Late Bronze Age to Iron Age land use and subsistence strategies in the Semirech'ye region of Kazakhstan

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Doctor of Philosophy

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I, Rebecca Claire Roberts, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

This thesis presents the results of phytolith and faecal spherulite analysis from three sites in the Semirech'ye region of south-eastern Kazakhstan, dating from the Bronze Age to the Iron Age (3rd to 1st millennia BC). The primary aim of the research is to generate new data relating to the exploitation of plant resources that can inform on changing land use and subsistence strategies over time. The research is placed in the context of the current understanding of the archaeological and palaeoclimatic record for the region, and aims to offer new insights into the transitional period from the Late Bronze Age to the Iron Age, around the turn of the 1st millennium BC. During this period both the archaeological and palaeoclimatic records point to significant changes in material culture, social organisation, and climate, and this thesis proposes resilience theory as a theoretical model with which to integrate these multi-level data and conceptualise human-environment interactions in the Semirech'ye region and the wider Eurasian steppe zone.

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List of contents, figures and tables

Table of Contents

Acknowledgements..4

Chapter 1 : Introduction..16

1.1. Overview of research aims..17

1.2. Structure of thesis..18

Chapter 2 : Background to phytoliths and faecal spherulites and their application in archaeology 21

2.1. Phytoliths..21

2.1.1. History of phytolith research in archaeology..21

2.1.2. Formation and preservation of phytolith assemblages..23

2.1.3. Phytolith extraction from sediment, identification, and quantification..27

2.1.4. Uses of phytolith data in archaeology..31

2.2. Spherulites..33

2.2.5. Structure and formation of faecal spherulites..33

2.2.6. Preservation of faecal spherulites..35

2.2.7. Use of faecal spherulites in archaeological analyses..36

Chapter 3 : Context and research questions..37

3.3. Political and academic context..38

3.4. Archaeology..39

3.4.8. Chronology..39

3.4.9. Late Bronze to Iron Age transitions in Central Asia..43

3.4.10. Archaeology of Semirech'ye..48

3.4.11. Archaeology of the exploitation of plant resources in Central Asia..54

3.5. Palaeoclimate..65

3.5.1. Geography and geology..65

3.5.2. Modelling climate mechanisms 67
3.5.3. Late Holocene climate 74
3.6. Research aims and original contribution of research 88

Chapter 4 : Theoretical approach 92

4.1. The purpose of archaeological theory 92

4.2. Resilience theory 95

4.3. Resilience Theory and Archaeology 103

4.4. Resilience theory in the case of Semirech'ye 106

Chapter 5 : Background to the sites in this study 116

5.1. Soils and vegetation in Semirech'ye 116

5.2. Tuzusai 128

5.2.1. Archaeology 130
5.2.2. Palaeoclimate 135
5.3. Tasbas 139

5.3.1. Archaeology 143
5.3.2. Palaeoclimate 145
5.4. Turgen II 145

5.4.1. Archaeology 147
5.4.2. Palaeoclimate 154
Chapter 6 : Methodology 156

6.1. Sampling strategy 156

6.1.1. Selection of samples 156
6.1.2. Collection of samples 160
6.2. Phytolith extraction methodology 162

6.3. Phytolith counting methodology 164

6.3.1. Counting strategy 164

6.3.2. Recording method 166
6.3.3. Numerical analysis of multi-celled phytoliths 169
6.3.4. Phytolith identification criteria 170
6.4. Faecal Spherulite extraction and identification 173
6.5. Multivariate analysis methodology 175
Chapter 7 : Results 180
7.1. Phytolith densities and the recognition of anthropogenic assemblages 180
7.1.1. The identification of archaeological sediments 185
7.1.1. Phytolith densities on individual sites 186
7.2. Overview of phytolith assemblages at the three sites 189
7.2.2. Tuzusai 189
7.2.3. Tasbas 196
7.2.4. Turgen 201
7.3. Ubiquity 203
7.3.1. Cultivated cereals 206
7.3.2. Phragmites australis and Cyperaceae 208
7.3.3. Ubiquities on individual sites 209
7.3.4. Wild grasses 217
7.4. Proportion of elongate psilate to dendritic phytolith morphotypes 220
7.5. Multivariate analysis 223
7.6. Climatic indices 237
7.6.5. Tasbas 240
7.6.6. Tuzusai 243
7.6.7. Turgen 245
7.7. Phytolith morphotypes 247
7.8. Faecal spherulites 253
Chapter 8 : Discussion and conclusions 258

8.1. Plant food resources 259

8.2. Land use and local environments 266

8.3. Resilience theory and the archaeological record in Semirech'ye 271

8.4. Conclusions 273

Bibliography 275

CD-ROM List of Contents 294

List of figures

Figure 1.1. Political map of Central Asia showing the location of Kazakhstan in relation to its neighbours Russia, China, and the Central Asian republics. The Semirech'ye region is highlighted in green. (Map created by author using www.simplemappr.net). 16

Figure 1.2. Physical map of the Semirech'ye region, showing the Tien Shan, Dzhungarian Alatau and Chu-Ili mountain ranges, Lake Balkhash and the Ili river, the largest river in the region. Note the Capchagai reservoir on the Ili river is labelled here using the Kazakh spelling 'Qapshaghay'. The three sites that are included in this study are marked with the red symbols, with the legend given in the top-right corner of the map. (Map created by author using www.simplemappr.net). 17

Figure 2.1. Cornelis and Delavaux's (2016) conceptual scheme of silica movement within the soil-plant system. The different boxes represent 'pools' of silica within the system, and the arrows represent the mechanisms by which silica moves around the system (Cornelis and Delavaux 2016: Figure 1) 24

Figure 2.2. Photograph of a faecal spherulite under a) plane light, showing dislocated inner core in the centre; and b) crossed polarised light, showing extinction cross. Scale bar is 10µm (author's photograph). 34

Figure 2.3 The structure of a spherulite as suggested by Canti, showing a formation consisting of radially crystallised calcium carbonate with an organic outer coating around a disolated inner core (Canti 1997, fig. 1) 35

Figure 3.1. Monument to the Iron Age Saka 'Golden Warrior', located opposite the parliament building and presidential palace in Republic Square in the city of Almaty in the Semirehc'ye region, Kazakhstan (author's photograph) 39

Figure 3.2. Location of the archaeological sites in Semirech'ye mentioned in this dissertation. The sites marked with yellow pins are those which were sampled for this research. Note that

due to the scale of the map, the marker for Tuzusai also covers the locations of Taldy Bulak and Tseganka. 50

Figure 3.3. Map of the Ili-Balkash basin, showing the catchment area of Lake Balkhash, and the main river and lake systems (adapted from Petr and Mitrofanov 1998, 146). 65

Figure 3.4. Map of the modern (1982) average annual rainfall for Semirech'ye, showing the sharp contrast in precipitation regimes between the mountainous regions to the south and east, and the plains to the north and west (after ANKSSR 1982)..68

Figure 3.5. Pollen diagram showing a selection of taxa from a sediment sequence from Kutuzhekovo Lake, located in south-central Siberia (vanGeel *et al.* 2004, fig. 2) 76

Figure 3.6. Reconstruction of average temperature and precipitation in Semirech'ye during the last 3200 yrs (150 yrs temporal resolution; based on palynological analyses). a) In the plains (Tamgaly, 800 m asl, semi-desert landscape); b) In the mountains of Semirech'ye (Turgen, 2300 m asl, alpine meadows). Temperature (T) is indicated by red lines, precipitation (P) by blue dashed lines. The absolute chronology is provided by EPR and 14C analyses (dots) and archaeological correlation (segments) (Aubekerov *et al.* 2003, fig. 2).................................82

