, that only the Upper Palaeolithic levels are *in situ*, with everything earlier being deposited by proluvial and mudflow processes (Kolobova, et al., 2012, p. 13).

Renewed work at the site from 2007-2010 has confirmed that some artefact layers appear redeposited (3-8. 11, 14, 17.1, and 17.3), although some layers earlier than the Upper Palaeolithic appear relatively undisturbed (9, 10, 12, 13, 15, 16, 17.2, and 18-23, Kolobova, et al., 2012, p. 14).

Layers 16 and 23 provide the most compelling evidence for *in situ* occupation "during the earlier stages of the Paleolithic" (Kolobova, et al., 2012, p. 15).

As at several other Lower Palaeolithic sites in Central Asia, the sequence consists of several layers of cultural material, interspersed with sterile layers (Vishnyatsky, 1999, p. 96).

Dating: A long sequence is in evidence at Kul'bulak, potentially stretching from the Upper Palaeolithic down to the Lower Palaeolithic (Acheulean, Moloney, et al., 2001, p. 138, Vishnyatsky, 1999, p. 96). The lowest levels at the site have been attributed to the early Pleistocene, but this is not widely accepted (Vishnyatsky, 1999, p. 96).

The new excavations between 2007-2010 provided OSL dating for layer 8, which was dated to 53 ± 10 kya and 50 ± 5 kya (Flas, et al., 2010).

Further OSL dating reported by Vandenberghe et al. (2014) confirm layers 2-10 as falling within the range of 39 ± 4 kya to 82 ± 9 kya, but earlier levels remain undated.

Kuldara (Tajikistan)

69.927038, 38.272777

Date: *c.* 955-880 kya (Dennell, 2009, pp. 326-7)

Site Type: Stratified Karatau Pebble Culture site

Technology: Ranov (1995, p. 735) attributes the Kuldara assemblage to the Karatau Pebble Culture, although most researchers regard the assemblage as typologically ambiguous (Glantz, 2010, p. 104). In particular, Vishnyatsky (1999, p. 89) has argued that the Kuldara assemblage is not easily defined typologically because of the artefacts' "amorphousness", and Ranov (1995, p. 735) identifies a lack of standardisation as a key feature of the assemblage.

Although 96 possible artefacts were recovered, only 40 are definitely regarded as genuinely humanly modified (Ranov, 1995, p. 735). These artefacts were recovered from an area 62 m^2, the estimated density being only one artefact for every $4m^3$ of deposit (Dennell, 2009, p. 329).

Ranov (1995, p. 735) gives a breakdown of the assemblage:

- 2 cores (5%)
- 2 blades (5%)
- 3 flakes (7.5%)
- 10 flakes with scars (10%)
- 2 wedges on the debris (5%)
- 3 debris with scars and accidental retouching (7.5%)
- 2 quartier d'orange (5%)
- 3 pebbles with scars (7.5%)

- 2 perforators (5%)
- 4 side scrapers and scrapers (10%)
- 1 part of a bifacial tool (2.5%)
- 6 waste (15%)

Overall. The assemblage from Kuldara has been described as “Short flakes, pebble techniques without choppers” (Ranov, 1995, p. 733). Despite the absence of choppers, the other lithic products in the assemblage are congruent with the Karatau Pebble Culture (Ranov, 1995, p. 735).

When retouch is present on artefacts it is *ad hoc* and partial, and none of the flake tools appear standardised in form (Ranov, 1995, p. 735). The lack of standardisation evident in the products of the pebble cores, which cannot be regarded as tool blanks or preforms, is used by Ranov (1995, p. 735) to argue against systematic core exploitation at the site. Ranov (1995, p. 735) notes debris from a possible bifacial tool, as well as a core described as microlithic, as surprising elements of the assemblage.

Davis & Ranov (1999, p. 188) identify two main forms of pebble reduction at Kuldara, including pebble cores with multiple small flake removals, and the *zitron/quartier d’orange* pebble cores. The resultant zitron/q*uartier d’orange* flakes, they describe as “semicircular, and wedge-shaped with pebble cortex on the “rind.”” (Davis & Ranov, 1999, p. 188). The zitron/*quartier d’orange* reduction process is described: “The pebble cortex served as the striking platform and the distal end tapered to a relatively sharp edge” (Davis & Ranov, 1999, p. 188).

25% of the flaked artefacts from Kuldara were <2 cm in length, with nearly 50% between 2-4 cm in length (Dennell, 2009, p. 328, Ranov, 1995, p. 735), the average length was 3.4 cm and the largest were just over 5 cm (Davis & Ranov, 1999, p. 188). (Vishnyatsky, 1999, p. 89) has

suggested that the small size of the artefacts at Kuldara may be a by-product of the small raw material package size.

The raw materials used include pebbles and slabs of quartzite and other rocks (Vishnyatsky, 1999, p. 89), although the majority of the tools at Kuldara are made on quartzite pebbles (Glantz, 2010, p. 104). Ranov (1995, p. 735) notes that the assemblage includes "felsites-porphyry, quartzite, silicified volcanic rocks, silicified schists, limestone, and bad quality flint".

The Kuldara assemblage and reduction strategies have been likened to those at the sites of Karatau and Lakhuti (Davis & Ranov, 1999, p. 188). Comparisons with the Early Pleistocene material from the Nihewan Basin sites have also been proposed by several authors (Davis & Ranov, 1999, p. 188, Glantz, 2010, p. 105, Ranov, 1995, p. 736), possibly supporting an east-west model of colonisation (Glantz, 2010, p. 105). In particular, Davis & Ranov (1999, p. 189) emphasise the "simple core and flake forms" and "their relatively small dimensions". Ranov (1995, p. 736) specifies "the techniques used to prepare tools and the types made" as points of similarity between Kuldara and the Nihewan sites of Donggutuo and Xiaochangliang.

Interpretation: Davis & Ranov (1999, p. 188) have speculated that the Kuldara assemblage lacks 'heavy-duty' tools or hunting equipment. Instead, they propose that the small flakes produced on pebbles could have been used for "cutting, scraping, and piercing functions", and were "appropriate for scavenging and plant processing", although that emphasise that no formal analysis of tool function had been undertaken (Davis & Ranov, 1999, p. 188).

Dating: Correlated with north Chinese loess and marine isotope sequences, which is more secure than previous TL dating that underestimated the age of the Tajik sequence (Dennell, 2009, pp. 326-7). The artefacts from Kuldara are present in the 11th and 12th palaeosols (Ranov, et al., 1995, p. 339).

Kumuktepe (Kazakhstan)

51.529011, 44.194491

Date: Lower Palaeolithic (?)

Technology: Handaxes were found at Kumuktepe (Dennell, 2009, p. 332, Vishnyatsky, 1999, p. 77).

Taphonomy: While some of the material from Kumuktepe is probably Palaeolithic in age, the assemblage has no firm geological context, and probably represents a mix of periods (Vishnyatsky, 1999, p. 77).

Dating: Typological

Kyzyltau (Kazakhstan)

Modelled sharing coordinates with the Karatau Range sites.

Localities: 2 major localities described as 'grounds', defined as "relatively flat areas" (Taimagambetov, et al., 2013, p. 687), and 30 minor localities described as 'points'.

Date: Middle Palaeolithic (?) Lower Palaeolithic (?)

Site Type: Undated non-handaxe surface assemblages

Situation: One of the sites in the Karatau complex (Taimagambetov, et al., 2013, p. 686).

Technology: In total, 16,111 artefacts have been recovered from the Kyzyltau localities (Taimagambetov, et al., 2013, p. 678). These localities are located close to prominent raw material sources (Taimagambetov, et al., 2013, p. 691).

Taimagambetov et al. (2013, p. 689) note "some differences ... associated with significant presence of Levalloisian elements" between the finds from the Kyzyltau localities and those from Semizbugu 2 and 4 in Siberia, although exactly what these differences are, or why the sites merit comparison, is not explained.

The Kyzyltau assemblage is reported to differ from the Karatau I and Obi-Mazar 6 sites in the lack of choppers, "choppings and chunks" (Taimagambetov, et al., 2013, p. 689), and is argued to represent more complex manufacture techniques. Some elements of the assemblage are also compared with Altai 'Mousterian' sites, Denisova Cave, Okladnikov Cave, and Tyumechin 1.

The assemblage is reported as lacking bifaces (Taimagambetov, et al., 2013, p. 690).

Interpretation: The proximity of raw material sources lead Taimagambetov et al. (2013, p. 691) to interpret the Kyzyltau localities as workshops used during multiple periods.

Research History: The site was originally identified in 1997 (Taimagambetov, et al., 2013, p. 686).

Taphonomy: Deflated surface assemblages, possibly multiple periods.

Dating: Typological.

Lakhuti I (Tajikistan)

69.879479, 38.271123

Localities: For Lakhuti III see Obi-Mazar.

Date: *c.* 530-475 kya (Dennell, 2009, p. 327).

Site Type: Stratified Karatau Pebble Culture site.

Situation: Located in the valley of the Obimazar river (Vishnyatsky, 1999, p. 77).

Technology: Glantz (2010, p. 104) and Vishnyatsky (1999, p. 90) both report 500 artefacts recovered from Lakhuti I. However, Ranov (1995, p. 739) reports 1047 artefacts, classifying 399 as debris, 388 as artefacts, and 260 as manuports. The features that define these manuports are not outlined, but the artefacts are broken down into several categories:

- 196 flakes (50.51%)
- 66 wedges and *quartier d'orange* slices (17.01%)
- 13 "tools resembling scrapers" (3.35%)
- 10 notches (verbatim "notched", 2.57%)
- 11 side scrapers (2.83%)
- 5 "rabot" (1.28%)
- 4 circular scrapers (1.03%)
- 4 knives (1.03%)
- 3 "tools with noses" (0.77%)
- 3 Tayac points (0.77%)
- 1 unifacial point (0.25%)
- 1 borer (0.25%)
- 1 adze tool (0.25%)

- 35 choppers (including incomplete examples, 9.02%)
- 6 blades (1.54%)
- 23 cores (including incomplete examples, 5.92%)

70% of the flakes were between 2.6 – 5.0 cm, and only 3.28% of flakes were 8 cm or longer (Ranov, 1995, p. 740).

As at Karatau I, Ranov (1995, p. 740) caveats his use of the terms Clactonian and Tayacian in regards to non-biface assemblages: "The term 'Tayacian' has long outgrown the framework of its initial reference and indicates, as does the term 'Clactonian', only general ideas about a local Palaeolithic culture with a 'non-classical' line of evolution--without bifaces, Levallois blades or Levallois technology."

The assemblage at Lakhuti I has been assigned to the Karatau Pebble Culture (Davis & Ranov, 1999, p. 187), and likened to the industry present at Karatau itself, although Vishnyatsky (1999, p. 90) describes the Lakhuti I assemblage as "somewhat less archaic" because it includes some prepared cores and blades (Glantz, 2010, p. 104). Vishnyatsky (1999, p. 90) regards the industry at Lakhuti I as "a derived variety" of the earlier Karatau Pebble Culture as represented at the Karatau site, while Ranov (1995, p. 733) describes it as an "[e]volved local pebble tools technology with a few Levallois elements", and "a pebble industry with Clactonian-Tayacian techno-typological elements and very faint Levallois technology features" (Ranov, 1995, p. 740).

Davis & Ranov (1999, pp. 187-8) define the Karatau Pebble Culture (verbatim: "pebble-tool industry") with specific reference to Karatau and Lakhuti. Chief among the features they highlight are:

- Cores that tend not to have prepared platforms.
- A majority of flakes retaining cortex on their proximal end.

- The presence of the *quartier d'orange* or *zitron* technique for fracturing pebbles.
- The presence of 'citrus' flakes, resulting from the *quartier d'orange*/*zitron* technique.
- The presence of pebble choppers, 'rough' scrapers, and flakes with marginal retouch.

The dominant manufacture techniques at Lakhuti I are reported as being the same as at Karatau I, i.e. the reduction of pebble-cores for simple flakes (Ranov, 1995, p. 739). The platforms of flakes are never more complex than dihedral or plain, and are most commonly cortical, retaining the original pebble surface (Ranov, 1995, p. 739). Facetted platforms are totally absent (Ranov, 1995, p. 739). Wedges and *quartier d'orange* flakes are better represented than at Karatau I (Ranov, 1995, p. 740). Choppers are well-represented, but predominantly fragmentary, and retouched tools are described as being made predominantly on pebble fragments rather than flakes, and are predominantly irregularly retouched scrapers (Ranov, 1995, p. 740).

Ranov (1995, p. 740) mentions that a small number of blades might be described as Levallois, but that blades represent only a small percentage of the assemblage. The examples from Lakhuti I potentially provide the earliest evidence in Central Asia for prepared core technologies (Dennell, 2009, p. 327), which have been described as "Levallois or proto-Levallois". Despite this, Ranov (1995, p. 743) emphasises the non-Mousterian aspect of the assemblage.

Vishnyatsky (1999, p. 90) lists the raw materials used at the site as including quartzitic sandstone, hornfels, and other locally available river-rolled materials in the form of pebbles. Ranov (1995, p. 739) lists them as "quartzite porphyry, cornelian, cornstones, hornfels, crystalline cherts, and possibly andesite".

Faunal Remains: Faunal remains are present, but are rare and mostly unidentifiable (Vishnyatsky, 1999, p. 90). Ranov (1995, p. 738) has described the recovered faunal remains as consisting of "small debris of ungulate bones", isolated long bone fragments, and a single cervid humerus.

Taphonomy: The patination and weathering of these artefacts is described as being the same as at Karatau I (i.e. highly variable, but never with rounded edges, Ranov, 1995, p. 739).

Dating: Correlated with the North Chinese loess and marine isotope sequences, which is a more secure date than previous thermoluminescence dating that underestimated the age of the Tajik sequence (Dennell, 2009, p. 327).

Additional Notes: One of the Tajik 'loess Palaeolithic' sites (Dennell, 2009, p. 326). Vishnyatsky (1999, p. 90) reports the excavation area as 200m^2; however, Ranov (1995, p. 738) reports the excavation area as 100m^2, and Dennell (2009, p. 329) calculates the artefact density at 10.5 per m^2.

Mugodjari (Kazakhstan)

Not included in the modelling. Included here for supplementary information.

Localities: 10 open-air sites (Derevianko, 2008, p. 24).

Date: Late Acheulean/Early Middle Palaeolithic (?, Derevianko, 2008, p. 24).

Site Type: Surface.

Situation: Located in the upper reaches of the Emba river, on the western slope of the Mugodjari mountains (Derevianko, 2008, p. 24).

Technology: Derevianko (2008, p. 25) describes the handaxe types as including "cordiform, foliate, ovoid and sub-rectangular handaxes, as well as comma-shaped varieties, tools of the Les Pendus type, and implements with a truncated apex reminiscent of backed cleavers".

The majority of artefacts are reported as resulting from Levallois reduction (Derevianko, 2008, p. 24). Derevianko (2008, p. 25) postulates that the Mugodjari assemblages represent acculturation between Acheulean/Levallois technology-using groups and local pebble/flake technology-using groups.

Derevianko (2008, p. 25) compares the Mugodjari localities with those at Semizbugu, also in Kazakhstan: "the sites of Semizbugu-2 and 4 have yielded artifacts clearly exemplifying Late Acheulian and early Middle Paleolithic traditions ... The Semizbugu collections exhibit techno-typological features similar to those from Mugodjari; however, the percentage of Middle Paleolithic tools is greater in the Semizbugu assemblages".