Figure 3.7. The percentage pollen diagram for Lake Balikun (Cheng-Bang *et al.* 2011, fig. 4)84

Figure 4.1. The 3D Adaptive cycle. Phases of rapid growth (r), conservation (K), release (Ω) and reorganization (α). Dearing (2008, Figure 1), adapted from Gunderson and Holling (2002).100

Figure 5.1. Modern vegetation map of Semirech'ye, showing the many different vegetation zones in the region. Each colour-coded number represents a different classification of vegetation, with the key to those numbers on this diagram given below (after ANKSSR 1982, translations from the original Russian my own): 117

Figure 5.2. Modern soil map of Semirech'ye, showing the distribution of soils in the region. Each colour-coded number represents a different soil classification, and the key to those numbers on this diagram is given below (after ANKSSR 1982, translations from the original Russian my own): 120

Figure 5.3. Desert/semi-desert steppe vegetaion of the pre-Balkhash region (author's photograph) 123

Figure 5.4. Vegetation of the steppe belt (c.1000m asl), showing mixed grass/forb meadows and deciduous woodlands. The foothills of the Tien Shan mountains are visible in the background (author's photograph)..123

Figure 5.5. Subalpine high mountain meadows near the site of Turgen, elevation c.2200m asl, showing mixed forb/grass meadows and *Picea Schrenkiana* forests (author's photograph).124

Figure 5.6. Assy plateau, elevation 2600-2800m asl, located at the alpine/subalpine ecotone, showing low-grass meadow vegetation (author's photograph)...124

Figure 5.7. View of the ecotone between the alpine and the glacier and moraine belt. Alpine vegetation cover is shown in the background, consisting of low-grass meadows, and in the foreground is glacier and moraine belt vegetation, consisting of single-standing species in the stony substrate (author's photograph). 125

Figure 5.8. Glacier at the head of the Small Almaty Gorge (c.3400m asl), showing sparse glacier and moraine belt vegetation in the foreground (author's photograph)............................ 125

Figure 5.9. Map of the three sites in this study.. 128

Figure 5.10. Google Earth image showing the location of Tuzusai on the Talgar alluvial fan129

Figure 5.11. Talgar river... 129

Figure 5.12. Google Earth image of the Tuzusai settlement located to the west of the Tuzusai ancient stream channel.. 130

Figure 5.13. View of the Tuzusai settlement from the opposite bank of the Tuzusai channel131

Figure 5.14. Tuzusai mud brick... 132

Figure 5.15. Tasbas location in the context of the Bayan-Zhurek low mountain range, the Kaskarau valley, and the foothills of the Dzhungar Alatau mountains 139

Figure 5.16. View to the south from above the Tasbas settlement looking towards the Dzhungar-Alatau mountains across the Kaskarau valley 140

Figure 5.17. Tasbas settlement amongst massive glacial boulders 141

Figure 5.18. Tasbas location showing location in relation to rivers and seasonal channels142

Figure 5.19. Seasonal watercourse near Tasbas settlement... 142

Figure 5.20. Turgen II site location showing relation to the Asi plateau (to the North-East) and water courses 146

Figure 5.21. Turgen II site location, showing relation to the upper Turgen river and moraine outcrop 147

Figure 5.22. Photograph of Turgen II site, showing upper Turgen channel (Kyzylbulak stream) and site location, indicated by tall vegetation 147

Figure 5.23. Worked stone object discovered at the base of a pit/post hole at Turgen-II, with carved triangular shapes, scratched lines, and 'sun head' symbol (author's own image of freshly-excavated find) 148

Figure 5.24. Turgen-II - Iron Age floor surface 150

Figure 5.25. Turgen-II site showing sampled profile in excavation wall to the left and the Iron Age occupation floor under excavation to the right 151

Figure 5.26. Turgen II profile in wall of excavations sampled for phytoliths. The large stones of the burial mound are visible in the top of the profile, and at the bottom of the profile is a small pit/post hole dug into the natural sediment which is pale yellow in colour. The large charcoal and ash deposit from which the radiocarbon date was obtained is visible in the centre of the profile. 152

Figure 5.27. Turgen profile showing the location of the sample (marked with the star) from which a radiocarbon date was obtained (1450-1400 cal BC (1 sigma, high peak). 154

Figure 6.1. Sampling a pit house floor at Tuzusai (1.4m in diameter) 158

Figure 6.2. Recording samples at Turgen 161

Figure 7.1. Mean density of phytolith material (mg phytoliths per g sediment) 181

Figure 7.2. Mean density of phytolith material by feature type at Tuzusai 186

Figure 7.3. Density of phytoliths from floors and other surfaces at Tuzusai 187

Figure 7.4. Tasbas phytolith densities (mg phytoliths per g sediment) 188

Figure 7.5. Turgen phytolith densities (mg phytoliths per g sediment) 189

Figure 7.6. Percentage composition of phytolith assemblage for single-celled morphotypes in mud brick samples. 195

Figure 7.7. Number of phytoliths per gram of sediment in mud brick samples 196

Figure 7.8: Ubiquity of economically significant plants for all sites 206

Figure 7.9: Tuzusai ubiquity by phase 211

Figure 7.10: Tasbas ubiquity by phase 211

Figure 7.11: Turgen ubiquity by phase 215

7.12. Ubiquity of wild grass husks for all phases 217

7.13. Tuzusai: ubiquity of wild grass husks by phase 218

7.14. Tasbas: Ubiquity of wild grass husks by phase 219

7.15. Turgen: ubiquity of wild grass husks by phase 219

Figure 7.16. Tuzusai. Proportion of psilate to dendritic phytolith morphotypes by phase. 220

Figure 7.17. Turgen. Proportion of psilate to dendritic phytolith morphotypes by phase. 220

Figure 7.18. Tasbas. Proportion of psilate to dendritic phytolith morphotypes. 221

Figure 7.19. Biplots of the results of Principal Components Analysis (a) without presence/absence data as environmental variables included in the analysis (the first two axes explain 26.9% of variability in the species data); (b) with these data included (the first two axes explain 27.1% of the variability in the species data). 224

Figure 7.20. Species and samples biplot of PCA (the first two axes explain 27.1% of the variability in the species data). Samples are classified by date. 227

Figure 7.21. Samples and environmental variables biplot of the PCA (the first two axes explain 27.1% of the variability in the species data), with the environmental variables passively projected onto the ordination space. Nominal environmental variables are unlabelled here in order to made the plot easier to read. The samples are classified by date. 229

Figure 7.22. Samples and environmental variables biplot of the PCA (the first two axes explain 27.1% of the variability in the species data). Samples are classified by altitude, and the environmental variables are passively projected onto the ordination space. 230

Figure 7.23. RDA. Species and environmental variable biplot. The total variability that is explained by the constrained (canonical) axis (first axis) is 7.5%, total variability explained by the unconstrained axis is 15.2%. 232

Figure 7.24. RDA. Samples and environmental variable biplot. The total variability that is explained by the constrained (canonical) axis (first axis) is 7.5%, total variability explained by the unconstrained axis is 15.2%. Samples are classified by date. 233

Figure 7.25. Second RDA. Species and environmental variables biplot. The amount of variability which is explained by the other environmental variables, in addition to the 7.5% of variability explained by the altitude, is 14.7%. 235

Figure 7.26. Second RDA. Species, samples and environmental variables triplot. Samples classified by date. The amount of variability which is explained by the other environmental variables, in addition to the 7.5% of variability explained by the altitude, is 14.7%. 236

Figure 7.27. Tasbas Climatic Index (Ic) 240

Figure 7.28. Tasbas Aridity Index (Iph) 241

Figure 7.29. Tasbas D/P ratio 242

Figure 7.30. Tuzusai Climatic Index (Ic) 243

Figure 7.31. Tuzusai Aridity Index (Iph) 244

Figure 7.32. Tuzusai D/P ratio 244

Figure 7.33. Turgen Climatic Index (Ic) 245

Figure 7.34. Turgen Aridity Index (Iph) 246

Figure 7.35. Turgen D/P ratio 247

Figure 7.36. Short cell phytoliths (see Piperno 2006; Twiss *et al.*, 1969): grass phytoliths a) & b) bilobes; c) square bilobe; d) scooped bilobe; e) half bilobe (broken); f) & g) polylobe; h), i) & j) quadralobes (crosses); k) bulliform; l) keystone; Cyperaceae phytolith m) sedge cone; n) 'fried egg' – possible sedge cone but firm identification not possible from variants of this form seen. Scale bar in each photograph is 10µm (author's own photographs). 248

Figure 7.37. Long cell grass phytoliths at the top, short cell saddle grass phytoliths and hair phytoliths underneath (see Piperno 2006): long cell - a) elongate psilate; b) elongate dendritic; c) elongate crenate; d) elongate echinate; e) & g) elongate psilate, cf. Cyperaceae; f) elongate sinuate; h) elongate psilate tapering one end; short cell - i)-k) saddles, j) appears to be of the 'plateau' morphotype originating in *Phragmites australis* (Lu and Liu 2003); l) hair; m) & n) trichomes. Scale bar in each photograph is 10µm (author's own photographs) 249

Figure 7.38. Short cell rondel grass phytoliths (Piperno 2006; Twiss *et al.*, 1969): a) rondel; b) tower rondel; c) conical rondel; d) tower rondel with processes; e) hide rondel (named for resemblance to animal hide); f) *Stipa*-type rondel; g) hat rondel; h) chunky rondel; i) long rondel; j) scutiform; k) horned rondel. Scale bar in each photograph is 10µm (author's own photographs) 250

Figure 7.39. Phytoliths from dicotyledons or of uncertain origin (Bozarth 1992; Piperno 2006): a) honeycomb structure from dicotyledon (Bozarth 1992); b) amorphous silica plates/sheets with mineral inclusions typical of woody dicotyledons; c) jigsaw-puzzle phytoliths from a dicotyledon; d) small plates from dicotyledon; e) plate with processes, possibly from dicotyledon; f) lightly silicified silica 'sheet' from woody dicotyledon; g) oval phytolith, possibly from dicotyledon; h) 'tombstone' phytolith, possibly from dicotyledon; i) blocky polyhedron phytolith, found in *Pinus* sp. (also observed in modern *Picea schrenkiana* reference); j) tracheid from dicotyledon; k) spheroid from dicotyledon. Scale bar in each photograph is 10µm (author's own photographs). 251

Figure 7.40. Multi-celled grass phytoliths that have been identified to genus level or beyond: a) barley husk (*Hordeum* sp.) (identified using references: Rosen 1992; Arlene Rosen pers. comm.; UCL reference collection); b) wheat husk (*Triticum* sp.), having large sometimes irregular dendritic wave pattern, papillae having 10-12 pits (Rosen 1992; Arlene Rosen pers. comm.; UCL reference collection); c), d) and e) silica skeletons characteristic of *Phragmites australis,* c) stem and d) & e) epidermal layer with many stomata (UCL reference collection, Arlene Rosen pers. comm.); f) *Setar`ia italica* husk, having symmetrical rounded dendritic forms (Lu *et al.* 2009b); g) & h) *Panicum miliaceum* husk, having asymmertrical 'finger-like' dendritic forms (Lu *et al.* 2009b). Scale bar in each photograph is 10µm (author's own photographs). 252

Figure 7.41. Multi-celled phytolith from grass leaf or stem, showing long and short cells *in situ* (elongate psilate, elongate echinate, elongate sinuate, and bilobe). Scale bar is 10µm (author's own photograph) 252

Figure 7.42. An example of biogenic opaline silica of non-plant origin: a sponge spicule, identified through its long narrow psilate form, and presence of central core (axial filament) running through its length (Uriz *et al.* 2003). Scale bar is 10µm (author's own photograph). 253

Figure 7.43. Faecal spherulite under a) plane polarised light and b) crossed polarised light, showing extinction cross. Scale bar in each photograph is 10µm (author's own photographs). 254

Figure 7.44. Presence of faecal spherulites in selected samples, presented as number of spherulites per gram of sediment 255

List of tables

Table 3.1. Comparative chronology of the sites in this study together with general technological/cultural trends across Eurasia (after Christian 1998) 41

Table 6.1: CANOCO Date coding table 177

Table 7.1. Tuzusai presence/absence of economically significant plants 191

Table 7.2. Tasbas presence/absence of economically significant plants 197

Table 7.3. Turgen presence/absence of economically significant plants 202

Table 8.1. Summary of exploitation of plant food resources over time 265

Table 8.2. Comparison of evidence for land use and palaeoclimatic data 270

Chapter 1: Introduction

The research presented in this thesis is based on phytolith and faecal spherulite data from three sites located in the Semirech'ye ('land of seven rivers') region of south-eastern Kazakhstan (Figure 1.1), an area consisting of a wide variety of different landscape zones (Frachetti 2008, 10). With a focus on land use and subsistence strategies this thesis explores the changes seen in both the palaeoclimatic and the archaeological record around the turn of the 1st millennium BC, a period identified through archaeological material culture as the transition from the Bronze Age to the Iron Age in this region (Hanks 2002, 183; Kuzmina 2008, 66).

Figure 1.1. Political map of Central Asia showing the location of Kazakhstan in relation to its neighbours Russia, China, and the Central Asian republics. The Semirech'ye region is highlighted in green. (Map created by author using www.simplemappr.net).

Original data has been generated through the analysis of phytolith and faecal spherulite samples taken from the three sites in this study (location shown in Figure 1.2): Tuzusai, a large Iron Age settlement consisting of pit-houses with mud brick architecture; Tasbas, a site with a settlement history from the Bronze Age to the Early Iron Age with both permanent dwellings and evidence of more ephemeral occupation; and Turgen II, a site with Bronze Age ritual structures, evidence of Late Bronze and Early Iron Age temporary encampments, and

Iron Age burial mounds. The majority of the data in this research comes from phytolith analysis, with faecal spherulite analysis providing a smaller but nonetheless valuable component of the research.