Interpretation: Variously described by Derevianko (2008, p. 24) as habitation loci and workshops.

Taphonomy: The presence of handaxes and Levallois might imply association, or assemblage conflation.

Dating: Typological. Derevianko's (2008, p. 25) estimate of 300-250 kya for the 'oldest' artefacts is based on typology and abrasion.

Muzbel I (Kazakhstan)

69.938531, 48.699769

Date: Lower Palaeolithic (?)

Site Type: Surface lithic scatter.

Technology: The assemblage from Muzbel I represents a core and flake industry made on quartzite pebbles, with bifaces being entirely absent (Dennell, 2009, p. 332, Moloney, et al., 2001, p. 142). The assemblage includes choppers and chopping tools, unretouched flakes, flake tools, a cleaver, a uniface, and cores described as having centripetal removals (Moloney, et al., 2001, p. 142).

The quartzite pebbles used as raw material range from medium to fine-grained (Moloney, et al., 2001, p. 142).

Moloney et al. (2001, p. 142) describe the assemblage as being “crude” in appearance, although they attribute this partly to the use of pebbles as a raw material, and compare the assemblage with similar quartzite assemblages from Iberia.

Taphonomy: The Muzbel I lithic scatter was recovered from the surface of a Late Pliocene pebble deposit, precluding accurate dating (Moloney, et al., 2001, p. 142).

Dating: Typological.

Bolshoy Narym (Kazakhstan)

84.094875, 49.197879

Date: Lower/Middle Palaeolithic (Chlachula, 2010).

Site Type: Surface

Situation: Located in the Bukhtarma Basin, eastern Kazakhstan (Chlachula, 2010, p. 76).

Technology: Chlachula (2010, p. 76) interprets Narym as representing the earliest Palaeolithic site in east Kazakhstan.

The assemblage represents a core and flake industry made via hard-hammer percussion on high-quality white quartz (Chlachula, 2010, p. 76). Chlachula (2010, p. 76)] describes the artefacts as choppers, polyhedral cores, and modified flakes.

Dating: Typological.

Obi-Mazar (Tajikistan)

Modelled as sharing coordinates with Lakhuti.

Localities: 11 separate localities, 10 along one stratigraphic exposure, 1 from a separate exposure (Ranov, 1995, p. 741). Derevianko (2008, p. 25) specifically mentions localities 4 and 6.

Date: *c.* 400 kya (Vishnyatsky, 1999, p. 90).

Site Type: Stratified Pebble culture finds from a vertical exposure.

Technology: Ranov (1995, p. 741) reports that 219 artefacts in total were recovered from the main 42 m exposure. These are reported as:

- 14 pebbles and large pebble fragments without flake scars (4%)
- 4 unworked pebbles (1.8%)
- 147 debris (67.1%)
- 9 *quartier d'orange* flakes and wedges (4.1%)
- 33 flakes (15%)
- 5 cores and "core-like pieces" (2.3%)
- 7 pieces "provisionally identified as tools" (3.2%)

'Formal' tools are absent, and the pebble cores are apparently crude and *ad hoc* (Ranov, 1995, pp. 741-2).

Ranov (1995, p. 742) describes the flake attributes: "The largest flakes are up to 8 cm long and the smaller ones are around 3 cm. Most of the flakes show a flat inclined striking platform. The others protected the pebble surface and only some flakes have a facetted or dihedral type of striking platform. Very few have curved striking platforms. The dorsal parts of the flakes have no regularly facetted surface".

The raw materials are described as being the same as at Lakhuti I (Ranov, 1995, p. 742).

Vishnyatsky (1999, p. 90) interprets the industry at Obi-Mazar as "[a]n even later manifestation of the same tradition" in evidence at Lakhuti I, which he regards as a derived form of the Karatau Pebble Culture. Ranov (1995, p. 743) has described the finds from Obi-Mazar as "Non clear with crude flakes, debris, pebble tools technology", and places it as contemporary with Mousterian assemblages, but stresses that "it is not possible to call this industry, or that at Lakhuti I, Mousterian".

Dating: Ranov (1995, p. 741) reports that the only finds from the Obi-Mazar localities involved those recovered during the cleaning of an exposed 42 m section of the 4th and 5th palaeosols, along which work was conducted at 10 separate places, and isolated finds associated with a separate exposure nearby. According to Dennell (2009, p. 328), the combined date range for the 4th and 5th palaeosols (based on correlations with the north Chinese loess record) would be 530-360 kya.

Most of the finds at the main section of Obi-Mazar are reported as being from palaeosol 4; however, Ranov (1995, p. 743) mentions, and appears to credit, an observation by Dodonov that this palaeosol has been misidentified at the site, and that it is actually palaeosol 5.

Dennell (2009, p. 328) also appears to make reference to artefacts at Obi-Mazar localities in palaeosols 3a, 6a, and 6b.

Sel'ungur (Kyrgyzstan)

71.325, 39.953 (from B. Viola)

Date: > 126 ± 5 kya (Dennell, 2009, p. 330).

Site Type: Stratified pebble culture cave site.

Technology: Dennell (2009, p. 330) reports 1,417 flaked artefacts from Sel'ungur, including:

- 306 tools
- 64 cores
- 777 flakes

Both Glantz (2010, p. 105) and Vishnyatsky (1999, p. 95) report over 1,500 stone artefacts from this site. Vishnyatsky (1999, p. 95) observes that the assemblage appears fairly homogenous, notable features being the preponderance of "short massive flakes with wide smooth platforms" and the small number of cores, most being heavily reduced. These cores are described as being worked predominantly by discoidal and opposed platform techniques (Davis & Ranov, 1999, pp. 189-90).

Vishnyatsky (1999, p. 95) lists the other tool types present as including:

- Choppers
- Simple straight or convex sidescrapers
- Notches and denticulates
- Retouched flakes
- Fragments

The retouch on the artefacts identified as scrapers, denticulates, and notches is described as irregular, and not resulting in "smooth" or "contoured" edges.

While Islamov identifies a biface and more than one cleaver at Sel'ungur (Dennell, 2009, p. 330), Vishnyatsky (1999, p. 95) identifies only one cleaver, and argues that the 'biface' is too much like a core in its morphology.

The assemblage at Sel'ungur has been classified as "meridional Acheulean" by Islamov, with blades being rare and no evidence for prepared core technology (Dennell, 2009, p. 330, Vishnyatsky, 1999, p. 95). Derevianko (2008, p. 25) accepts Islamov's designation of bifaces and cleavers, and suggests that the assemblage represents an instance of Acheulean/Middle Palaeolithic acculturation with local pebble cultures *c.* 350-300 kya. However, Derevianko's date is primarily typological, and the theory of acculturation is based on interpretations of deflated surface assemblages at Mugodjari and Semizbugu.

Alternatively, Vishnyatsky (1999, p. 95) highlights the lack of true handaxes and parallels with other Central Asian pebble industries, and classifies the Sel'ungur assemblage as belonging to a Lower Palaeolithic pebble industry of Central Asia. Davis & Ranov (1999, pp. 189-90) concur with Vishnyatsky, reporting that their own examination of the artefacts led them to regard the Acheulean designation as "doubtful". Instead, they conclude that: "[t]here is little from this site that would fit into the Acheulean technocomplex. Rather, the collection much more easily falls into the pebble and flake industries known from the Central Asia loess" (Davis & Ranov, 1999, pp. 189-90).

Ranov et al. (1995, p. 339) describe the assemblage as "a more developed strategy" than that at Karatau I, although broadly similar in terms of being a pebble core industry with an absence of shaped cores.

The majority of artefacts were made using derived river pebbles of jasper or slate, with little use made of volcanic materials (Davis & Ranov, 1999, pp. 189-90, Vishnyatsky, 1999, p. 95). Dennell (2009, p. 330) also mentions the use of jasper as a raw material, as well as schist.

Faunal Remains: > 5,000 faunal remains were recovered, although poorly preserved, including some identified as hominin remains (Dennell, 2009, p. 330, Glantz, 2010, p. 105). Analysis of the fossil rodent remains recovered from the 'Acheulean' levels indicate a Middle Pleistocene age (Markova, 1992, p. 238).

Hominin Remains: The proposed hominin remains included six teeth, fragments of a humerus, and a possible occipital fragment, and these were classified by the original excavators as a local variant of *H. erectus* with advanced traits (Glantz, 2010, p. 105, Vishnyatsky, 1999, p. 95). V. P. Alekseev is noted by Velichko as classifying the occipital fragment as "preneandertal", although there is no elaboration made on that interpretation (Davis & Ranov, 1999, p. 189). However, Glantz et al. 2004 (Glantz, 2010, p. 105) have identified the teeth as non-hominin, although the long bone is classified as having belonged to an unidentifiable juvenile hominin.

Interpretation: Ranov et al. (1995, p. 339) suggest that Sel'ungur might represent a "home base".

Taphonomy: The lithics initially dubbed 'Acheulean' are reported as coming from 5 separate layers (Markova, 1992, p. 217).

Dating: The deposits at the site are overlain with travertine, which has been dated via Uranium-Thorium dating to 126 ± 5 kya, confirming the deposits as Middle Pleistocene, and possibly indicating that the uppermost archaeological deposit dates to MIS 5e (Dennell, 2009, p. 330).

Climate: As with the Tajik loess Palaeolithic sites, the archaeological layers at Sel'ungur appear to indicate interglacial conditions, while the sterile layers indicate glacial conditions (Dennell, 2009, p. 330).

Additional Notes: Derevianko (2008, p. 25) identifies Sel'ungur as being located in Uzbekistan, which contradicts Dennell (2009).

Semizbugu (Kazakhstan)

77.152100, 46.733704 (from M. Glantz)

Localities: Semizbugu localities 2 and 4 are specifically referenced by Derevianko (Derevianko, 2008, p. 25).

Date: Late Acheulean/Early Middle Palaeolithic (?, Derevianko, 2008, p. 25).

Situation: The Semizbugu mountain sites are located in the northern Lake Balkhash region of Kazakhstan (Derevianko, 2008, p. 25, Vishnyatsky, 1999, p. 103).

Technology: Semizbugu localities 2 and 4 have provided artefacts described as "clearly exemplifying Late Acheulian and early Middle Paleolithic traditions" (Derevianko, 2008, p. 25), and as a result, are compared to the Mugodjari sites, where Derevianko (2008, p. 25) has argued for acculturation between Acheulean/Levallois-using hominins and local pebble culture hominins.

Bifaces have been identified in the assemblages from the Semizbugu localities (Taimagambetov, et al., 2013, p. 690). Taimagambetov et al. (2013, p. 690) ascribe the artefacts from Semizbugu 2 and 4 to the Middle Palaeolithic.

Referring to Semizbugu, Khantau, and Chingiz (all sites located around the Lake Balkhash region), Vishnyatsky (1999, p. 103) has listed the raw materials as flint, porphyrite, and alevrolite (pelitic rock formed from cemented soil).

Shakhbagata (Kazakhstan)

51.529011, 44.194491

Date: Lower Palaeolithic (?)

Site Type: Surface scatter with handaxes.

Technology: Handaxes have been reported from Shakhbagata (Dennell, 2009, p. 332, Vishnyatsky, 1999, p. 77).

Taphonomy: Probably deflated, probably a mix of periods.

Dating: While some of the lithic material from Shakhbagata is undoubtedly Palaeolithic in age, the collection from this site has no firm geological context, and probably represents a mix of periods (Vishnyatsky, 1999, p. 77).

Shoktas (Kazakhstan)

Modelled as sharing coordinates with Koshkurgan.

Localities: Shoktas I, II, and III.

Date: 500 kya (Moloney, et al., 2001, p. 139).

Technology: As with the Koshkurgan localities, the industry represented at the Shoktas localities is considered a "microindustry", and compared with that at Vértesszölös and Bilzingsleben (Vishnyatsky, 1999, p. 102).

Dating: Dated to *c.* 500 kya via ESR dating on travertine deposits (Moloney, et al., 2001, p. 139). Taimagambetov et al. (2013, p. 689) report the combined ESR date range from Shoktas I and Koshkurgan I as 500-300 kya.

Vishnëvka (Kazakhstan)

71.266579, 50.787350

Localities: Vishnëvka 3 and 6.

Date: Lower Palaeolithic/Middle Palaeolithic (?).

Site Type: Open-air site with handaxes.

Technology: Handaxes were found at Vishnëvka 3, which Vishnyatsky (1999, p. 103) interprets as possibly Acheulean.

The artefacts recovered from Vishnëvka 6 also include bifaces, described as small ovates, as well as biface thinning flakes and debris, cores, and flakes, some with retouch (Moloney, et al., 2001, p. 141). Moloney et al. (2001, p. 141) report that similar finds were found in a surface context during a visit to the site (probably by Sandra Olsen in 2000). The bifaces and thinning flakes are indicative of soft-hammer use (Moloney, et al., 2001, p. 142). Moloney et al. (2001, p. 142) interpret the small handaxes and the retouched component of the assemblage as indicating a Middle Palaeolithic technology.

Taphonomy: Vishnëvka 6 is a well-preserved open-air site (Moloney, et al., 2001, p. 141).

Dating: Typological.

Yangdja (Turkmenistan)

53.632454, 40.294554

Date: Lower Palaeolithic (?)

Site Type: Surface scatter with bifaces.

Situation: Located on the surface of an eroded stream terrace on the Krasnovodsk plateau... uncertain citation (Dennell, 2009, p. 332, Glantz, 2010, p. Table 8.1, Vishnyatsky, 1999, p. 72).

Technology: Yangdja is a surface scatter of tools, consistent with an Acheulean technology... uncertain citation (Dennell, 2009, p. 332, Glantz, 2010, p. Table 8.1, Vishnyatsky, 1999, p. 72). Derevianko (2008, p. 24) attributes the artefacts to a Late Acheulean/Middle Palaeolithic transitional industry.

The assemblage includes up to 20 bifacial tools, including some definite handaxes, some of which are broken or unfinished (Dennell, 2009, p. 332, Vishnyatsky, 1999, p. 72). The surface section that produced the handaxes also produced unretouched flakes and irregular cores, but no other tool types (Vishnyatsky, 1989, p. 97, Vishnyatsky, 1999, p. 72).

The raw material for all the tools is locally-sourced flint from the stream terrace where the site is located (Dennell, 2009, p. 332, Vishnyatsky, 1999, p. 72).

Interpretation: Interpreted as a lithic workshop… uncertain citation (Dennell, 2009, p. 332, Glantz, 2010, p. Table 8.1, Vishnyatsky, 1999, p. 72).

Taphonomy: The proposed Acheulean assemblage is seen to be differentially worn by “desert varnish” versus a nearby Neolithic assemblage made on the same flint (Vishnyatsky, 1999, p. 72). This patina suggest to VISHNYATSKY (1989:97) that the finds are of Pleistocene age.

Dating: Typological. Vishnyatsky (1999, p. 72) interprets the Yangdja assemblage as Acheulean partly on a typological basis, but also because he regards handaxes as largely absent throughout the Middle Palaeolithic record of Central Asia.