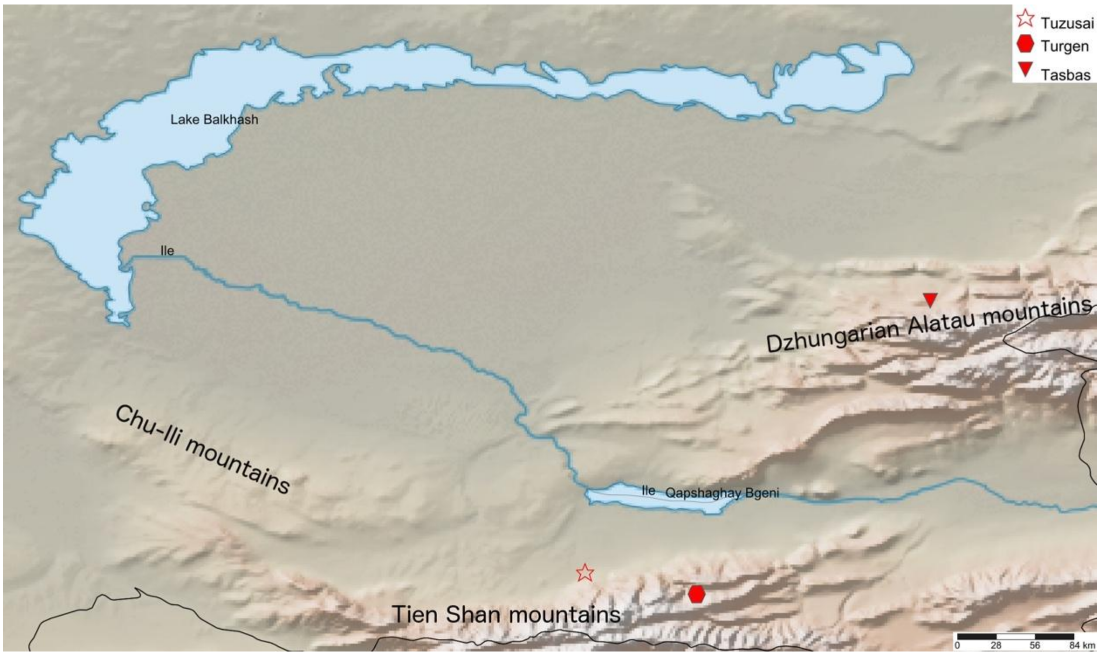

Figure 1.2. Physical map of the Semirech'ye region, showing the Tien Shan, Dzhungarian Alatau and Chu-Ili mountain ranges, Lake Balkhash and the Ili river, the largest river in the region. Note the Capchagai reservoir on the Ili river is labelled here using the Kazakh spelling 'Qapshaghay'. The three sites that are included in this study are marked with the red symbols, with the legend given in the top-right corner of the map. (Map created by author using www.simplemappr.net).

1.1. Overview of research aims

The research questions and aims of this project are expanded upon in detail at the end of Chapter 3, following a review of the current understanding of the archaeological and palaeoclimatic record. It was felt that this context was needed in order to provide the fullest possible context with which to frame the questions.

The primary aim of the research is to generate new data relating to the exploitation of plant resources during the transitional period from the Late Bronze to the Iron Age, such as evidence for the cultivation of domesticated cereals, the gathering of wild plant resources for food, construction, and craft, or grazing and foddering practices. The reason for approaching this period through these datasets is that during the Soviet period systematic archaeobotanical work in this region was a sorely under-represented area of archaeological activity (Anthony *et al.* 2005; Coolidge 2010, 62; Popova 2006), and therefore any new data on the exploitation of plant resources has the potential to shed new light on the interpretation of the archaeological record.

With this in mind, the first part of this thesis is concerned with providing an extensive literature review of the current understanding of the archaeological and palaeoclimatic record for the region in order to provide a frame for the research questions. The aim of this approach is to highlight the unique nature of the Semirech'ye study area in relation to its geographical and ancient cultural setting, and also to demonstrate the complexity of the interactions of its people and environment in the past. During this period both the archaeological and palaeoclimatic records point to significant changes in material culture, social organisation (Hanks 2002, 183), and climate (van Geel *et al.* 2004), and a secondary aim of this thesis is to test the resilience theory model for its suitability with which to integrate these multi-level data and conceptualise human-environment interactions in the Semirech'ye region and the wider Eurasian steppe zone. The resilience theory model has not been proposed for this region and period before, and therefore this thesis offers a fresh approach to the archaeological record, both established and newly generated in the course of this research.

The following section outlines the structure of the thesis, giving a summary of each chapter and a brief overview of its contents.

1.2. **Structure of thesis**

Chapter 2 provides a literature review of both phytolith and faecal spherulite analysis, discussing the strengths and weaknesses of both approaches with reference to their formation and taphonomy. The chapter also highlights particular studies which are of relevance to answering the questions posed in this thesis.

Chapter 3 of this thesis details the current understanding of the archaeological and palaeoclimatic record through an extensive literature review, and uses this information to frame the research questions which drive this project. Both the archaeological and palaeoclimatic data on Semirech'ye are presented with reference to the wider context of northern Eurasia, and this chapter aims to highlight both the unique characteristics of the Semirech'ye region, and its similarities with the northern Eurasian steppe zone in general. The research questions also reflect this relationship between the specifics of the activities at the three sites and how they can inform the general picture of land use and subsistence strategies in the region during the period in question.

Chapter 4 outlines the theoretical approach which underpins the research. In this thesis resilience theory is adopted as the theoretical model with which to approach and answer the research questions, and the first part of the chapter details the resilience model. The latter part of the chapter demonstrates the applicability of this theory to archaeology, and how the resilience model might be applied to the archaeological record in Semirech'ye.

Chapter 5 provides detailed site information for each of the three sites in this study, setting each site in its geographical context and providing an overview of the key structures and features present. For each site the phasing is provided together with any absolute dates that have been obtained, and a brief overview is given of the material culture and, where available, the macrobotanical and faunal assemblages. Any palaeoclimatic data local to the site is also presented here.

With the background, research questions, and theoretical approach having been presented Chapter 6 details the methodology by which the data was gathered in order to answer the research questions. This chapter details the sampling strategy for the collection of sediment samples in the field, the lab protocol for the extraction of phytoliths, and the recording and counting methodology for the analysis of phytolith data. The chapter ends with details about the extraction and recording methods for faecal spherulites, which form a small but nonetheless important component of this research.

The results of the phytolith and faecal spherulite analysis are presented in Chapter 7. The phytolith analysis forms the majority of the data in this study. The chapter begins by discussing the identification of anthropogenic sediments, before giving a general overview of the phytolith assemblages from each of the three sites. The rest of the chapter is then divided into sub-sections, each addressing a different angle of analysis of the phytolith data. At the end of the chapter the results of the faecal spherulite analysis are presented. Both the sites as a whole and their individual phases are considered in this analysis.

The results and their significance in relation to one another and the research questions are discussed in Chapter 8. This chapter highlights specific outcomes of the research in broadly themed sections, and relates these back to the palaeoclimatic and archaeological data and the theoretical model. The chapter offers a critical assessment of the resilience theory model, how far it has proven to be a useful approach for this research, and what refinements might be applied to this model in light of the new data. Concluding remarks are offered at the end of the chapter, together with suggestions for future research directions.

Chapter 2: Background to phytoliths and faecal spherulites and their application in archaeology

2.1. Phytoliths

Phytoliths are the microscopic three-dimensional amorphous biogenic silica (opal) infillings of cavities within and between the cells of certain plants (Thorn 2007). This process starts when dissolved monosilicic acid (H_4SiO_4) in groundwater is taken up by the roots of plants and carried up to the aerial organs through the xylem (Piperno 2006,5). The silica is not metabolised by the plant, and it is deposited as siliceous gel which gradually crystalises into a solid particle (Thorn 2007). Once deposited, phytoliths are incredibly durable, and following the death and decay of the plant they are deposited into soils and sediments, forming a fossil record of the plants which formed them (Piperno 2006, 5). Of course, many different factors affect the resulting phytolith assemblage that is found in archaeological soils and sediments, and this chapter will consider the different mechanisms and processes that might affect the final phytolith assemblage that is analysed in the laboratory. The first part of this chapter gives a brief history of phytolith research, then the formation and taphonomic processes that can affect the phytolith assemblage which is available to archaeologists is assessed, and finally examples are discussed of the ways in which phytolith data have been used which are relevant to this research.

2.1.1. *History of phytolith research in archaeology*

The history of the study of phytoliths covers a multitude of disciplines, including archaeology, biology, ecology, botany, plant genetics, geology and soil science (Piperno 2006). The first study of phytoliths was published in 1835 (Struve 1835), and the earliest taxonomic studies were conducted between 1900-1935 (Bryant 1993), including the identification by Ehrenberg of over sixty-seven phytolith forms from samples of wind-blown dust collected by Darwin from the sails of HMS *Beagle* in 1833 (Darwin 1909, 5; Piperno 2006, 3). Despite these early observations, Bryant (1993) has highlighted the slow start in the use of phytolith data in archaeobotanical research during the 20th century in contrast to that of pollen. Neolitzky identified phytoliths from wheat and barley in prehistoric sediments from European archaeological sites in 1900 (Neolitzky 1900), and later used phytoliths to prove the use of economically important plants in settlements from other European sites (Neolitzky 1914). However, these early archaeological studies failed to gain momentum, and it was not until half a century later that detailed archaeobotanical research into phytoliths began in earnest, with the identification of rice, wheat and barley phytoliths demonstrated at archaeological sites in Japan and the Middle East by Watanabe (1955; 1968) and Helbaek (1961; 1969) (Bryant 1993, 176; Piperno 2006,3). Metcalfe's (1960) important publication on the leaf anatomy of grasses provided the basis for further morphological study of phytoliths, most notably by Twiss *et al.* (1969), who developed a classification system for the discrimination of phytoliths belonging to the Panicoideae, Pooideae and Chloridoideae subfamilies. Rovner (1971) further highlighted the potential of phytolith data for palaeobotanical research, in particular demonstrating the complementary role that phytolith and pollen data can play. Importantly for archaeobotanical research, further studies were also made at this time into the morphological characteristics of phytoliths from cereals, such as Parry and Smithson's (1964; 1966) publications on phytoliths from British grasses and cereals, and Blackman's (1968; 1969) studies of wheat and rye. Research into New World cereals was also being conducted, for example with Pearsall (1978) using phytolith evidence to demonstrate maize cultivation in Ecuador.

Further research into phytolith evidence of prehistoric plant use and domestication in the Americas by researchers such as Bozarth (1986; 1987), Piperno (1984; 1985a; 1985b; 1988; 1989) and Pearsall (1982; 1987) contributed to the establishment of phytolith research in archaeology, the real blossoming of which was marked by two publications: the first dedicated publication on the use of phytoliths in archaeology by Piperno (1988); and the inclusion by Pearsall (1989) of phytolith analysis in her handbook of palaeoethnobotanical procedures. These two publications brought phytolith analysis to the attention of a wide audience, and provided a useful single-source starting point for interested researchers (Bryant 1993).

With the foundation laid by these early pioneers, the number of phytolith researchers has since grown dramatically, with an increasing diversity of research topics (Hart 2016). The latter part of this chapter will review those techniques and studies which are most relevant to this research, and the following section will highlight research on the factors affecting the formation and preservation of archaeological phytoliths assemblages.

2.1.2. ***Formation and preservation of phytolith assemblages***

When analyzing any phytolith assemblage, there are a number of factors that must be considered with regards to how the assemblage was formed, and how the depositional environment may have affected the formation and preservation of the phytoliths, leading to biases in the phytolith record. The first factor to consider is that not all plant families produce phytoliths, and of those that do, only some of the phytoliths produced have taxonomic significance (Piperno 1988, 2006; Strömberg 2003). Those families of primary relevance to the mountainous, semi-arid and arid steppe zones of Central Asia whose phytolith production is both high and phytolith forms have taxonomic significance are: Poaceae (grasses); Cyperaceae (sedges); and Equisetaceae (horsetails, scouring rushes) (Piperno 2006, 7). Additionally, phytoliths have been observed in the Pinaceae which may have diagnostic value but which are not produced in such abundance (Klein and Geis 1978; Rovner 1971). Klein and Geis (1978) note that some species of *Picea* produce silicified endodermal cells, which could be confused with grass bulliforms. This may have particular relevance to the analysis of high mountain steppe zones, where the tree line meets the high-mountain grass meadows. In addition to those phytolith morphotypes that have taxonomic value, phytoliths are also produced in wood and twigs which have a distinct form attributable to woody plants, but for which no further attribution is possible (namely globular/ellipsoid forms, irregular forms with mineral inclusions, and silica aggregates) (Albert *et al.* 1999; Piperno 2006, 41; Scurfield *et al.* 1974;). Recent work by Collura and Neumann (2016) on West African bark and wood indicated that silica production in bark is much more common than in wood, but that overall production is uneven at different taxonomic levels.

In addition to genetically driven species-specific variations in phytolith formation, aspects such as soil chemistry, water availability and evapotranspiration rates have been demonstrated to affect both the amount of available dissolved silica and the rate at which it is taken up by plants (Piperno 2006, 8). Laboratory studies have shown that the amount of available dissolved silica is an important factor in the rate of phytolith production, with grasses in particular showing a direct positive correlation between amounts of solid silica deposited in the plant and the amount of dissolved silica in the growth medium (Blackman, 1968; Blackman and Parry, 1969; Jones and Handreck 1965; Parry and Smithson, 1958, 1964, 1966; Yoshida *et al.*, 1959;). The amount of silica available in groundwater depends on a complex soil-plant cycle, best illustrated in the diagram by Cornelis and Delavaux (2016) below (Figure 2.1).

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Figure 2.1. Cornelis and Delavaux's (2016) conceptual scheme of silica movement within the soil-plant system. The different boxes represent 'pools' of silica within the system, and the arrows represent the mechanisms by which silica moves around the system (Cornelis and Delavaux 2016, Figure 1)

The rate at which this cycle occurs is governed by the same factors that govern soil formation processes (namely climate, topography, soil parent material, the age of the soil) and biotic factors (vegetation, micro-organisms, and land use) (Alexandre *et al.* 1997; Alexandre *et al.* 2011; Cornelis *et al.* 2011; Cornelis and Delavaux 2016; Sommer *et al.* 2006; Street-Perrott & Barker 2008; White *et al.* 2012). Acidic soil environments are known to have more free silica available, but high concentrations of iron and aluminium oxides can absorb or bind silica to their surfaces, thus removing it from solution (Piperno 2006, 8).

Research into the relationship between water availability and phytolith production in grasses, or more specifically cereals, has indicated that an increase in water supply, whether through rainfall or irrigation, leads to an increase in the production of phytoliths, with Rosen and Weiner (1994) noting an increase in the number of conjoined phytoliths, and Madella *et al.* (2009) and Jenkins *et al.* (2011) noting an increased ratio of long cells to short cells. High evapotranspiration rates can also cause an increase in solid silica deposition in the aerial structures of grasses due to the presence of a supersaturated solution of silica leading to the precipitation of solid forms (Jones and Handreck 1965; Piperno 2006, 8; Rosen and Weiner 1994).

Having considered the factors affecting phytolith formation processes within plants, the second group of factors to consider are the external mechanisms behind the deposition and subsequent taphonomy of the phytolith record. Zurro *et al.* (2016) identify two major groups of mechanisms that influence the composition of a phytolith assemblage: 1) the origin of the input plant assemblage (whether anthropic, natural or both); and 2) pre- and post-depositional taphonomy. The origin of the deposition of plant material in an archaeological sediment can be assumed to be largely deposited by human activity (although periods of no occupation should also be considered for sites with multiple occupancy periods), and therefore phytolith assemblages recovered from various contexts can be expected to reflect different activities around a site, such as crop processing (Harvey and Fuller 2005), craft production (Ryan 2011), bedding (Cabanes *et al.* 2010), and the burning of fuel (Lancelotti and Madella 2012). Phytolith and spherulite data has the potential to answer some of these questions by identifying, for example, whether a sediment contains evidence for a concentration of crop processing waste or sheep/goat dung, which might indicate a midden, or a phytolith assemblage that is concurrent with surrounding mud brick, indicating that the fill was caused by the collapse of a wall (Katz *et al.* 2007; Lancelotti and Madella 2012; Portillo *et al.* 2009).