Appendix 2. Spatial Data Sources

1. Site coordinate data for the mapping in this project has been obtained from several sources:
    i. Site coordinate data provided by Mica Glantz of Colorado State University (CSU). Collected by Mica Glantz, Tyler Beeton, and Sayat Temirbekov.
    ii. The coordinate data for Sel'ungur was provided by Bence Viola of the University of Toronto.
    iii. Site coordinate data reverse-engineered from geo-referenced maps available in the literature: (Chlachula, 2010), (Dennell, 2009), (Dodonov, et al., 2006), (Frumkin, 1970), (Gupta, 1979), (Klein, 1966), (Moloney, et al., 2001), (Ranov, et al., 1995)
2. Administrative area data has been used from the Global Administrative Areas (GADM) dataset, developed by Robert Hijmans and colleagues http://www.gadm.org/about
3. 1:10m modern physical data has been used from the Natural Earth dataset. Free vector and raster map data @ naturalearthdata.com
4. WorldClim 1.4 temperature and precipitation derived from LIG palaeoclimate models, published by (Otto-Bliesner, et al., 2006).
5. Shuttle Radar Topography Mission (SRTM) Version 4 dataset, Jarvis A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT), available from http://srtm.csi.cgiar.org
6. Generalized Geology of the Former Soviet Union (geo1ec). Published in 1998 by the U.S. Geological Survey, Central Energy Resources Team and Dr. Thomas Ahlbrandt. https://certmapper.cr.usgs.gov/data/we/ofr97470e/spatial/shape/geo1ec.zip https://energy.cr.usgs.gov/oilgas/wep/
7. World map of carbonate outcrops, version 3. Published by (Williams & Fong, 2010).

Bibliography

Abe, Manabu, Tetsuzo Yasunari, and Akio Kitoh. 2005. Sensitivity of the central Asian climate to uplift of the Tibetan Plateau in the coupled climate model (MRI-CGCM1). *The Island Arc* 14: 378-388.

Abramowski, U, A Bergau, D Seebach, R Zech, B Glaser, P Sosin, P Kubik, and W Zech. 2006. Pleistocene glaciations of Central Asia: results from 10Be surface exposure ages of erratic boulders from the Pamir (Tajikistan), and the Alay–Turkestan range (Kyrgyzstan). *Quaternary Science Reviews* 25 (9-10): 1080-1096.

Aiello, L, and P Wheeler. 1995. The expensive-tissue hypothesis: the brain and the digestive system in human and primate evolution. *Current anthropology* 36 (2): 199-221.

Aizen, V, E Aizen, J Melack, and J Dozier. 1997. Climatic and Hydrologic Changes in the Tien Shan, Central Asia. *Journal of Climate* 10: 1393-1404.

Alexeiev, Dmitriy V, Harry E Cook, Vasiliy M Buvtyshkin, and Lyudmila Y Golub. 2009. Structural evolution of the Ural–Tian Shan junction: A view from Karatau ridge, South Kazakhstan. *C. R. Geoscience* 341: 287–297.

Alibaigi, Sajjad, and Shokouh Khosravi. 2009. Tepeh Khaleseh: a new Neolithic and Palaeolithic site in the Abharrud basin in north-western Iran. *Antiquity* 83 (319).

Alibaigi, Sajjad, Kamal Aldin Niknami, and Shokouh Khosravi. 2010. A Preliminary Report on the Investigations of the Lower Paleolithic site of Khaleseh in the Khoram Dareh Valley, Zanjan. *Iranian Archaeology* 1: 8-14.

Alibaigi, Sajjad, Kamal Aldin Niknami, Mohsen Heydari,, Meysam Nikzad, Mohsen Zainivand, Sirvan Manhobi, Sirvan Mohammadi Qasrian, Mehdi Khalili, and Nasim Islami. 2011.

Palaeolithic open-air sites revealed in the Kuran Buzan Valley, Central Zagros, Iran. *Antiquity* 85 (329).

Alipova, S B. 2012. Nižnepaleolitičeskaja stojanka Južnogo Kazahstana Kyzyltau v Evrazii. *KazNU Bulletin: History Series* 67 (4): 105-110.

Antón, S, W Leonard, and M Robertson. 2002. An ecomorphological model of the initial hominid dispersal from Africa. *Journal of Human Evolution* 43 (6): 773-785.

Ao, H, C Deng, M Dekkers, and Q Liu. 2010b. Magnetic mineral dissolution in Pleistocene fluvio-lacustrine sediments, Nihewan Basin (North China). *Earth and Planetary Science Letters* 292: 191–200.

Ao, Hong, Chenglong Deng, Mark J Dekkers, Youbin Sun, Qingsong Liu, and Rixiang Zhu. 2010a. Pleistocene environmental evolution in the Nihewan Basin and implication for early human colonization of North China. *Quaternary International* 223-224: 472-478.

Ao, Hong, Mark J Dekkers, Qi Wei, Xiaoke Qiang, and Guaqiao Xiao. 2013b. New evidence for early presence of hominids in North China. *Scientific Report* 3 (2403): 1-5.

Ao, Hong, Zhisheng An, Mark J Dekkers, Qi Wei, Shuwen Pei, Hui Zhao, Hongli Zhao, et al. 2012. High-resolution record of geomagnetic excursions in the Matuyama chron constrains the ages of the Feiliang and Lanpo Paleolithic sites in the Nihewan Basin, North China. *Geochemistry, Geophysics, Geosystems* 13 (8).

Ao, Hong, Zhisheng An, Mark J Dekkers, Yongxiang Li, Guoqiao Xiao, Hui Zhao, and Xiaoke Qiang. 2013a. Pleistocene magnetochronology of the fauna and Paleolithic sites in the Nihewan Basin: Significance for environmental and hominin evolution in North China. *Quaternary Geochronology.*

Arribas, A, and P Palmqvist. 1999. On the ecological connection between sabre-tooths and hominids: faunal dispersal events in the lower Pleistocene and a review of the evidence for the first human arrival in Europe. *Journal of Archaeological Science* 26 (5): 571-585.

Attwell, L, K Kovarovic, and J Kendal. 2015. Fire in the Plio-Pleistocene: the functions of hominin fire use, and the mechanistic, developmental and evolutionary consequences. *Journal of anthropological sciences* 93: 1-20.

Babaev, A. 1994. The Natural Conditions of Central Asian Deserts. In *Desert problems and desertification in central Asia: The researchers of the desert institute*, edited by A Babaev, 5-20. Springer Science & Business Media.

Baena, Javier, David Lordkipanidze, Felipe Cuartero, Reid Ferring, David Zhvania, Diego Martin, Teona Shelia, Giorgi Bidzinashuili, Marta Roca, and Daniel Rubio. 2010. Technical and technological complexity in the beginning: The study of Dmanisi lithic assemblage. *Quaternary International* 223: 45-53.

Baigunakov, D, and G Sabdenova. 2014. Some Results Of Studying The Ancient History of Kazakhstan. *Procedia - Social and Behavioral Sciences* 131: 304-308.

Bailey, Geoffrey N, and Geoffrey C. P King. 2011. Dynamic landscapes and human dispersal patterns: tectonics, coastlines, and the reconstruction of human habitats. *Quaternary Science Reviews* 30 (11): 1533-1553.

Bailey, Geoffrey N, Sally C Reynolds, and Geoffrey C. P King. 2011. Landscapes of human evolution: models and methods of tectonic geomorphology and the reconstruction of hominin landscapes. *Journal of Human Evolution* 3: 257-280.

Bar-Yosef, O, M I Eren, J Yuan, D J Cohen, and Y Li. 2012. Were bamboo tools made in prehistoric Southeast Asia? An experimental view from South China. *Quaternary International* 269: 9-21.

Bar-Yosef, Ofer. 1994. The Lower Paleolithic of the Near East. *Journal of World Prehistory* 8 (3): 211-265.

Bar-Yosef, Ofer, and Youping Wang. 2012. Palaeolithic Archaeology in China. *Annual Review of Anthropology* 41 (3): 19-35.

Basell, Laura S. 2008. Middle Stone Age (MSA) site distributions in eastern Africa and their relationship to Quaternary environmental change, refugia and the evolution of Homo sapiens. *Quaternary Science Reviews* 27: 2484–2498.

Beeton, Tyler A, Michelle M Glantz, Anna K Trainer, Sayat S Temirbekov, and Robin M Reich. 2014. The fundamental hominin niche in late Pleistocene Central Asia: a preliminary refugium model. *Journal of Biogeography* 41 (1): 95-110.

Berna, F, P Goldberg, L Horwitz, J Brink, S Holt, M Bamford, and M Chazan. 2012. Microstratigraphic evidence of in situ fire in the Acheulean strata of Wonderwerk Cave, Northern Cape province, South Africa. *PNAS* 109 (20): E1215-E1220.

Biglari, Fereidoun, and Sonia Shidrang. 2006. The Lower Paleolithic Occupation of Iran. *Near Eastern Archaeology* 69 (3/4): 160-168.

Biglari, Fereidoun, and Vali Jahani. 2011. The Pleistocene Human Settlement in Gilan, Southwest Caspian Sea: Recent Research. *Eurasian Prehistory* 8 (1-2): 3-28.

Biglari, Fereidoun, Saman Heydari, and Sonia Shidrang. 2004. Ganj Par: The first evidence for Lower Paleolithic occupation in the Southern Caspian Basin, Iran. *Antiquity* 78 (302).

Biglari, Fereydoun, Gabriel Nokandeh, and Saman Heydari. 2000. A recent find of a possible Lower Palaeolithic assemblage from the foothills of the Zagros Mountains. *Antiquity* 74: 749-750.

Blackwell, P G. 2007. Heterogeneity, patchiness and correlation of resources. *Ecological Modelling* 207: 349-355.

Blain, Hugues-Alexandre, Jordi Agustí, David Lordkipanidze, Lorenzo Rook, and Massimo Delfino. 2014. Paleoclimatic and paleoenvironmental context of the Early Pleistocene hominins from Dmanisi (Georgia, Lesser Caucasus) inferred from the herpetofaunal assemblage. *Quaternary Science Reviews* 105: 136-150.

Blinkhorn, James, Hema Achyuthan, Michael Petraglia, and Peter Ditchfield. 2013. Middle Palaeolithic occupation in the Thar Desert during the Upper Pleistocene: the signature of a modern human exit out of Africa? *Quaternary Science Reviews* 77: 233-238.

Boëda, Eric, and Ya-Mei Hou. 2011. Analyse des artefacts lithiques du site de Longgupo. *L'anthropologie* 115: 78-175.

Boomer, Ian, Nikolai Aladin, Igor Plotnikov, and Robin Whatley. 2000. The palaeolimnology of the Aral Sea: a review. *Quaternary Science Reviews* 19: 1259-1278.

Bowen, Robert. 1980. *Ground Water.* London: Applied Science Publishers Ltd.

Bradley, R. 2015. *Paleoclimatology: Reconstructing climates of the Quaternary.* 3rd. Oxford: Academic Press.

Brill Olcott, M. 1997. Kazakhstan. In *Kazakstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan*, edited by G Curtis, 3-98. Department of the US Army.

Bronger, A. 2003. Correlation of loess–paleosol sequences in East and Central Asia with SE Central Europe: towards a continental Quaternary pedostratigraphy and paleoclimatic history. *Quaternary International* 106: 11-31.

Bronger, A, R Winter, and T Heinkele. 1998. Pleistocene climatic history of East and Central Asia based on paleopedological indicators in loess–paleosol sequences. *Catena* 34 (1-2): 1-17.

Burdukiewicz, Jan Michal. 2009. Lower Palaeolithic Transitions in the Northern Latitudes of Eurasia. In *Sourcebook of Paleolithic Transitions: Methods, Theories, and Interpretations*, edited by Marta Camps and Parth Chauhan, 195-209. London: Springer.

Burov, E, and P Molnar. 1998. Gravity anomalies over the Ferghana Valley (central Asia) and intracontinental deformation. *Journal of Geophysical Research: Solid Earth* 103 (B8): 18137-18152.

Cai, M, X Fang, F Wu, Y Miao, and E Appel. 2012. Pliocene–Pleistocene stepwise drying of Central Asia: evidence from paleomagnetism and sporopollen record of the deep borehole SG-3 in the western Qaidam Basin, NE Tibetan Plateau. *Global and Planetary Change* 94: 72-81.

Calvo-Rathert, M, A Goguitchaichvili, D Sologashvili, J J Villalaín, M F Bógalo, A Carrancho, and G Maissuradze. 2008. New paleomagnetic data from the hominin bearing Dmanisi paleo-anthropologic site (southern Georgia, Caucasus). *Quaternary Research* 69: 91-96.

Cerling, Thure E, Jonathan G Wynn, Samuel A Andanje, Michael I Bird, David Kimutai Korir, Naomi E Levin, William Mace, Anthony N Macharia, Jay Quade, and Christopher H

Remien. 2011. Woody cover and hominin environments in the past 6 million years. *Nature* 476 (4): 51-56.

Chappell, John E. 1963. Soviet Cartography: Comparisons and Gaps. *The Professional Geographer* 15 (2): 1-7.

Charlet, F, N Fagel, M De Batist, F Hauregard, B Minnebo, D Meischner, and SONIC Team. 2005. Sedimentary dynamics on isolated highs in Lake Baikal: evidence from detailed high-resolution geophysical data and sediment cores. *Global and Planetary Change* 46 (1-4): 125-144.

Chauhan, Parth R. 2007. Soanian cores and core-tools from Toka, Northern India: Towards a new typo-technological organization. *Journal of Anthropological Archaeology* 26: 412-441.

Chen, F, Z Yu, M Yang, E Ito, S Wang, D Madsen, X Huang, et al. 2008. Holocene moisture evolution in arid central Asia and its out-of-phase relationship with Asian monsoon history. *Quaternary Science Reviews* 27 (3-4): 351-364.

Cheng, H, P Z Zhang, C Spötl, R L Edwards, Y J Cai, D Z Zhang, W C Sang, M Tan, and Z S An. 2012. The climatic cyclicity in semiarid-arid central Asia over the past 500,000 years. *Geophysical Research Letters* 39: L01705.

Chlachula, Jiri. 2010. Pleistocene climate change, natural environments and Palaeolithic occupation of East Kazakhstan. *Quaternary International* 220 (1): 64-87.

Chlachula, Jiri. 2001. Pleistocene climate change, natural environments and palaeolithic occupation of the upper Yenisei area, south-central Siberia. *Quaternary International* 80-81: 101-130.

Clark, J Desmond, and Kathy D Schick. 1988. Context and content: impressions of Palaeolithic sites and assemblages in the People's Republic of China. *Journal of Human Evolution* 17: 439-448.

Clark, Peter U, David Archer, David Pollard, Joel D Blum, Jose A Rial, Victor Brovkin, Alan C Mix, Nicklas G Pisias, and Martin Roy. 2006. The middle Pleistocene transition: characteristics, mechanisms, and implications for long-term changes in atmospheric pCO2. *Quaternary Science Reviews* 25: 3150–3184.

Clarkson, Chris, Sacha Jones, and Clair Harris. 2012. Continuity and change in the lithic industries of the Jurreru Valley, India, before and after the Toba eruption. *Quaternary International* 258: 165-179.

Codrington, K de B. 1944. A geographical introduction to the history of Central Asia. *Geographical journal* 1 (Jul): 27-40.

Coe, Angela L, Tom W Argles, David A Rothery, and Robert A Spicer. 2010. *Geological Field Techniques.* Oxford: Blackwell.

Conolly, James, and Mark Lake. 2006. *Geographical Systems in Archaeology.* Cambridge: Cambridge University Press.

Copeland, S, M Sponheimer, D de Ruiter, J Lee-Thorp, D Codron, P le Roux, V Grimes, and M Richards. 2011. Strontium isotope evidence for landscape use by early hominins. *Nature* 474 (7349): 76-78.

Cristescu, M, P Hebert, and T Onciu. 2003. Phylogeography of Ponto-Caspian crustaceans:a benthic-planktonic comparison. *Molecular Ecology* 12: 985-996.

Darabi, Hojjat, Ardeshir Javanmardzadeh, Amir Beshkani, and Mana Jami-Alahmadi. 2012. Palaeolithic occupation of the Mehran Plain in Southwestern Iran. *Documenta Praehistorica* 39: 443-451.

Davis, Richard S. 1987. Regional Perspectives on the Soviet Central Asian Paleolithic. In *The Pleistocene Old World: Regional Perspectives*, edited by O Soffer, 121-133. New York: Plenum Press.

Davis, Richard S. 1988. The Implications of Improved Chronological Determinations for the Soviet Central Asian Paleolithic. In *Upper Pleistocene Prehistory of Western Eurasia*, edited by Harold Lewis Dibble and Anta Montet-White, 297-301. Philadelphia: University of Pennsylvania.

Davis, Richard S, and Louis Dupree. 1977. Prehistoric Survey in Central Afghanistan. *Journal of Field Archaeology* 4 (2): 139-148.

Davis, Richard S, and Vadim A Ranov. 1999. Recent Work on the Paleolithic of Central Asia. *Evolutionary Anthropology* 8 (5): 186-193.

Davis, Richard S, Vadim A Ranov, and Andrey E Dodonov. 1980. Early Man ·in Soviet Central Asia. *Scientific American* 243 (6): 130-137.

Davoudi, D, B Bazgir, R Abbasnejad, D Barsky, A Ollé, and M Otte. 2015. The Lower Palaeolithic of Iran: Probing New Finds from Mar Gwergalan Cave (Holeylan, Central Zagros). *Archaeology Ethnology & Anthropology of Eurasia* 43 (1): 3-15.

de Lumley, Henry, Médéa Nioradzé, Deborah Barsky, Dominique Cauche, Vincenzo Celiberti, Giorgie Nioradzé, Olivier Notter, David Zvania, and David Lordkipanidze. 2005. Les industries lithiques préoldowayennes du début du Pléistocène inférieur du site de Dmanissi en Géorgie. *L'anthropologie* 109: 1-182.

Demko, George J. 1965. Trends and Controversies in Soviet Geography. In *The State of Soviet Science*, 165-172. Cambridge: The M.I.T. Press.

Demory, F, N Nowaczyk, A Witt, and H Oberhänsli. 2005. High-resolution magnetostratigraphy of late quaternary sediments from Lake Baikal, Siberia: timing of intracontinental paleoclimatic responses. *Global and Planetary Change* 46 (1-4): 167-186.

Deng, C, R Zhu, R Zhang, H Ao, and Y Pan. 2008. Timing of the Nihewan formation and faunas. *Quaternary Research* 69: 77–90.

Deng, Chenglong, Fei Xie, Caicai Liu, Hong Ao, Yongxin Pan, and Rixiang Zhu. 2007. Magnetochronology of the Feiliang Paleolithic site in the Nihewan Basin and implications for early human adaptability to high northern latitudes in East Asia. *Geophysical Research Letters* 34: 1-6.

Deng, Chenglong, Qi Wei, Rixiang Zhu, Hongqiang Wang, Rui Zhang, Hong Ao, Liao Chang, and Yongxin Pan. 2006. Magnetostratigraphic age of the Xiantai Paleolithic site in the Nihewan Basin and implications for early human colonization of Northeast Asia. *Earth and Planetary Science Letters* 244: 336-348.

Dennell, Robin. 2013a. Hominins, deserts, and the colonisation and settlement of continental Asia. *Quaternary International* 300: 13-21.

Dennell, Robin. 2016. Life without the Movius line: the structure of the east and Southeast Asian Early Palaeolithic. *Quaternary International* 400: 14-22.

—. 2009. *The Palaeolithic Settlement of Asia.* Cambridge: Cambridge Univesity Press.

Dennell, Robin W. 2007. Resource-rich, stone-poor : Early hominin land use in large river systems of northern India and Pakistan. In *The Evolution and History of Human Populations in South Asia*, edited by M D Petraglia and B Allchin, 41-68. Springer.

Dennell, Robin W. 1998. Grasslands, tool making and the hominid colonization of southern Asia: a reconsideration. In *Early Human Behaviour in Global Context: The Rise and Diversity of the Lower Palaeolithic Record*, edited by Michael D Petraglia and Ravi Korisettar, 280-303. London: Routledge.

Dennell, Robin W. 2013b. The Nihewan Basin of North China in the Early Pleistocene: Continuous and flourishing, or discontinuous, infrequent and ephemeral occupation? *Quaternary International* 295: 223-236.

Dennell, Robin W, H M Rendell, and E Hailwood. 1988a. Late Pliocene Artefacts from Northern Pakistan. *Current Anthropology* 29 (3): 495-498.

Dennell, Robin W, H Rendell, and E Hailwood. 1988b. Early tool-making in Asia: two-million-year-old artefacts in Pakistan. *Antiquity* 62: 98-106.

Dennell, Robin, and Wil Roebroeks. 2005. An Asian perspective on early human dispersal from Africa. *Nature* 438 (7071): 1099-1104.

Derevianko, A P. 2008. The Bifacial Technique in China. *Archaeology Ethnology and Anthropology of Eurasia* 33 (1): 2-32.

Derevianko, A P, and M V Shunkov. 2008. The Settling of the Ancient Man by the Example of North-Western Altai. In *Biosphere Origin and Evolution*, edited by Nikolay Dobretsov, Nikolay Kolchanov, Alexy Rozanov and Georgy Zavarzin, 395-406. Springer.

Derevianko, A P, J W Olsen, D Tseveendorj, A I Krivoshapkin, V T Petrin, and P J Brantingham. 2000. The stratified cave site of Tsagaan Agui in the Gobi Altai (Mongolia). *Archaeology, Ethnology and Anthropology of Eurasia* 1 (1): 23-36.

DeSilva, J, E McNutt, J Benoit, and B Zipfel. 2018. One small step: A review of Plio-Pleistocene hominin foot evolution. *YEARBOOK OF PHYSICAL ANTHROPOLOGY* 168 (S67): 63–140.

Devés, Maud H, Sally Reynolds, Geoffrey C. P King, Simon Kuebler, Derek Sturdy, and Nan Godet. 2015. Insights from Earth Sciences into Human Evolution studies:The example of prehistoric landscape use in Africa and the Levant. *Comptes Rendus Geoscience* 347: 201-211.

Devés, Maud, Derek Sturdy, Nan Godet, Geoffrey C. P King, and Geoffrey N Bailey. 2014. Hominin reactions to herbivore distribution in the Lower Palaeolithic of the Southern Levant. *Quaternary Science Reviews* 96: 140-160.

Ding, Z L, V Ranov, S L Yang, A Finaev, J M Han, and G A Wang. 2002. The loess record in southern Tajikistan and correlation with Chinese loess. *Earth and Planetary Science Letters* 200: 387-400.

Dixon, Dougal, and Raymond L Bernor. 1992. *The Practical Geologist.* London: Quarto.

Dodonov, A E. 1991. Loess of Central Asia. *GeoJournal* 24 (2): 185-194.

Dodonov, A E, and L L Baiguzina. 1995. Loess Stratgraphy of Central Asia: Palaeoclimatic and Palaeoenvironmental Aspects. *Quaternary Science Reviews* 14: 707-720.

Dodonov, A E, N Shackleton, L P Zhou, S P Lomov, and A F Finaev. 1999. Quaternary Loess Paleosol Stratigraphy of Central Asia: Geochronology, Correlation, and Evolution of Paleoenvironments. *Stratigraphy and Geological Correlation* 7 (6): 581-593.

Dodonov, A E, T A Sadchikova, S N Sedov, A N Simakova, and L P Zhou. 2006. Multidisciplinary approach for paleoenvironmental reconstruction in loess-paleosol studies of the Darai Kalon section, Southern Tajikistan. *Quaternary International* 152-153: 48-58.

Dodonov, A. 2005. The stratigraphic transition and suggested boundary between the Early and Middle Pleistocene in the loess record of northern Eurasia. *Geological Society, London, Special Publications* 247 (1): 209-219.

Domínguez-Rodrigo, M. 2014. Is the Savanna Hypothesis a Dead Concept for Explaining the Emergence of the Earliest Hominins? *Current Anthropology* 55 (1): 59-81.

Dunbar, R. 1992. Neocortex size as a constraint on group size in primates. *Journal of human evolution* 22 (6): 469-493.

Dunbar, R. 2009. The social brain hypothesis and its implications for social evolution. *Annals of human biology* 36 (5): 562-572.

Dupree, Louis, and Richard S Davis. 1976. New Prehistoric Localities in the Dasht-i-Newar. *Afghanistan* 29 (3): 13-37.

Dupree, Nancy Hatch. 2006. Prehistoric Afghanistan. In *Art and Archaeology in Afghanistan, its Fall and Survival*, edited by Juliette van Krieken-Pieters, 79-93. Leiden-Boston: Brill.

Ebert, James I. 2000. The State of the Art in Inductive Predictive Modeling: Seven Big Mistakes (and Lots of Smaller Ones). In *Practical Applications of GIS for Archaeologists: A Predictive Modeling Kit*, edited by Konnie L Westcott and R Joe Brandon, 129-134. London: Taylor & Francis.

Edlund, M, and E Stoermer. 2000. A 200,000-year, high-resolution record of diatom productivity and community makeup from Lake Baikal shows high correspondence to the marine oxygen-isotope record of climate change. *Limnology and Oceanography* 45 (4): 948-962.

Fan, Guangwe, James F Ni, and Terry C Wallace. 1994. Active tectonics of the Pamirs and Karakorum. *Journal of Geophysical Research* 99 (B4): 7131-7160.

Feakins, Sarah J, Naomi E Levin, Hannah M Liddy, Alexa Sieracki, Timothy I Eglinton, and Raymonde Bonnefille. 2013. Northeast African vegetation change over 12 m.y. *Geology* 41: 295-298.

Fernández, P, C Mongle, L Leakey, D Proctor, C Orr, B Patel, S Almécija, M Tocheri, and W Jungers. 2018. Evolution and function of the hominin forefoot. *PNAS* 115 (35): 8746–8751.

Ferring, Reid, Oriol Oms, Jordi Augusti, Francesco Berna, Medea Nioradze, Teona Shelia, Martha Tappen, Abesalom Vekua, David Zhvania, and David Lordkipanidze. 2011. Earliest human occupations at Dmanisi (Georgian Caucasus) dated to 1.85–1.78 Ma. *PNAS* 108 (26): 10432–10436.

Field, Julie S, and Marta Mirazón Lahr. 2005. Assessment of the southern dispersal: GIS-based analyses of potential routes at Oxygen Isotopic Stage 4. *Journal of World Prehistory* 19 (1): 1-45.

Field, Julie S, Michael D Petraglia, and Marta Mirazón Lahr. 2007. The southern dispersal hypothesis and the South Asian archaeological record: Examination of dispersal routes through GIS analysis. *Journal of Anthropological Archaeology* 26 (1): 88-108.

Finlayson, Clive. 2014. *The Improbable Primate: How Water Shaped Human Evolution.* Oxford: Oxford University Press.

Flas, Damien, Ksenia Kolobova, Kostantin Pavlenok, Dimitri A. G. Vandenberghe, Morgan De Dapper, Sergei Leschisnky, Bence Viola, Utkur Islamov, Anatoly P. Derevianko, and Nicolas Cauwe. 2010. Preliminary results of new excavations at the Palaeolithic site of Kulbulak (Uzbekistan). *Antiquity* 84 (325).

Foley, Robert. 1981a. A Model of Regional Archaeological Structure. *Proceedings of the Prehistoric Society* 47: 1-17.

Foley, Robert. 1981b. Off-site archaeology: an alternative approach for the short-sighted. In *Pattern of the Past: Studies in Honour of David Clarke*, edited by Ian Hodder, Glynn Isaac and Norman Hammond, 157-183. Cambridge: Cambridge University Press.

Forster, T, and F Heller. 1994. Loess deposits from the Tajik depression (Central Asia): magnetic properties and paleoclimate. *Earth and Planetary Science Letters* 128 (3-4): 501-512.

Frachetti, Michael D. 2012. Multiregional Emergence of Mobile Pastoralism and Nonuniform Institutional Complexity across Eurasia. *Current Anthropology* 53 (1): 2-38.

Frenchen, M, and A E Dodonov. 1998. Loess Chronology of the Middle and Upper Pleistocene in Tadjikistan. *Geologische Rundschau* 87: 2-20.

Frumkin, Grégoire. 1970. *Archaeology in Soviet Central Asia.* Leiden: E. J. Brill.

Gabounia, Leo, Marie-Antoinette de Lumley, Abesalom Vekua, David Lordkipanidze, and Henry de Lumley. 2002. Découverte d'un nouvel hominidé à Dmanissi (Transcaucasie, Géorgie). *Paléontologie humaine et préhistoire* 1: 243-253.

Gabunia, L, and A Vekua. 1995. A Plio-Pleistocene hominid from Dmanisi, East Georgia, Caucasus. *Nature* 373: 509-512.

Gabunia, Leo, Abesalom Vekua, and David Lordkipanidze. 2000b. The environmental contexts of early human occupation of Georgia human occupation of Georgia. *Journal of Human Evolution* 38: 785-802.

Gabunia, Leo, Abesalom Vekua, David Lordkipanidze, Carl C Swisher III, Reid Ferring, Antje Justus, Medea Nioradze, et al. 2000a. Earliest Pleistocene Hominid Cranial Remains from Dmanisi, Republic of Georgia: Taxonomy, Geological Setting, and Age. *Science* 288: 1019-1025.

Gabunia, Leo, Susan C Antón, David Lordkipanidze, Abesalom Vekua, Antje Justus, and Carl C Swisher III. 2001. Dmanisi and Dispersal. *Evolutionary Anthropology* 10: 158-170.

Gaffney, V, and M van Leusen. 1995. Postscript - GIS, environmental determinism and archaeology: a parallel text. In *Archaeology and geographic information systems: A European perspective*, edited by Gary R Lock and Zoran Stančič, 367-382. Boca Raton: CRC Press.

Galat, G, A Galat-Luong, and G Nizinski. n.d. Our cousins chimpanzees and baboons face global warming by digging wells to filtrate drinking water. Proceedings 13th International Water Resource Association Congress.

Gamble, C, and M Porr. 2005. From empty spaces to lived lives. In *Hominid Individual in Context: Archaeological Investigations of Lower and Middle Palaeolithic landscapes, locales and artefacts*, edited by C Gamble and M Porr, 1-12. London: Routledge.

Gamble, Clive. 2013. *Settling the Earth: The Archaeology of Deep Human History.* Cambridge: Cambridge University Press.

Ganjoo, R K, and R W Dennell. 1986. On Lower Palaeolithic Artefacts From Pakistan. *Current Anthropology* 27 (2): 152-153.