Pre- and post-depositional taphonomic processes begin with the death of the plant, leading to the release of phytoliths. This can happen through a number of different pathways, for example the natural death and decay of plants within a soil A horizon, through the deliberate burning of plant material (phytolith morphology is preserved at temperatures up to 800°C (Parr 2006; Shillito 2011)), deposition through animal dung (which may also be redeposited by human action for example as fuel or temper (Lancelotti and Madella 2012)), and midden deposits to name but a few (Piperno 2006, 21). Jenkins (2009) compared the extraction of phytoliths from modern durum wheat plants (*Triticum durum*) using dry ashing and acid digestion methods, and determined that the resulting number of conjoined phytoliths was greatly reduced using the acid digestion method. This not only has implications for future studies using modern plant material, but also illustrates how pre-depositional taphonomic processes might change resulting phytolith assemblage. An example of this might be the destruction of a thatched house through fire compared to a gradual process of disuse and collapse.

Madella and Lancelotti (2012) highlight that following the death of the plant, the decay of the plant tissues releases the phytoliths and at this point they may be subject to pre-depositional transport by wind or water which can cause damage, for example through abrasion and chipping. In open, wind-blown environments such as deserts this transport might be significant, however in most cases it is minimal since phytoliths are relatively ‘heavy’ particles. In archaeological contexts phytoliths might be spread and dislocated through actions such as sweeping a floor, which may also lead to the redeposition of material in a different place to that of its origin (Madella and Lancelotti 2012), for example the clearing and burning of crop processing waste away from a threshing floor.

Post-deposition, phytoliths in both natural and anthropic contexts are exposed to the processes of pedogenesis, fossil diagenesis, and bioturbation (Madella and Lancelotti 2012). A study by Fishkis *et al.* (2010) using a fluorescent marker on phytoliths extracted from *Phragmites australis* and added to active soils found that over the course of a year, phytoliths were found to move downwards by an average of 4cm, with smaller phytoliths exhibiting greater movement than larger ones. Cabanes *et al.* (2011) also determined that root activity and active soil formation on an archaeological site can affect the preservation of phytoliths. Bioturbation is also acknowledged to be a major factor in the post-depositional relocation of phytoliths (Hart and Humphreys 1997, Madella and Lancelotti 2012), and is certainly an issue witnessed at the sites in this study, for example pit fills having been used by burrowing mammals and section walls being colonised by tunneling wasps and bees (personal observations). These factors mean that one must be very vigilant when sampling a context in order to ensure that the original context is sampled and not an artefact of animal disturbance (an example of which is given in the results chapter of this thesis). In addition to these natural processes, human activity can greatly affect the depositional environment (Madella and Lancelotti 2012) for example through trampling of floors which might change the rate of water percolation, and industrial activity which could affect local soil chemistry for example through the dumping of large quantities of alkaline ash, where highly alkaline soils have demonstrated low phytolith densities (Piperno 1985a, 1985b). Different pH values in soils and sediments have been proven to affect the dissolution rate of different phytolith morphotypes, with some forms being more sensitive to dissolution than others (Cabanes *et al.* 2011), with alkaline conditions causing dissolution, and mechanical agitation causing the loss of appendages on certain morphotypes.

2.1.3. ***Phytolith extraction from sediment, identification, and quantification***

Following the collection of samples in the field, the sediment must be treated in order to isolate the phytoliths, and then once extracted a subsample of phytoliths is mounted to a slide for morphological identification and quantification. Coil *et al.* (2005) provide a useful comparison of different microfossils that can be extracted from sediments, and how they might be affected by various laboratory processes as well as the strengths and weaknesses of different mounting media. Their paper also makes the point that identifying the end-goal of the extraction and the specific nature of the sediment are important factors to consider when devising a protocol. There is no single agreed method for the isolation of phytoliths from sediment, nor indeed should there be, since the researcher may be attempting to extract another microfossil at the same time, such as starches (Horrocks 2005). Discussion on methods for phytolith extraction is ongoing, and different methods have been developed to address specific requirements, such as the type of sediment and expected phytolith density (Rosen 1999), microfossils required in addition to phytoliths (Horrocks 2005; Lentfer and Boyd 1998), cost considerations, and the availability of equipment and chemicals (Madella *et al.* 1998; Parr 2002; Piperno1988; 2006; Pearsall 1989; Zhao and Pearsall 1998). Strömberg (2003, 40) has identified three common steps in all these processing methods: 1) pretreatment of the sediment to 'free' the phytoliths (disaggregation through the removal of binding agents such as carbonates, and the removal of clays and organics); 2) separation of the phytoliths from the mineral fraction; and 3) preparation of slides. As can be seen from the above discussion, the process for extracting phytoliths depends on the type of information required, the nature of the sediment, and the laboratory equipment available to the researcher.

The identification of phytolith morphotypes can be conducted on two levels: identifying and recording the form of the phytolith and then where possible attributing it to a particular family or genus (and sometimes species). Of course, confident identification of family or genus-specific phytolith morphotypes is dependent on having locally-obtained plant reference material with which to compare the archaeological samples, since one must also bear in mind that a) local species may be found to produce forms similar to different species in other regions (the problem of redundancy (Rovner 1971)), and b) a single plant may be found to produce a wide range of morphotypes (multiplicity (Rovner 1971; Piperno 1988)). Not being able to compare local variants in phytolith producing plants is a particular problem in Kazakhstan, and indeed Central Asia more widely, where systematic archaeobotanical studies are still relatively new (Wu *et al.* 2015) and very little phytolith work has been carried out (see Rosen 2001; Rosen *et al.* 2000). Unfortunately, the creation of a reference collection was outside the scope of this study, but it is acknowledged that this will be an essential next step for continued phytolith research in the region. Given these biases in production, which leave many plant species either 'silent' or underrepresented in the phytolith record, and the lack of region-specific phytolith work in Kazakhstan, phytoliths are most useful in this case for studying plant community structure as a whole, as opposed to providing specific information on taxonomic diversity within a given sample (Piperno 1988; Strömberg 2003), with the exception of the domesticated cereals, which are discussed below.

The exceptions to the potential problems with identifications mentioned above are multi-celled silica skeletons from the seed bracts of domesticated cereals, which have been widely studied in many regions of the world, providing a wealth of comparative material to aid in the identification of these phytoliths in archaeological samples. General resources covering the cereals include Mullholland and Rapp 1992; Piperno 1988, 2006; Ball *et al.* 2016; and the UCL reference collection and online database www.homepages.ucl.ac.uk/~tcrndfu/phytoliths.html. For millets see Lu *et al.* 2009, Zhang *et al.* 2011; for wheat and barley see Ball *et al.* 1993, Ball *et al.* 1996, Ball *et al.* 1999, Rosen 1992; for rice see Pearsall *et al.* 1995, Zhao *et al.* 1998. Based on previous macrobotanical and phytolith work in Kazakhstan and Central Asia, cereals of relevance to this study are wheat, barley, millet (*Panicum miliaceum* and *Setaria italica*), and rice (Chang *et al.* 2003; Charles and Bogaard 2010; Frachetti *et al.* 2010; Hunt *et al.* 2008; Miller 2003; Motuzaite-Matuzeviciute 2012; Rosen 2001; Rosen *et al.* 2000; Spengler *et al.* 2013; Wu *et al.* 2015).

The identification and recording of single-celled phytoliths has been moved towards greater standardisation since the creation of the International Code for Phytolith Nomenaclature (ICPN) developed by Madella *et al.* (2005), which proposes a standard naming protocol for describing phytolith morphotypes. This is discussed in more detail in the Methodology chapter of this thesis. Important early work on phytolith morphotype identification was carried out by Twiss *et al.* (1969), who classified grass phytolith morphotypes according to subfamilies. Further important works on identification and classification of single-celled phytoliths include Mullholland and Rapp (1992), Parry and Smithson (1964 and 1966), Piperno (1988 and 2006), Rosen (1992), Rovner (1971), Tubb *et al.* (1993) and Wang (1993).

In addition to identifying phytolith morphotypes, quantification of the phytoliths is also needed in order to allow the assemblage to be analysed and answer questions about relative abundances of morphotypes and ratios of taxonomically significant phytoliths. As with their extraction and identification, there is no single methodology for counting the number of phytoliths on a slide (Piperno 2006, 115), particularly with regards to the number of individual phytoliths that must be counted before a statistically significant representative sample of the assemblage has been recorded, although the general consensus appears to be between 200 and 300 phytoliths (Alexandre et al. 1999; Alexandre and Bremond 2009; Ball et al. 1996; Fredlund and Tieszen 1994; Iriarte 2003; Pearsall 2000; Piperno and Jones 2003; Rosen 1999; Strömberg 2009). In a study tallying phytolith morphotypes recorded against a high reference count size of 800 phytoliths, Albert and Weiner (2001) noted that less abundant phytolith morphotypes were lost when fewer than 200 phytoliths were counted. Statistical analysis by Strömberg (2009) into two commonly employed indices, *D/P* (tree cover index) and I_{ph} (aridity index), determined that while a count of around 200 diagnostic phytoliths appeared to be a good starting point, the value of the index and the number of diagnostic phytoliths together determined the statistical significance of the result. She also argues that for vegetation inference, more skewed samples towards a particular vegetation signature show more statistical significance than evenly distributed assemblages (Strömberg 2009).

This serves to demonstrate that, as with extraction methods, effective and statistically valid counting methods depend upon the nature of the assemblage and the number of diagnostic morphotypes that are present, and these factors should be taken into account both when counting phytoliths and when analysing the subsequent data.

2.1.4. ***Uses of phytolith data in archaeology***

This section will look at some of the ways in which phytolith data have been used to answer archaeological questions. The focus of the literature referenced here will be on those studies which are of direct relevance to the research questions in this thesis, and it is important to note that this is not an attempt to encompass all the many and varied ways in which phytolith data have been employed in archaeology (a comprehensive review can be found in Piperno 2006).

2.1.4.1.Identification of cereals

As outlined above in the discussion about the identification of taxonomically significant morphotypes, many studies have been focused on identifying cereals in the phytolith record (see for example Ball et al. 1993, 1996, 1999, 2016; Lu et al. 2009; Mullholland and Rapp 1992; Pearsall et al. 1995; Piperno 1988, 2006; Rosen 1992; Zhang et al. 2011; Zhao et al. 1998), which means that agricultural activity should be identifiable in the phytolith record in Kazakhstan, as proven by Rosen (2001) who identified wheat, barley, millet and rice at Tuzusai. This also opens the possibility for the calculation of the ubiquity of cereals in the same way as macrobotanical assemblages (Pearsall 2010). This would allow for a direct numerical comparison between macrobotanical and phytolith data. Since macrobotanical work is being carried out at both Tuzusai and Tasbas, calculating these values will be of value for the future integration of phytolith and macrobotanical data, as demonstrated in studies by Dickau et al. (2012), García-Granero et al. (2015) and Weisskopf et al. (2015).

2.1.4.2.Agricultural practices and land use

In addition to identifying the types of cereals being cultivated, phytolith data can also be used to indicate agricultural practices. As noted above, research into the identification of irrigation using phytolith assemblages has been carried out by Rosen and Weiner (1994), Madella et al. (2009), Jenkins et al. (2011), and Weisskopf et al. (2015b), with results indicating that changing water availability does have an impact on the nature of phytolith assemblages, meaning that it may be possible to identify cereals which have been irrigated through the ratio of 'fixed' and 'sensitive' phytolith forms which respond to water availability, or (as argued by Rosen and Weiner 1994) through an increased number of conjoined phytoliths. Phytoliths also have the potential to provide information about crop processing. Harvey and Fuller (2005) propose a model whereby phytolith forms attributable to different parts of the plant, such as leaves and stems, and husks, can be used to identify different stages of crop processing. This has the potential to inform about the differing use of space in an archaeological site, and the use and disposal of crop processing waste, for example as temper or fuel.

The analysis of phytolith assemblages using multivariate statistical methods, most commonly used in biological data analysis, has the potential to provide information about land use through the spatial patterning of data relating to phytolith communities. The use of multivariate statistical analysis in phytolith studies was first explored by Powers-Jones and Padmore (1993), who recognised that statistical patterning in the data could be related to different ecological zones. Weisskopf (2014) (see also Weisskopf et al. 2014) has explored the potential of correspondence analysis for the interpretation of phytolith assemblages relating to different arable systems of rice and millet farming. She demonstrates that by exploring phytolith assemblages as one would a biological community, groupings in the data can be found which correspond to different environmental zones (Weisskopf et al. 2014). The potential to explore different environmental 'signatures' through the multivariate analysis of phytolith data has the potential to be very useful in answering questions about the exploitation of different environmental zones around the three sites in this study.

2.1.4.3.Climate reconstruction

Phytolith data have been used to indicate past climate and land use through the calculation of two climatic indices using single cell morphotypes that are particular to the Pooid, Panicoid and Chloridoid subfamilies of grasses, as identified by Twiss *et al.* (1969; 1987). These are the climatic index, *Ic*, and the aridity index I_{ph} (Alexandre *et al.* 1997; Bremond *et al.* 2008; Piperno 2006, 32–34; Rosen 2001, 187; Strömberg 2009). In addition, vegetation cover can be indicated through the ratio of phytoliths from woody dicotyledonous plants to those from grasses (D/P°) (Bremond et al. 2005; 2008; Piperno 2006, 121). Although the archaeological samples will be viewed through an anthropogenic filter, these indices have the potential to answer questions about climate and land use around the three sites in this study, and may also provide an indication of the amount of wood material brought to the site relative to that from grasses, which may indicate aspects such as choices in fuel types (wood versus dung). The identification of dung in archaeological contexts will be further discussed in the following section, which will review literature relating to the study of faecal spherulites and their application in archaeology.

2.2. **Spherulites**

2.2.5. ***Structure and formation of faecal spherulites***

In 1983 Brochier carried out a comparative study of fresh ovicaprine droppings and Neolithic deposits from four caves in France and Greece, and proposed that archaeological deposits of sheep/goat dung could be determined through the presence of faecal spherulites in association with grass phytoliths in sediments (Brochier 1983). Further ethnoarchaeological and geological work in Sicily reinforced these discoveries, and determined that spherulites are always present in sheep droppings but sometimes absent from goat droppings, and never present in rabbit faeces (Brochier 1992). Through further investigation, Canti (Canti 1997; 1999) determined that the largest number of spherulites are produced by ruminants (sheep, cow, goat, deer), low numbers are produced by omnivorous and carnivorous species (pig, human, badger, dog, cat, fox), and they are not produced by caecal digesters (horse, rabbit, hare) (Canti 1999).

Following work by Brochier *et al.* which identified spherulites as being a calcium salt (Brochier *et al.* 1992), Canti determined that spherulites are "minute (typically 5–15 μm) spheres of radially crystallized calcium carbonate surrounded by an organic coating" (Canti 1997). Spherulites can be identified in sediment samples (and distinguished from calcium oxalate druses) by their size (much smaller than calcium oxalate druses), and the presence of a permanent extinction cross in crossed polarised light (Canti 1997; 1998; Figure 2.2).