Gao, Xing, and Ying Guan. 2018. Handaxes and the Pick-Chopper Industry of Pleistocene China. *Quaternary International* 1-9.

Gao, Xing, Qi Wei, Chen Shen, and Susan Keates. 2005. New Light on the Earliest Hominid Occupation in East Asia. *Current Anthropology* 46 (S5): S115-S120.

Garcia, Tristan, Gilbert Féraud, Christophe Falguères, Henry de Lumley, Christian Perrenoud, and David Lordkipanidze. 2010. Earliest human remains in Eurasia: New 40Ar/39Ar dating of the Dmanisi hominid-bearing levels, Georgia. *Quaternary Geochronology* 5 (4): 443-451.

Gardelle, J, E Berthier, Y Arnaud, and A Kaab. 2013. Region-wide glacier mass balances over the Pamir-Karakoram-Himalaya during 1999-2011. *The Cryosphere* 7 (6): 885-1886.

Gessner, U, V Naeimi, I Klein, C Kuenzer, D Klein, and S Dech. 2013. The relationship between precipitation anomalies and satellite-derived vegetation activity in Central Asia. *Global and Planetary Change* 110: 74–87.

Gibson, James J. 2015. *The Ecological Approach to Visual Perception.* New York: Taylor & Francis.

Gillings, Mark. 2009. Visual affordance, landscape, and the megaliths of Alderney. *Oxford Journal of Archaeology* 28 (4): 335-356.

Glantz, Michelle M. 2010. The History of Hominin Occupation of Central Asia in Review. In *Asian Palaeoanthropology: From Africa to China and Beyond*, edited by Christopher J Norton and David R Braun, 101-112. London: Springer.

Glantz, Michelle, Adam Van Arsdale, Sayat Temirbekov, and Tyler Beeton. 2018. How to survive the glacial apocalypse: Hominin mobility strategies in late Pleistocene Central Asia. *Quaternary International* 466: 82-92.

Goldberg, E, M Phedorin, M Grachev, V Bobrov, I Dolbnya, O Khlystov, O Levina, and G Ziborova. 2000. Geochemical signals of orbital forcing in the records of paleoclimates found in the sediments of Lake Baikal. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 448 (1-2): 384-393.

Goudie, A. 1983. Dust storms in space and time. *Progress in Physical Geography* 7 (4): 502-530.

—. 2002. *Great warm deserts of the world: landscapes and evolution.* Oxford: Oxford University Press.

Grabowski, M, K Hatala, and W Jungers. 2018. Body mass estimates of the earliest possible hominins and implications for the last common ancestor. *Journal of Human Evolution* 122: 84-92.

Gręzak, A, A Sołtysiak, H R Valipour, and H Davoudi. 2010. Short Fieldwork Report: Tepe Khaleseh (Iran), season 2009. *Bioarchaeology of the Near East* 4: 58-63.

Gribbin, John, and Mary Gribbin. 1990. *Children of the Ice.* Oxford: Basil Blackwell.

Grigoryev, A A. 1955. The State of Soviet Geography. *The Geographical Journal* 121 (4): 429-439.

Grun, Rainer, Pei-Hua Huang, Xinzhi Wu, Chris B Stringer, Alan G Thorne, and Malcolm McCulloch. 1997. ESR analysis of teeth from the palaeoanthropological site of Zhoukoudian, China. *Journal of Human Evolution* 32: 83-91.

Grygar, T, A Bláhová, D Hradil, P Bezdička, J Kadlec, P Schnabl, G Swann, and H Oberhänsli. 2007. Lake Baikal climatic record between 310 and 50 ky BP: Interplay between diatoms, watershed weathering and orbital forcing. *Palaeogeography, Palaeoclimatology, Palaeoecology* 250 (1-4): 50-67.

Guan, Ying, Fa-Gang Wang, Fei Xie, Shu-Wen Pei, Zhen-Yu Zhou, and Xing Gao. 2016. Flint knapping strategies at Cenjiawan, an Early Paleolithic site in the Nihewan Basin, North China. *Quaternary International* 400: 86-92.

Guo, Y-J, B Li, J-F Zhang, and R Roberts. 2015. Luminescence-based chronologies for Palaeolithic sites in the Nihewan Basin, northern China: First tests using newly developed optical dating procedures for potassium feldspar grains. *Journal of Archaeological Science: Reports* 3: 31-40.

Guo, Y-J, B Li, J-F Zhang, B-Y Y, F Xie, and R Roberts. 2016. Luminescence ages for three 'Middle Palaeolithic' sites in the Nihewan Basin, northern China, and their archaeological and palaeoenvironmental implications. *Quaternary Research* 85: 456-470.

Gupta, S P. 1979. *The Archaeology of Soviet Central Asia and The Indian Borderlands Vol. 1.* Delhi: B. R. Publishing Corporation.

Hagg, W, M Hoelzle, S Wagner, E Mayr, and Z Klose. 2013. Glacier and runoff changes in the Rukhk catchment, upper Amu-Darya basin until 2050. *Global and Planetary Change* 110: 62-73.

Han, Fei, Jean-Jacques Bahain, Chenglong Deng, Eric Boeda, Yamei Hou, Guangbiao Wei, Wanbo Huang, et al. 2017. The earliest evidence of hominid settlement in China: Combined electron spin resonance and uranium series (ESR/U-series) dating of mammalian fossil teeth from Longgupo cave. *Quaternary International* 434: 75-83.

Han, Fei, Jean-Jacques Bahain, Éric Boëda, Yamei Hou, Wanbo Huang, Christophe Falguères, Michel Rasse, et al. 2012. Preliminary results of combined ESR/U-series dating of fossil teeth from Longgupo cave, China. *Quaternary Geochronology* 10: 436-442.

Han, Y, X Fang, S Kang, H Wang, and F Kang. 2008. Shifts of dust source regions over central Asia and the Tibetan Plateau: Connections with the Arctic oscillation and the westerly jet. *Atmospheric Environment* 42 (10): 2358-2368.

Head, M, and P Gibbard. 2005. Early-Middle Pleistocene transitions: an overview and recommendation for the defining boundary. *Geological Society, London, Special Publications* 247 (1): 1-18.

Heath, Ralph C. 1983. *Basic ground-water hydrology.* Washington, D.C.: U.S. G.P.O.

Hemingway, Martin F, Dick Stapert, and R W Dennell. 1989. Early Artefacts from Pakistan? Some Questions for the Excavators. *Current Anthropology* 30 (3): 317-322.

Hemmer, H, R D Kahlke, and A K Vekua. 2010. Panthera onca georgica ssp. nov. from the Early Pleistocene of Dmanisi (Republic of Georgia) and the phylogeography of jaguars (Mammalia, Carnivora, Felidae). *Neues Jahrbuch für Geologie und Paläontologie-Abhandlungen* 257 (1): 115-127.

Hemmer, H, R D Kahlke, and A K Vekua. 2011. The cheetah Acinonyx pardinensis (Croizet et Jobert, 1828) sl at the hominin site of Dmanisi (Georgia)–A potential prime meat supplier in Early Pleistocene ecosystems. *Quaternary Science Reviews* 30 (19-20): 2703-2714.

Hernandez-Aguilar, R. 2009. Chimpanzee nest distribution and site reuse in a dry habitat: implications for early hominin ranging. *Journal of Human Evolution* 57 (4): 350-364.

Hetzel, Ralf, Samuel Niedermann, Mingxin Tao, Peter W Kubik, Susan Ivy-Ochs, Bo Gao, and Manfred R Strecker. 2002. Low slip rates and long-term preservation of geomorphic features in Central Asia. *Nature* 417: 428-432.

Heydari, Saman. 2004. Stone Raw Material sources in Iran: Some Case Studies. *Persiens antike Pracht: Bergbau, Handwerk, Archaologie: Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum vom* 28: 124-129.

Hijmans, Robert J, Susan Cameron, Juan Parra, Peter Jones, Andrew Jarvis, and Karen Richardson. n.d. *WorldClim - Global Climate Data.* Accessed 02 17, 2016. http://worldclim.org/paleo-climate.

Holdaway, Simon J, Geoffrey C. P King, Matthew J Douglass, and Patricia C Fanning. 2015. Human–environment interactions at regional scales: the complex topography hypothesis applied to surface archaeological records in Australia and North America. *Archaeology in Oceania* 50: 58-69.

Holmes, Kathryn M. 2007. Using Pliocene palaeoclimatic data to postulate dispersal pathways of early hominins. *Palaeogeography, Palaeoclimatology, Palaeoecology* 248 (1): 96-108.

Hooson, David J. M. 2001. Geography in Russia: Glories and Disappointments. In *Geography: Discipline, Profession and Subject since 1870*, edited by G S Dunbar, 225-243. Springer.

Hooson, David J. M. 1959. Some Recent Developments in the Content and Theory of Soviet Geography. *Annals of the Association of American Geographers* 49 (1): 73-82.

Hopkirk, Kathleen. 1993. *Central Asia through writer's eyes.* London: Eland.

Hou, Y M, and L X Zhao. 2010. An archeological view for the presence of early humans in China. *Quaternary International* 223-224: 10-19.

Hou, Yamei, Richard Potts, Yuan Baoyin, Guo Zhengtang, Alan Deino, Wang Wei, Jennifer Clark, Xie Guangmao, and Huang Weiwen. 2000. Mid-Pleistocene Acheulean-like Stone Technology of the Bose Basin, South China. *Science* 287: 1622-1626.

Huang, Shengmin, Wei Wang, Christopher J Bae, Guilin Xu, and Kangti Liu. 2012. Recent Paleolithic field investigations in Bose Basin (Guangxi, China). *Quaternary International* 281: 5-9.

Hubbard, W. 1928. Observations on the elephants of Northern Rhodesia and Portuguese East Africa. *Journal of Mammalogy* 9 (1): 39-43.

Hughes, John K, Alan Haywood, Steven J Mithen, Bruce W Sellwood, and Paul J Valdes. 2007. Investigating early hominin dispersal patterns: developing a framework for climate data integration. *Journal of Human Evolution* 53: 465-474.

Hunt, Chris O, David D Gilbertson, Evan A Hill, and David Simpson. 2015. Sedimentation, re-sedimentation and chronologies in archaeologically-important caves: problems and prospects. *Journal of Archaeological Science* 56: 109-116.

Huntley, D J, and M P Richards. 1997. The Age of the Diring Yuriakh Archaeological Site. *Ancient TL* 15 (2-3): 48-49.

Indoitu, R, G Kozhoridze, M Batyrbaeva, I Vitkovskaya, N Orlovsky, D Blumberg, and L Orlovsky. 2015. Dust emission and environmental changes in the dried bottom of the Aral Sea. *Aeolian Research* 17: 101-115.

Ingold, Tim. 1992. Culture and the perception of the environment. In *Bush base: forest farm. Culture, environment and development*, edited by Elisabeth Croll and David Parkin, 39-56. London: Routledge.

Ingold, Tim. 1993. The Temporality of the Landscape. *World Archaeology* 25 (2): 152-174.

Ingold, Tim. 1993. The Temporality of the Landscape. *World Archaeology* 25 (2): 152-174.

Irish, J, S Bailey, D Guatelli-Steinberg, L Delezene, and L Berger. 2018. Ancient teeth, phenetic affinities, and African hominins: Another look at where Homo naledi fits in. *Journal of human evolution* 122: 108-123.

Islamov, Y I. 1990. Sel'oungour, un Nouveau Site du Paleolithique Inferieur en Asie Centrale. *L'Anthropologie* 94 (4): 675-688.

Issanova, G, and J Abuduwaili. 2017. *Aeolian processes as dust storms in the deserts of central Asia and Kazakhstan.* Springer.

Jamialahmadi, Mana, Hamed Vahdati Nasab, Hassan Fazeli Nashli, and Amir Beshkani. 2008. Kashafrud revisited: discovery of new Palaeolithic sites in north-eastern Iran. *Antiquity* 82 (317).

Janson, C, and M Goldsmith. 1995. Predicting group size in primates: foraging costs and predation risks. *Behavioral Ecology* 6 (3): 326-336.

Jaubert, Jacques. 2015. The Paleolithic Peopling of Mongolia: An Updated Assessment. In *Emergence and Diversity of Modern Human Behavior in Paleolithic Asia*, edited by Yousuke Kaifu, Masami Izuho, Ted Goebel, Hiroyuki Sato and Akira Ono, 453-469. Texas A&M University Press.

Jaubert, Jacques, Fereidoun Biglari, Jean-Guillaume Bordes, Laurent Bruxelles, Vincent Mourre, Sonia Shidrang, Rahmat Naderi, and Simko Alipour. 2006. New Research on Paleolithic of Iran:. *Preliminary Report of 2004' Iranian-French Joint Mission* 3: 1-12.

Jones, Sacha, and J N Pal. 2009. The Palaeolithic of the Middle Son valley, north-central India: Changes in hominin lithic technology and behaviour during the Upper Pleistocene. *Journal of Anthropological Archaeology* 28: 323-341.

Kääb, A, E Berthier, C Nuth, J Gardelle, and Y Arnaud. 2012. Contrasting patterns of early twenty-first-century glacier mass change in the Himalayas. *Nature* 488 (7412): 495-498.

Kahlke, Ralf-Dietrich, Nuria Garcia, Dimitris S Kostopoulos, Frederic Lacombat, Adrian M Lister, Paul P. A Mazza, Nikolai Spassov, and Vadim V Titov. 2011. Western Palaearctic palaeoenvironmental conditions during the Early and early Middle Pleistocene inferred from large mammal communities, and implications for hominin dispersal in Europe. *Quaternary Science Reviews* 30: 1368-1395.

Kaplan, J O, N H Bigelow, I C Prentice, S P Harrison, P J Bartlein, T R Christensen, W Cramer, et al. 2003. Climate change and Arctic ecosystems: 2. Modeling, paleodata-model comparisons, and future projections. *Journal of Geophysical Research* 108 (D19): 1-17.

Kaser, G, M Großhauser, and B Marzeion. 2010. Contribution potential of glaciers to water availability in different climate regimes. *PNAS* 107 (47): 20223-20227.

Kashiwaya, K, M Ryugo, H Sakai, and T Kawai. 1998. Long-term climato-limnological oscillation during the past 2.5 million years printed in Lake Baikal sediments. *Geophysical research letters* 25 (5): 659-662.

Kashiwaya, K, M Ryugo, M Horii, H Sakai, T Nakamura, and T Kawai. 1999. Climato-limnological signals during the past 260 000 years in physical properties of bottom sediments from Lake Baikal. *Journal of Paleolimnology* 21 (2): 143-150.

Kashiwaya, K, S Ochiai, H Sakai, and T Kawai. 2001. Orbit-related long-term climate cycles revealed in a 12-Myr continental record from Lake Baikal. *Nature* 410 (6824): 71-74.

Kashiwaya, K, T Nakamura, N Takamatsu, H Sakai, M Nakamura, and T Kawai. 1997. Orbital signals found in physical and chemical properties of bottom sediments from Lake Baikal. *Journal of Paleolimnology* 18 (3): 293-297.

Keates, Susan G. 2010. Evidence for the earliest Pleistocene hominid activity in the Nihewan Basin of northern China. *Quaternary International* 223-224: 408-417.

Khursevich, G, E Karabanov, A Prokopenko, D Williams, M Kuzmin, and S Fedenya. 2001b. Biostratigraphic significance of new fossil species of the diatom genera Stephanodiscus and Cyclotella from Upper Cenozoic deposits of Lake Baikal, Siberia. *Micropaleontology* 47 (1): 47-71.

Khursevich, G, E Karabanov, A Prokopenko, D Williams, M Kuzmin, S Fedenya, and A Gvozdkov. 2001a. Insolation regime in Siberia as a major factor controlling diatom production in Lake Baikal during the past 800,000 years. *Quaternary International* 80: 47-58.

King, Geoffrey, and Geoff Bailey. 2006. Tectonics and human evolution. *Antiquity* 80 (308): 265-286.

Kingston, John D. 2007. Shifting Adaptive Landscapes: Progress and Challenges in Reconstructing Early Hominid Environments. *Yearbook of Physical Anthropology* 50: 20-58.

Klein, Richard G. 1966. Chellean and Acheulean on the Territory of the Soviet Union: A Critical Review of the Evidence as Presented in the Literature. *American Anthropologist* 68 (2): 1-45.

Kohl, Philip L. 1984. *Central Asia: Palaeolithic Beginnings to the Iron Age.* Paris: Éditions Recherche sur les Civilisations.

Kolobova, K A, A I Krivoshapkin, K K Pavlenok, D Flas, A P Derevianko, and U I Islamov. 2012. The Denticulate Mousterian as a Supposedly Distinct Facies in Western Central Asia. *Archaeology Ethnology & Anthropology of Eurasia* 40 (1): 11-23.

Komedchikov, N N. 2000. Cartography in the USSR Academy of Sciences, 1917-1991. *Mapping Sciences and Remote Sensing* 37 (1): 17-39.

Kong, P, J Jia, and Y Zheng. 2013. Cosmogenic 26Al/10Be burial dating of the Paleolithic at Xihoudu, North China. *Journal of Human Evolution* 64: 466-470.

Kozma, E, N Webb, W Harcourt-Smith, D Raichlen, K D'Août, M Brown, E Finestone, S Ross, P Aerts, and H Pontzer. 2018. Hip extensor mechanics and the evolution of walking and climbing capabilities in humans, apes, and fossil hominins. *PNAS* 115 (16): 4134–4139.

Kravchinsky, V, M Krainov, M Evans, J Peck, J King, M Kuzmin, H Sakai, T Kawai, and D Williams. 2003. Magnetic record of Lake Baikal sediments: chronological and paleoclimatic implication for the last 6.7 Myr. *Palaeogeography, Palaeoclimatology, Palaeoecology* 195 (3-4): 281-298.

Krestnikov, V N, I L Nersesov, and D V Stange. 1984. The Relationship Between the Deep Structure and Quaternary Tectonics of the Pamir and Tien-Shan. *Tectonophysics* 104: 67-83.

Kriegel, D, C Mayer, W Hagg, S Vorogushyn, D Duethmann, A Gafurov, and D Farinotti. 2013. Changes in glacierisation, climate and runoff in the second half of the 20th century in the Naryn basin, Central Asia. *Global and planetary change* 110: 51-61.

Krivoshapkin, A, B Viola, T Chargynov, M T Krajcarz, M Krajcarz, S Fedorowicz, S Shnaider, and K Kolobova. 2020. Middle Paleolithic variability in Central Asia: Lithic assemblage of Sel'Ungur cave. *Quaternary International* 535: 88-103.

Kübler, Simon, Peter Owenga, Sally C Reynolds, Stephen M Rucina, and Geoffrey C. P King. 2015. Animal movements in the Kenya Rift and evidence for the earliest ambush hunting by hominins. *Scientific Reports* 5: 1-7.

Kübler, Simon, Stephen Rucina, Sally Reynolds, Peter Owenga, Geoffrey Bailey, and Geoffrey C. P King. 2016. Edaphic and Topographic Constraints on Exploitation of the Central Kenya Rift by Large Mammals and Early Hominins. *Open Quaternary* 2 (5): 1-18.

Kukla, G. 1987. Loess stratigraphy in central China. *Quaternary Science Reviews* 6 (3-4): 191-219.

Kuman, Kathleen, Chaorong Li, and Hao Li. 2014. Large cutting tools in the Danjiangkou Reservoir Region, central China. *Journal of Human Evolution* 76: 129-153.

Kuman, Kathleen, Hao Li, and Chaorong Li. 2016. Large Cutting Tools from the Danjiangkou Reservoir Region, central China: Comparisons and contrasts with western and south Asian Acheulean. *Quaternary International* 400: 58-64.

Kupczik, K, L Delezene, and M Skinner. 2019. Mandibular molar root and pulp cavity morphology in Homo naledi and other Plio-Pleistocene hominins. *Journal of human evolution* 130: 83-95.

Kuzmin, M, E Karabanov, A Prokopenko, V Gelety, V Antipin, D Williams, and A Gvozdkov. 2000. Sedimentation processes and new age constraints on rifting stages in Lake Baikal: results of deep-water drilling. *International Journal of Earth Sciences* 89 (2): 183-192.

Kuzmin, Ya V, and A Yu Kazanskii. 2015. Debatable Questions of Siberia Settlement by Early Humans. *Stratigraphy and Geological Correlation* 23 (1): 114-118.

Kuzmin, Yaroslav V, and Sergei K Krivonogov. 1999. More about Diring Yuriakh: Unsolved Geoarchaeological Problems at a Lower Paleolithic Site in Central Siberia. *Geoarchaeology* 14 (4): 351-359.

Kuzmin, Yaroslav V, and Sergei K Krivonogov. 1994. The Diring Paleolithic Site, Eastern Siberia: Review of Geoarchaeological Studies. *Geoarchaeology* 9 (4): 287-300.

Lake Baikal Paleoclimate Project Members. 1992. Initial results of US-Soviet paleoclimate study of Lake Baikal. *Eos, Transactions American Geophysical Union* 73 (43): 457-462.

Larichev, Vitaliy, Uriy Khol'ishkin, and Inna Laricheva. 1987. Lower and Middle Paleolithic of Northern Asia: Achievements, Problems, and Perspectives. *Journal of World Prehistory* 1 (4): 415-464.

Li, Feng. 2016. An experimental study of bipolar reduction at Zhoukoudian locality 1, north China. *Quaternary International* 400: 23-29.

Li, Hao, ChaoRong Li, and Kathleen Kuman. 2017a. Longgudong, an Early Pleistocene site in Jianshi, South China, with stratigraphic association of human teeth and lithics. *Science China Earth Sciences* 60 (3): 452-462.

Li, Hao, Chao-rong Li, and Kathleen Kuman. 2014a. Rethinking the Acheulean in East Asia: Evidence from recent investigations in the Danjiangkou Reservoir Region, central China. *Quaternary International* 347: 163-175.

Li, Hao, Chao-rong Li, Kathleen Kuman, Jie Cheng, Hai-tao Yao, and Zhao Li. 2014b. The Middle Pleistocene handaxe site of Shuangshu in the Danjiangkou Reservoir Region, central China. *Journal of Archaeological Science* 52: 391-409.

Li, Hao, Chaorong Li, Nicole L Sherwood, and Kathleen Kuman. 2017b. Experimental flaking in the Danjiangkou Reservoir Region (central China): A rare case of bipolar blanks in the Acheulean. *Journal of Archaeological Science: Reports* 13: 26-35.

Li, Xiaoli, Shuwen Pei, Zhenxiu Jia, Ying Guan, Dongwei Niu, and Hong Ao. 2016. Paleoenvironmental conditions at Madigou (MDG), a newly discovered Early Paleolithic site in the Nihewan Basin, North China. *Quaternary International* 400: 100-110.

Li, Z, Y Chen, W Li, H Deng, and G Fang. 2015. Potential impacts of climate change on vegetation dynamics in Central Asia. *Journal of Geophysical Research: Atmospheres* 120: 12345–12356.

Lioubimtseva, E, and G Henebry. 2009. Climate and environmental change in arid Central Asia: Impacts, vulnerability, and adaptations. *Journal of Arid Environments* 73 (11): 963-977.

Lioubimtseva, E, and R Cole. 2006. Uncertainties of climate change in arid environments of Central Asia. *Reviews in Fisheries Science* 14 (1-2): 29-49.

Lioubimtseva, E, R Cole, J Adams, and G Kapustin. 2005. Impacts of climate and land-cover changes in arid lands of Central Asia. *Journal of Arid Environments* 62 (2): 285-308.

Littmann, T. 1991. Dust storm frequency in Asia: climatic control and variability. *International Journal of Climatology* 11 (4): 393-412.

Liu, Chun-Ru, Gong-Ming Yin, Cheng-Long Deng, Fei Han, and Wei-Juan Song. 2014. ESR dating of the Majuangou and Banshan Paleolithic sites in the Nihewan Basin, North China. *Journal of Human Evolution* 73: 58-63.

Liu, Chun-Ru, Gong-Ming Yin, Lu Gao, Jean-Jacques Bahain, Jian-Ping Li, Min Lin, and Shi-Ming Chen. 2010a. ESR dating of Pleistocene archaeological localities of the Nihewan Basin, North China – Preliminary results. *Quaternary Geochronology* 5: 385-390.

Liu, Ping, Chenglong Deng, Shihu Li, and Rixiang Zhu. 2010b. Magnetostratigraphic dating of the Huojiadi Paleolithic site in the Nihewan Basin, North China. *Palaeogeography, Palaeoclimatology, Palaeoecology* 298: 399-408.

Liu, T, and Z Ding. 1998. Chinese loess and the paleomonsoon. *Annual review of earth and planetary sciences* 26 (1): 111-145.

Liu, Y, Y Hu, and Q Wei. 2013b. Early to Late Pleistocene human settlements and the evolution of lithic technology in the Nihewan Basin, North China: A macroscopic perspective. *Quaternary International* 295: 204-214.

Liu, Y, Y M Hou, and H Ao. 2013a. Analysis of lithic technology of Lower Pleistocene sites and environmental information in the Nihewan Basin, North China. *Quaternary International* 295: 215-222.

Lockey, A, Z Alemseged, J Hublin, and M Skinner. 2020. Maxillary molar enamel thickness of Plio-Pleistocene hominins. *Journal of Human Evolution* 142: 1-8.

Lordkipanidze, D, T Jashashvili, A Vekua, M S P De León, C P Zollikofer, G P Rightmire, H Pontzer, et al. 2007. Postcranial evidence from early Homo from Dmanisi, Georgia. *Nature* 449 (7160): 305-310.

Lu, H, X Sun, S Wang, R Cosgrove, H Zhang, S Yi, X Ma, M Wei, and Z Yang. 2011. Ages for hominin occupation in Lushi Basin, middle of South Luo River, central China. *Journal of Human Evolution* 60: 612-617.

Lu, H, X Wang, and L Li. 2010. Aeolian sediment evidence that global cooling has driven late Cenozoic stepwise aridification in central Asia. *Geological Society, London, Special Publications* 342 (1): 29-44.

Lu, Huayu, Hongyan Zhang, Shejiang Wang, Richard Cosgrove, Xuefeng Sun, Jun Zhao, Donghuai Sun, Cunfa Zhao, Chen Shen, and Ming Wei. 2011. Multiphase timing of hominin occupations and the paleoenvironment in Luonan Basin, Central China. *Quaternary Research* 76: 142-147.

Lycett, Stephen J, and C J Bae. 2010. The Movius Line controversy: the state of the debate. *World Archaeology* 42 (4): 521-544.

Lycett, Stephen J, and Christopher J Norton. 2010. A demographic model for Palaeolithic technological evolution: The case of East Asia and the Movius Line. *Quaternary International* 211: 55-65.

Macdonald, D W, and D Johnson. 2015. Patchwork planet: the resource dispersion hypothesis, society, and the ecology of life. *Journal of Zoology* 295: 75-107.

Machalett, Björn, Eric A Oches, Manfred Frechen, Ludwig Zöller, Ulrich Hambach, Nadira G Mavlyanova, Slobodan B Marković, and Wilfried Endlicher. 2008. Aeolian dust dynamics in central Asia during the Pleistocene: Driven by the long-term migration,

seasonality, and permanency of the Asiatic polar front. *Geochemistry, Geophysics, Geosystems* 9 (8): 1-22.

Mackay, A, E Karabanov, M Leng, H Sloane, D Morley, V Panizzo, G Khursevich, and D Williams. 2008. Reconstructing hydrological variability in Lake Baikal during MIS 11: an application of oxygen isotope analysis of diatom silica. *Journal of Quaternary Science: Published for the Quaternary Research Association* 23 (4): 365-374.

Maman, S, L Orlovsky, D Blumberg, P Berliner, and B Mamedov. 2011. A landcover change study of takyr surfaces in Turkmenistan. *Journal of arid environments* 75 (9): 842-850.

Mannig, B, M Müller, E Starke, C Merkenschlager, W Mao, X Zhi, R Podzun, D Jacob, and H Paeth. 2013. Dynamical downscaling of climate change in Central Asia. *Global and planetary change* 110: 26-39.

Margvelashvili, Ann. 2008. The Morphological description of the Dental Remains from the Early Paleolithic site of Dmanisi (Georgia). *Annali dell'Università degli Studi di Ferrara Museologia Scientifica e Naturalistica* 117-122.

Markova, Anastasia. 1992. Fossil rodents (Rodentia, Mammalia) from the Sel'-Ungur Acheulian cave site (Kirghizstan). *Acta Zoologica Cracoviensia* 35 (2): 217-239.

Maslin, Mark A, and Beth Christensen. 2007. Tectonics, orbital forcing, global climate change, and human evolution in Africa: introduction to the African paleoclimate special volume. *Journal of Human Evolution* 53: 443-464.

Mathis, M, P Sorrel, S Klotz, X Huang, and H Oberhänsli. 2014. Regional vegetation patterns at lake Son Kul reveal Holocene climatic variability in central Tien Shan (Kyrgyzstan, Central Asia). *Quaternary Science Reviews* 89: 169-185.

Meorgan, Nick. 2012. Rethinking the Study of International Boundaries: A Biography of the Kyrgyzstan–Uzbekistan Boundary. *Annals of the Association of American Geographers* 102 (2): 464-481.

Messager, E, D Lordkipanidze, C Delhon, and C R Ferring. 2010a. Palaeoecological implications of the Lower Pleistocene phytolith record from the Dmanisi Site (Georgia). *Palaeogeography, Palaeoclimatology, Palaeoecology* 288: 1-13.

Messager, E, D Lordkipanidze, E Kvavadze, C R Ferring, and P Voinchet. 2010b. Palaeoenvironmental reconstruction of Dmanisi site (Georgia) based on palaeobotanical data. *Quaternary International* 223: 20-27.

Meyer, M, C Woodward, A Tims, and M Bastir. 2018. Neck function in early hominins and suspensory primates: Insights from the uncinate process. *American Journal of Physical Anthropology* 166: 613–637.

Mgeladze, Ana, David Lordkipanidze, Marie-Hélène Moncel, Jackie Despriee, Rusudan Chagelishvili, Medea Nioradze, and Giorgi Nioradze. 2010. First human settlement of the Caucasus: Technical behavior and raw material acquisition at Dmanisi, Georgia (1.77 Ma). *Quaternary International* 223: 422–425.

Mgeladze, Ana, David Lordkipanidze, Marie-Hélène Moncel, Jackie Despriee, Rusudan Chagelishvili, Medea Nioradze, and Giorgi Nioradze. 2011. Hominin occupations at the Dmanisi site, Georgia, Southern Caucasus: Raw materials and technical behaviours of Europe's first hominins. *Journal of Human Evolution* 60: 571-596.

Miao, Y, M Herrmann, F Wu, X Yan, and S Yang. 2012. What controlled Mid–Late Miocene long-term aridification in Central Asia?—Global cooling or Tibetan Plateau uplift: A review. *Earth-Science Reviews* 112 (3-4): 155-172.

Middleton, N. 1986. A geography of dust storms in South-west Asia. *Journal of Climatology* 6 (2): 183-196.

Mitchell, J, and R Westaway. 1999. Chronology of Neogene and Quaternary uplift and magmatism in the Caucasus: constraints from K–Ar dating of volcanism in Armenia. *Tectonophysics* 304 (3): 157-186.

Molnar, P, P Tapponnier, and W Chen. 1981. Extensional tectonics in central and eastern Asia: a brief summary. *Philosophical Transactions of the Royal Society London A* 300: 403-406.

Moloney, Norah, Sandra L Olsen, and Valery Voloshin. 2001. Lower and Middle Palaeolithic occupation in Central Kazakhstan: the Batpak Valley and environs. In *A very remote period indeed: Papers on the Palaeolithic presented to Derek Roe*, edited by Sarah Milliken and Jill Cook, 138-143. Oxford: Oxbow Books.

Monmonier, Mark. 1996. *How to Lie with Maps.* 2nd. Chicago: Chicago University Press.

Motes-Rodrigo, A, P Majlesi, T Pickering, M Laska, H Axelsen, T Minchin, C Tennie, and R Hernandez-Aguilar. 2019. Chimpanzee extractive foraging with excavating tools: Experimental modeling of the origins of human technology. *PloS one* 14 (5).

Movius, Hallam L. 1953. Palaeolithic and Mesolithic Sites in Soviet Central Asia. *Proceedings of the American Philosophical Society* 97 (4): 383-421.

Movius, Hallam L. 1948. The Lower Palaeolithic cultures of southern and eastern Asia. *Transactions of the American Philosophical Society* 38 (4): 329-420.

Murakami, T, T Takamatsu, N Katsuta, M Takano, K Yamamoto, Y Takahashi, T Nakamura, and T Kawai. 2012. Centennial-to millennial-scale climate shifts in continental interior Asia repeated between warm–dry and cool–wet conditions during the last

three interglacial states: evidence from uranium and biogenic silica in the sediment of Lake Baikal, southeast Sib. *Quaternary Science Reviews* 52: 49-59.

Nasab, Hamed Vahdati. 2011. Paleolithic Archaeology in Iran. *International Journal of Humanities* 18 (2): 63-87.

Neil, E, and G Houseman. 1997. Geodynamics Of the Tarim Basin and the Tian Shan in central Asia. *Tectonics* 16 (4): 571-584.

Norbury, G, and D Norbury. 1992. The impact of red kangaroos on the rangelands. *Journal of the Department of Agriculture, Western Australia, Series 4* 33 (2): 57-61.

Norton, Christopher J, and Kidong Bae. 2008. The Movius Line sensu lato (Norton et al., 2006) further assessed and defined. *Journal of Human Evolution* 55: 1148-1150.

Norton, Christopher J, and Xing Gao. 2008. Zhoukoudian Upper Cave Revisited. *Current Anthropology* 49 (4): 732-745.

Norton, Christopher J, K Bae, J W Harris, and H Lee. 2006. Middle Pleistocene handaxes from the Korean peninsula. *Journal of Human Evolution* 51 (5): 527-536.

Norton, Christopher J, Xing Gao, Wu Liu, David R Braun, and Xiujie Wu. 2010. Central-East China – A Plio-Pleistocene Dispersal Corridor: The Current State of Evidence for Hominin Occupations. In *Asian Paleoanthropology: From Africa to China and Beyond*, edited by C J Norton and D R Braun, 159-168. Springer.

Okladnikov, A P. 1978. The Paleolithic of Mongolia. In *Early Paleolithic in South and East Asia*, edited by Fumiko Ikawa-Smith, 317-328. Paris: Mouton.

Okladnikov, A P, and G A Pospelova. 1982. Ulalinka, the Oldest Palaeolithic Site in Siberia. *Current Anthropology* 23 (6): 710-712.

OneGeology. 2016. *OneGeology.* Accessed 02 17, 2016. http://portal.onegeology.org/OnegeologyGlobal/.

Opp, C, M Groll, I Aslanov, T Lotz, and N Vereshagina. 2017. Aeolian dust deposition in the southern Aral Sea region (Uzbekistan): Ground-based monitoring results from the LUCA project. *Quaternary International* 429: 86-99.

Otte, M, A Derevianko, Z Taimagambetov, and V Petrine. 2000. Paléolithique au Kazakhstan. In *Approches du Comportement au Moustérien*, edited by M Otte, 106-143. Banbury: British Archaeological Reports.

Otto-Bliesner, B L, S J Marshall, J T Overpeck, G H Miller, and A Hu. 2006. Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation. *Science* 311: 1751-1753.

Pappu, Shanti, Yanni Gunnell, Kumar Akhilesh, Régis Braucher, Maurice Taieb, François Demory, and Nicolas Thouveny. 2011. Early Pleistocene Presence of Acheulian Hominins in South India. *Science* 331: 1596-1599.

Parajuli, S, and C Zender. 2017. Connecting geomorphology to dust emission through high-resolution mapping of global land cover and sediment supply. *Aeolian research* 27: 47-65.

Peck, J, J King, S Colman, and V Kravchinsky. 1994. A rock-magnetic record from Lake Baikal, Siberia: evidence for Late Quaternary climate change. *Earth and Planetary Science Letters* 122 (1-2): 221-238.

Pei, SW, XL Li, DC Liu, N Ma, and F Peng. 2009. Preliminary study on the living environment of hominids at the Donggutuo site, Nihewan Basin. *Chinese Science Bulletin* 54: 3896-3904.

Peng, Hongxia, Zhibang Ma, Wanpo Huang, and Jing Gao. 2014. 230Th/U chronology of a paleolithic site at Xinglong Cave in the three-Gorge region of south China. *Quaternary Geochronology* 24: 1-9.

Peterson, C, C Shen, C Chen, W Chen, and Y Tang. 2003. Taphonomy of an Early Pleistocene Archaeofauna from Xiaochangliang, Nihewan Basin, North China. In *Current Research in Chinese Pleistocene Archaeology*, edited by C Shen and S Keates, 83-98. Oxford: Archaeopress.

Petraglia, Michael D, and Ceri Shipton. 2008. Large cutting tool variation west and east of the Movius Line. *Journal of Human Evolution* 55 (6): 962-966.

Petraglia, Michael, Ravi Korisettar, Nicole Boivin, Christopher Clarkson, Peter Ditchfield, Sacha Jones, Jinu Koshy, et al. 2007. Middle Paleolithic Assemblages from the Indian Subcontinent Before and After the Toba Super-Eruption. *Science* 317: 114-116.

Potts, Richard. 2013. Hominin evolution in settings of string environmental variability. *Quaternary Science Reviews* 73: 1-13.

Prokopenko, A, E Bezrukova, G Khursevich, E Solotchina, M Kuzmin, and P Tarasov. 2010. Climate in continental interior Asia during the longest interglacial of the past 500 000 years: the new MIS 11 records from Lake Baikal, SE Siberia. *Climate of the Past* 6 (1): 31–48.

Prokopenko, A, L Hinnov, D Williams, and M Kuzmin. 2006. Orbital forcing of continental climate during the Pleistocene: a complete astronomically tuned climatic record from Lake Baikal, SE Siberia. *Quaternary Science Reviews* 25 (23-24): 3431-3457.

Qadir, M, A Noble, A Qureshi, R Gupta, T Yuldashev, and A Karimov. 2009. Salt-induced land and water degradation in the Aral Sea basin: A challenge to sustainable agriculture in Central Asia. *Natural Resources Forum* 33 (2): 134-149.

Ranov, V A, and R S Davis. 1979. Toward a New Outline of the Soviet Central Asian Paleolithic. *Current Anthropology* 20 (2): 249-270.

Ranov, V A, R S Davis, Jean S Aiger, Miklós Gábori, Alexander Gallus, Anthony E Marks, G C Mohapatra, Hallam L Movius, and Ian S Zeiler. 1979. Toward a New Outline of the Soviet Central Asian Paleolithic. *Current Anthropology* 20 (2): 249-270.

Ranov, Vadim A. 2001. Cleavers: their distribution, chronology and typology. In *A Very Remote Period Indeed*, edited by Sarah Milliken and Jill Cook, 105-113. Oxford: Oxbow.

Ranov, Vadim A. 1984. Douze années de recherches sur la préhistoire au Tadjikistan méridional et au Pamir (1971-1982). *Paléorient* 10 (2): 5-22.

Ranov, Vadim A, and Andrey E Dodonov. 2003. Small instruments of the Lower Palaeolithic site Kuldara and their geoarchaeological meaning. In *Lower Palaeolithic Small Tools in Europe and the Levant*, edited by J M Burdukiewicz and A Ronen, 133-147. Banbury: British Archaeological Reports.

Ranov, Vadim A, D Dorj, and Z.-E. Lü. 1992. Lower Palaeolithic Cultures. In *History of Civilizations of Central Asia Volume 1 The Dawn of Civilization: Earliest Times to 700 B.C.*, edited by A H Dani and V M Masson, 45-63. Paris: UNESCO Publishing.

Ranov, Vadim A, Eudald Carbonell, and Xose Pedro Rodriguez. 1995. Kuldara: Earliest Human Occupation in Central Asia in Its Afro-Asian Context. *Current Anthropology* 36 (2): 337-346.

Ranov, Vadim Alexandrovitch. 1991. Les Sites Très Anciens de l'âge de la Pierre en U.R.S.S. In *Les Premier Européens*, 209-216. Paris: Comité des Travaux Historiques et Scientifiques.

Ranov, Vadim. 1995. The 'Loessic Palaeolithic' in south Tadjikistan, Central Asia: Its Industries, Chronology and Correlation. *Quaternary Science Reviews* 14: 731-745.

Reynolds, Sally C, David M Wilkinson, Christopher G Marston, and Hannah J O'Regan. 2015. The 'mosaic habitat' concept in human evolution: past and present. *Transactions of the Royal Society of South Africa* 70 (1): 57-69.

Rightmire, G. 2004. Brain size and encephalization in early to mid-Pleistocene Homo. *American Journal of Physical Anthropology* 124 (2): 109-123.

Rightmire, G, A Margvelashvili, and D Lordkipanidze. 2019. Variation among the Dmanisi hominins: Multiple taxa or one species? *American Journal of Physical Anthropology* 168: 481-495.

Rost, K. 2000. Pleistocene paleoenvironmental changes in the high mountain ranges of central China and adjacent regions. *Quaternary International* 65: 147-160.

Ruff, C, E Trinkaus, and T Holliday. 1997. Body mass and encephalization in Pleistocene Homo. *Nature* 387 (6629): 173-176.

Ruff, C, M Burgess, N Squyres, J Junno, and E Trinkaus. 2018. Lower limb articular scaling and body mass estimation in Pliocene and Pleistocene hominins. *Journal of Human Evolution* 115: 85-111.

Rupper, S, G Roe, and A Gillespie. 2009. Spatial patterns of Holocene glacier advance and retreat in Central Asia. *Quaternary Research* 72 (3): 337-346.

Salnikov, V, G Turulina, S Polyakova, Y Petrova, and A Skakova. 2015. Climate change in Kazakhstan during the past 70 years. *Quaternary international* 358: 77-82.

Schepartz, L A, S Miller-Antonio, and D A Bakken. 2000. Upland Resources and the Early Palaeolithic Occupation of Southern China, Vietnam, Laos,Thailand and Burma. *World Archaeology* 32 (1): 1-13.

Schick, K, N Toth, W Qi, J D Clark, and D Etler. 1991. Archaeological perspectives in the Nihewan basin, China. *Journal of Human Evolution* 21 (1): 13-26.

Schick, Kathy, and Dong Zhuan. 1993. Early Paleolithic of China and Eastern Asia. *Evolutionary Anthropology* 2 (1): 22-35.

Schwartz, G, A McGrosky, and D Strait. 2020. Fracture mechanics, enamel thickness and the evolution of molar form in hominins. *Biology letters* 16 (1): 20190671.

Semenov, S A. 1964. *Prehistoric technology.* London: Cory. Adams & mackay.

Shackley, Myra. 1984. Palaeolithic Archaeology in the Mongolian People's Republic; A Report on the state of the art. *Proceedings of the Prehistoric Society* 50: 23-34.

Shen, Chen, and Wei Qi. 2004. Lithic Technological Variability of the Middle Pleistocene in the Eastern Nihewan Basin, Northern China. *Asian Perspectives* 43 (2): 281-301.

Shen, Chen, Xiaoling Zhang, and Xing Gao. 2016. Zhoukoudian in transition: Research history, lithic technologies, and transformation of Chinese Palaeolithic archaeology. *Quaternary International* 400: 4-13.

Shen, Chen, Xing Gao, and Qi Wei. 2010. The Earliest Hominin Occupations in the Nihewan Basin of Northern China: Recent Progress in Field Investigations. In *Asian Paleoanthropology: From Africa to China and Beyond*, edited by C J Norton and D R Braun, 169-180. Springer.

Shen, Guanjun, Teh-Lung Ku, Hai Cheng, R Lawrence Edwards, Zhenxin Yuan, and Qian Wang. 2001. High-precision U-series dating of Locality 1 at Zhoukoudian, China. *Journal of Human Evolution* 41: 679-688.

Shen, Guanjun, Xing Gao, Bin Gao, and Darryl E Granger. 2009. Age of Zhoukoudian Homo erectus determined with 26Al/10Be burial dating. *Nature* 458: 198-200.

Shen, Guanjun, Xing Gao, Jian-xin Zhao, and Kenneth D Collerson. 2004. U-series dating of Locality 15 at Zhoukoudian, China, and implications for hominid evolution. *Quaternary Research* 62: 208-213.

Shichi, K, K Kawamuro, H Takahara, Y Hase, T Maki, and N Miyoshi. 2007. Climate and vegetation changes around Lake Baikal during the last 350,000 years. *Palaeogeography, Palaeoclimatology, Palaeoecology* 248 (3-4): 357-375.

Sinnot, P. 1992. The Physical Geography of Soviet Central Asia and the Aral Sea Problem. In *Geographic Perspectives on Soviet Central Asia*, edited by R Lewis, 73-98. London: Routledge.

Snyder, C. 2016. Evolution of global temperature over the past two million years. *Nature* 538 (7624): 226-228.

Sohl, Linda E, Mark A Chandler, Robert B Schmunk, Ken Mankoff, Jeffrey A Jonas, Kevin M Foley, and Harry J Dowsett. 2009. *PRISM3/GISS Topographic Reconstruction, Data Series 419.* Reston: U.S. Geological Survey.

Stewart, J, and A Lister. 2001. Cryptic northern refugia and the origins of the modern biota. *Trends in Ecology & Evolution* 16 (11): 608-613.

Stoddard, Steven T. 2010. Continuous versus binary representations of landscape heterogeneity in spatially-explicit models of mobile populations. *Ecological Modelling* 221: 2409–2414.

Stommel, C, H Hofer, M Grobbel, and M East. 2016. Large mammals in Ruaha National Park, Tanzania, dig for water when water stops flowing and water bacterial load increases. *Mammalian Biology* 81 (1): 21-30.

Strecker, M R, W Frisch, M W Hamburger, L Ratschbacher, S Semiletkin, A Zamoruyev, and N Sturchio. 1995. Quaternary deformation in the Eastern Pamirs, Tadzhikistan and Kyrgyzstan. *Tectonics* 14 (5): 1061-1079.

Sun, Xuefeng, Huayu Lu, Shejiang Wang, Richard Cosgrove, Wenchao Zhang, Kaifeng Yu, and Haixin Zhuo. 2014. Age of newly discovered Paleolithic assemblages at Liuwan site Luonan Basin, central China. *Quaternary International* 347: 193-199.

Sun, Y, and Z An. 2005. Late Pliocene-Pleistocene changes in mass accumulation rates of eolian deposits on the central Chinese Loess Plateau. *Journal of Geophysical Research: Atmospheres* 110.

Suslov, S P. 1961. *Physical Geography of Asiatic Russia.* London: W.H. Freeman and Company.

Swanson, James M. 1965. Reorganisation: 1963. In *The State of Soviet Science*, 36-40. Cambridge: The M.I.T. Press.

Taimagambetov, Z, and S Alipova. 2013. Paleolithic of Eurasia by the Example of the Lower Palaeolithic Site in Southern Kazakhstan Kyzyltau. *World Applied Sciences Journal* 25 (11): 1549-1559.

Taimagambetov, Zhaken Kozhakhmetovich, Saya B Alipova, Nazgul Kazhymuratovna Baigabatova, and Gulzhan Bolegenovna Tleubekova. 2013. Studies of the Stone Industry at the Kyzyltau Lower Palaeolithic Site Of Southern Kazakhstan in Eurasia. *Middle-East Journal of Scientific Research* 13 (5): 686-692.

The CGIAR Consortium for Spatial Information. 2008. *CGIAR-CSI SRTM 90m DEM Digital Elevation Database.* Accessed 02 17, 2016. http://srtm.csi.cgiar.org/.

Tian, S, J Sun, and Z Gong. 2017. Loess deposits in Beijing and their paleoclimatic implications during the last interglacial-glacial cycle. *Quaternary Science Reviews* 177: 78-87.

Tungsheng, L, D Menglin, and E Derbyshire. 1996. Gravel deposits on the margins of the Qinghai-Xizang Plateau, and their environmental significance. *Palaeogeography, Palaeoclimatology, Palaeoecology* 120 (1-2): 159-170.

Ungar, P. 2019. Inference of diets of early hominins from primate molar form and microwear. *Journal of dental research* 98 (4): 398-405.

United Nations. 2013. *United Nations Statistics Division - Standard Country and Area Codes Classifications (M49).* Accessed December 14, 2014. http://millenniumindicators.un.org/unsd/methods/m49/m49regin.htm.

van Baak, C, I Vasiliev, M Stoica, K Kuiper, A Forte, E Aliyeva, and W Krijgsman. 2013. A magnetostratigraphic time frame for Plio-Pleistocene transgressions in the South Caspian Basin, Azerbaijan. *Global and Planetary Change* 103: 119–134.

van der Made, J, and A Mateos. 2010. Longstanding biogeographic patterns and the dispersal of early Homo out of Africa and into Europe. *Quaternary International* 223-224: 195-200.

Vandenberghe, D A. G, D Flas, M De Dapper, J Van Nieuland, K Kolobova, K Pavlenok, U Islamov, E De Pelsmaeker, A.-E Debeer, and J.-P Buylaert. 2014. Revisiting the Palaeolithic site of Kulbulak (Uzbekistan): First results from luminescence dating. *Quaternary International* 324: 180-189.

Vasilyev, S, and H Amirkhanov. 2018. Palaeolithic Caucasus: Paleoanthropological Panorama. *Quaternary International* 465: 105-116.

Veneziano, A, J Irish, C Meloro, C Stringer, and I DeGroote. 2019. The functional significance of dental and mandibular reduction in Homo: A catarrhine perspective. *American journal of primatology* 81 (3): e22953.

Vinogradov, A P. 1966-8. *Atlas litologo-paleogeograficheskikh kart SSSR.* Moscow: Vses. Aėorologicheskiĭ Trest.

Vishnyatsky, Leonid B. 1989. The discovery of Palaeolithic handaxes in Western Turkmenia: A preliminary report. *Paléorient* 15 (2): 95-98.

Vishnyatsky, Leonid B. 1999. The Paleolithic of Central Asia. *Journal of World Prehistory* 13 (1): 69-122.

Vishnyatsky, Leonid. 1996. *Paleolit Sredneĭ Azii i Kazakhstana.* St. Petersburg: Evropeiskiy Dom.

Viviroli, D, and R Weingartner. 2004. The hydrological significance of mountains: from regional to global. Hydrology and Earth System Sciences Discussions, European Geosciences Union, 2004.

Von Le Coq, A. 1928. *Buried Treasures of Chinese Turkestan.* Oxford: Oxford University Press.

Wake, C, P Mayewski, Z Li, J Han, and D Qin. 1994. Modern eolian dust deposition in central Asia. *Tellus B: Chemical and Physical Meteorology* 46 (3): 220-233.

Wang, Hongqiang, Chenglong Deng, Rixiang Zhu, Qi Wei, Yamei Hou, and Eric Boëda. 2005. Magnetostratigraphic dating of the Donggutuo and Maliang Paleolithic sites in the Nihewan Basin, North China. *Quaternary Research* 64: 1-11.

Wang, Hongqiang, Deng Chenglong, Zhu Rixiang, and Fei Xie. 2006. Paleomagnetic dating of the Cenjiawan Paleolithic site in the Nihewan Basin, northern China. *Science in China Series D Earth Sciences* 49 (3): 295-303.

Wang, J, Y Wang, Z Liu, J Li, and P Xi. 1999. Cenozoic environmental evolution of the Qaidam Basin and its implications for the uplift of the Tibetan Plateau and the drying of central Asia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 152 (1-2): 37-47.

Wang, Shejiang, Huayu Lu, and Luda Xing. 2014a. Chronological and typo-technological perspectives on the Palaeolithic archaeology in Lantian, central China. *Quaternary International* 347: 183-192.

Wang, Shejiang, Huayu Lu, Hongyan Zhang, Xuefeng Sun, Shuangwen Yi, Yingyong Chen, Gaike Zhang, Luda Xing, and Weigang Sun. 2014c. Newly discovered Palaeolithic artefacts from loess deposits and their ages in Lantian, central China. *Chinese Science Bulletin* 59 (7): 651-661.

Wang, Wei, Christopher J Bae, Shengmin Huang, Xin Huang, Feng Tian, Jinyou Mo, Zhitao Huang, Chaolin Huang, Shaowen Xie, and Dawei Li. 2014b. Middle Pleistocene bifaces from Fengshudao (Bose Basin, Guangxi, China). *Journal of Human Evolution* 69: 110-122.

Wang, Wei, JinYou Mo, and ZhiTao Huang. 2008. Recent discovery of handaxes associated with tektites in the Nanbanshan locality of the Damei site, Bose basin, Guangxi, South China. *Chinese Science Bulletin* 53 (6): 878-883.

Wang, Wei, Stephen J Lycett, Noreen von Cramon-Taubadel, Jennie J. H. Jin, and Christopher J Bae. 2012. Comparison of Handaxes from Bose Basin (China) and the Western Acheulean Indicates Convergence of Form, Not Cognitive Differences. *PLOS one* 7 (4): 1-7.

Wang, X, H Wei, M Taheri, F Khormali, G Danukalova, and F Chen. 2016. Early Pleistocene climate in western arid central Asia inferred from loess-palaeosol sequences. *Scientific reports* 6 (1): 1-9.

Wang, X, Y Ding, S Liu, L Jiang, K Wu, Z Jiang, and W Guo. 2013. Changes of glacial lakes and implications in Tian Shan, central Asia, based on remote sensing data from 1990 to 2010. *Environmental Research Letters* 8 (4): 1-11.

Ward, R C, and M Robinson. 2000. *Principles of Hydrology.* 4th. London: McGraw-Hill Publishing Company.

Waters, Michael R, Steven L Forman, and James M Pierson. 1997. Diring Yuriakh: A Lower Paleolithic Site in Central Siberia. *Science* 275 (5304): 1281-1284.

Wei, Guanbiao, Cunding He, Yue Hu, Kefu Yu, Shaokun Chen, Libo Pang, Yan Wu, Wanbo Huang, and Wenge Yuan. 2017b. First discovery of a bone handaxe in China. *Quaternary International* 434: 121-128.

Wei, Guangbiao, Wanbo Huang, Eric Boeda, Hubert Forestier, Cunding He, Shaokun Chen, Jianxin Zhao, et al. 2017a. Recent discovery of a unique Paleolithic industry from the Yumidong Cave site in the Three Gorges region of Yangtze River, southwest China. *Quaternary International* 434: 107-120.

Wei, Guangbiao, Wanbo Huang, Shaokun Chen, Cunding He, Libo Pang, and Yan Wu. 2014. Paleolithic culture of Longgupo and its creators. *Quaternary International* 354: 154-161.

Weiner, Steve, Qinqi Xu, Paul Goldberg, Jinyi Liu, and Ofer Bar-Yosef. 1998. Evidence for the Use of Fire at Zhoukoudian, China. *Science* 281: 251-253.

Whitley, Thomas G, Inna Moore, Gitisha Goel, and Damon Jackson. 2010. Beyond the Marsh: Settlement Choice, Perception, and Spatial Decision-making on the Georgia Coastal Plain. In *Making History Interactive. Computer Applications and Quantitative Methods in Archaeology (CAA). Proceedings of the 37th International Conference, Williamsburg, Virginia, United States of America, March 22-26 (BAR International Series S2079)*, edited by B Frischer, J Webb Crawford and D Koller, 380-390. Oxford: Archaeopress.

Williams, P, and Y T Fong. 2010. *World Map of Carbonate Rock Outcrops.* Accessed 02 17, 2016. http://web.env.auckland.ac.nz/our_research/karst/.

Winder, Isabelle C. 2015. Landscape Structures and Human Evolutionary Ecology: space, scale and environmental patterning in Africa. *Internet Archaeology* 38.

Winder, Isabelle C, Maud H Devés, Geoffrey C. P King, Geoffrey N Bailey, Robyn H Inglis, and Matthew Meredith-Williams. 2015. Evolution and dispersal of the genus Homo: A landscape approach. *Journal of Human Evolution* 87: 48-65.

Wrangham, R, and R Carmody. 2010. Human adaptation to the control of fire. *Evolutionary Anthropology: Issues, News, and Reviews* 19 (5): 187-199.

Wu, X. 2000. Longgupo hominoid mandible belongs to ape. *Acta Anthropologica Sinica* 19 (1): 1-10.

Wu, Xinzhi. 2004. On the origin of modern humans in China. *Quaternary International* 117: 131-140.

Xu, Guilin, Wei Wang, Christopher J Bae, Shengmin Huang, and Zhiming Mo. 2012. Spatial distribution of Paleolithic sites in Bose Basin, Guangxi, China. *Quaternary International* 281: 10-13.

Xu, H, X Wang, and X Zhang. 2016. Decreased vegetation growth in response to summer drought in Central Asia from 2000 to 2012. *International Journal of Applied Earth Observation and Geoinformation* 52: 390–402.

Yafeng, S, and R Jiawen. 1990. Glacier recession and lake shrinkage indicating a climatic warming and drying trend in central Asia. *Annals of Glaciology* 14: 261-265.

Yang, S, and Z Ding. 2006. Winter–spring precipitation as the principal control on predominance of C3 plants in Central Asia over the past 1.77 Myr: evidence from δ13C of loess organic matter in Tajikistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 235 (4): 330-339.

Yang, S, F Ding, and Z Ding. 2006. Pleistocene chemical weathering history of Asian arid and semi-arid regions recorded in loess deposits of China and Tajikistan. *Geochimica et Cosmochimica Acta* 70 (7): 1695-1709.

Yang, S, W Huang, Y Hou, and B Yuan. 2014. Is the Dingcun lithic assembly a chopper-chopping tool industry , or Late Acheulian ? *Quaternary International* 321: 3-11.

Yang, Shi-Xia, Ya-Mei Hou, Jian-Ping Yue, M D Petraglia, Cheng-Long Deng, and Ri-Xiang Zhu. 2016. The Lithic Assemblages of Xiaochangliang, Nihewan Basin: Implications for Early Pleistocene Hominin Behaviour in North China. *PLOS One* 11 (5): 1-19.

Yang, X, L Scuderi, P Paillou, Z Liu, H Li, and X Ren. 2011. Quaternary environmental changes in the drylands of China–a critical review. *Quaternary Science Reviews* 30 (23-24): 3219-3233.

Yi, Seonbok, and G A Clark. 1983. Observations on the Lower Palaeolithic of Northeast Asia. *Current Anthropology* 24 (2): 181-190.

Yuretich, R, M Melles, B Sarata, and H Grobe. 1999. Clay minerals in the sediments of Lake Baikal; a useful climate proxy. *Journal of Sedimentary Research* 69 (3): 588-596.

Yurtsev, B. 2001. The Pleistocene Tundra-Steppe and the productivity paradox: the landscape approach. *Quaternary Science Reviews* 20 (1-3): 165-174.

Zhang, Pu, Weiwen Huang, and Wei Wang. 2010. Acheulean handaxes from Fengshudao, Bose sites of South China. *Quaternary International* 223-224: 440-443.

Zhou, L, A Dodonov, and N Shackleton. 1995. Thermoluminescence dating of the Orkutsay loess section in Tashkent region, Uzbekistan, Central Asia. *Quaternary Science Reviews* 14 (7-8): 721-730.

Zhu, R X, R Potts, F Xie, K A Hoffman, C L Deng, C D Shi, Y X Pan, et al. 2004. New evidence on the earliest human presence at high northern latitudes in northeast Asia. *Nature* 431: 559-562.

Zhu, R, k Hoffman, R Potts, C Deng, Y Pan, B Guo, C Shi, et al. 2001. Earliest presence of humans in northeast Asia. *Nature* 413 (6854): 413-417.

Zhu, Zhao-Yu, Robin Dennell, Wei-Wen Huang, Yi Wu, Zhi-Guo Rao, Shi-Fan Qiu, Jiu-Bing Xie, et al. 2015. New dating of the Homo erectus cranium from Lantian (Gongwangling), China. *Journal of Human Evolution* 78: 144-157.

Zhuo, Haixin, Huayu Lu, Shejiang Wang, Khobaib Ahmad, Wenfeng Sun, Hongyan Zhang, Shuangwen Yi, Yongxiang Li, and Xianyan Wang. 2016. Chronology of newly-discovered Paleolithic artifact assemblages in Lantian (Shaanxi province), central China. *Quaternary Research* 86: 316-325.

Zubakov, V A. 2001. History and Causes of Variations in the Caspian Sea Level: the Miopliocene, 7.1–1.95 Million Years Ago. *Water Resources* 28 (3): 249-256.

Zwyns, Nicolas, S Gladyshev, A Tabarev, and B Gunchinsuren. 2014. Mongolia: Paleolithic. In *Encyclopedia of Global Archaeology*, edited by Claire Smith, 5025-5032. Springer.