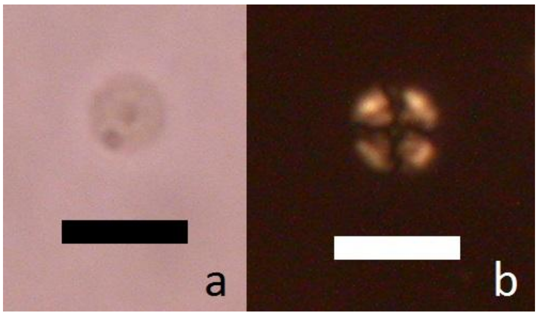

Figure 2.2. Photograph of a faecal spherulite under a) plane light, showing dislocated inner core in the centre; and b) crossed polarised light, showing extinction cross. Scale bar is 10μm (author's photograph).

Figure 2.3 shows the structure of spherulites as suggested by Canti (1997, fig. 1). He suggests that spherulites have a detached inner core, which is frequently visible under plane polarised light (see Figure 2.2 above), and an organic outer coating .

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Figure 2.3 The structure of a spherulite as suggested by Canti, showing a formation consisting of radially crystallised calcium carbonate with an organic outer coating around a disolated inner core (Canti 1997, fig. 1)

By sampling sections of sheep intestines, Canti was able to determine that faecal spherulites are absent in the upper acidic small intestine, but become abundant in the more alkaline lower sections of the small intestine (Canti 1999). The spherulites form when acidic chyme containing Ca2+ and Cl- ions from the breakdown by hydrochloric acid of calcium rich plant cell walls, plant calcium oxalates and calcite ingested in soil is neutralised by secretions rich in sodium bicarbonate lower in the small intestine (Canti 1999). These conditions are ideal for the formation of calcium carbonate spherulites (Canti 1999).

2.2.6. *Preservation of faecal spherulites*

Experiments by Canti (1997) have shown that faecal spherulites will dissolve in distilled water if subject to constant stirring, although not in calcareous water, and they are therefore sensitive to water flow through sediment. In simulating leaching conditions for various pH values, Canti (1999) determined that a pH below 7.7 is detrimental to spherulite preservation. He also points out that if the dung has been burned the pH value will be much higher, and therefore the spherulites are more likely to be preserved in dung ash. Canti (1999) also suggests that spherulites may be victim to bioturbation if consumed by meso-organisms whose digestive tract would then destroy them.

2.2.7. ***Use of faecal spherulites in archaeological analyses***

Where preserved, spherulites indicate the presence of dung, and as Canti (1999) pointed out, dung which has been turned to ash is more likely to preserve spherulites. This is particularly useful for answering questions about the use of animal dung for fuel, since the presence of spherulites in a hearth context indicates the presence of dung as fuel (Lancelotii and Madella 2012), and this information is likely to be preserved due to the alkaline nature of ash. Spherulite data was also used by Portillo *et al.* (2009) to interpret certain loci within the site of Ain Abu Nukhayla (Wadi Rum, Southern Jordan) as having been used for animal penning, since a high concentration of spherulites were observed in some areas. They also combined these data with phytolith data to infer the spatial distribution of domestic activities around the site (Portillo *et al.* 2009).

In an experimental archaeology study on deposits from Butser Ancient Farm, McPhail (2004) reported variable preservation of spherulites depending on the pH of the deposit, which demonstrates that spherulites will not necessarily be found in contexts where dung was deposited. Lancelotti and Madella (2012) also concluded that the absence of spherulites does not necessarily indicate the absence of dung, and that phytolith and chemical analysis together could also be used to give a signature for the presence of dung where spherulites have not been preserved. Therefore, despite their fragile nature, and variable preservation rates, spherulites can be useful in answering archaeological questions, but their absence cannot be taken to indicate an absence of dung, and the use of other indicators such as phytolith and chemical signatures should be used.

Chapter 3: Context and research questions

This chapter will provide an overview of the current understanding of the archaeological and palaeoclimatic record of Northern Eurasia and Semirech'ye, with a particular focus on Mid- to Late-Holocene changes, and will endeavour to place this within the context of wider issues in Central Asian archaeology. The absolute dating of sites will be considered together with the detailed relative chronologies that were created through the Soviet and post-Soviet culture-historical approach to the archaeological record.

The chapter will begin with a broad view of the archaeological record for Central Asia before focusing on Semirech'ye as a geographical and cultural entity. The archaeological evidence for the exploitation of plants in Central Asia will be given a special focus in a separate section of this chapter. The section on the palaeoclimatic record has two aims: first, to provide an account of the changes in climate that were experienced in Semirech'ye in the 2nd and 1st millennia BC, with reference to the archaeological record, as far as this can be determined; and second, to explore the relationship between Semirech'ye and the Northern Eurasian steppe zone in terms of the effects of climate change. This section will first outline the geographical and geological context of Semirech'ye before presenting reconstructions of the past climate. Reconstructions of the Holocene climatic history of Northern Eurasia, and central Asia in particular, have been conducted on a variety of different scales, using many different types of proxy data.

The current state of research resembles a partially-loaded Google Earth satellite image, with information on some areas available in very high resolution, while others remain under the broad impressionism of low-resolution, macro-scale models. Nevertheless, it is possible to draw this information together to provide some useful insights into the climatic history of the region and its implications for human habitation such as vegetation cover, landscape stability and water availability. It is argued here that comparison of large-scale and local data shows that the Mid- to Late-Holocene climatic history of Semirech'ye must be understood both in terms of broad trends common to the Northern Eurasian temperate zone and also with regards to the local reactions of microenvironments within the study area, and their varying exploitation potential for human groups, not forgetting the influence of anthropogenic actions on the landscape.

3.3. Political and academic context

Before outlining the current understanding of the archaeological record, I would like to highlight the context (both academic and political) within which archaeologists work in Kazakhstan. At present, the majority of archaeological research in Semirech'ye is controlled and conducted by two state institutes: The A. Kh. Margulan Institute of Archaeology, and the Scientific Research Institute for the Study of Nomadic Culture, located in the city of Almaty. There are also a number of foreign archaeological missions who participate in collaborative research projects with these institutes. It is interesting to note here that the Kazakh Scientific Research Institute for the Study of Nomadic Culture was formerly named the National Institute for Scientific Research and Planning on Monuments of Material Culture (Beardmore 2007a).

This state-endorsed focus on the study of pastoral nomadism is a product of the Kazakhstani government's agenda of national identity building, where the nomadic way of life is viewed as the pre-Soviet, pre-Russian empire, and, therefore, 'pure state' of the Kazakh population (Beardmore 2007a; Chang 2015; Karin, E. and A. Chebotarev 2002). Archaeological research has the potential to be employed as a legitimating tool in ancestrally-based claims to the territory of Kazakhstan, and clear ideological links have already been forged between the Saka population of Semirech'ye and the modern state of Kazakhstan, for example in the use of a Nelson's column style of monument featuring the Saka 'Golden Warrior', located opposite the parliament building and presidential palace in Republic Square in the city of Almaty (Figure 3.1) (Beardmore 2007a; Chang 2015). Any researcher studying this period of prehistory in Kazakhstan must be constantly aware of the political context in which they are working, and the ways in which their research may be aided or hampered by these social, cultural, and political considerations. Archaeology, as Sherratt (1993) has pointed out, is never a neutral endeavour. Although an in-depth discussion of these issues does not form part of this thesis, I believe it is important to at least acknowledge the deep-seated political and social beliefs that influence the methods and outcomes of our research.

Figure 3.1. Monument to the Iron Age Saka 'Golden Warrior', located opposite the parliament building and presidential palace in Republic Square in the city of Almaty in the Semirehc'ye region, Kazakhstan (author's photograph)

3.4. Archaeology

3.4.8. *Chronology*

The following section will provide the chronological context of the sites with reference to the wider archaeology of Central Asia. The place and archaeology of Semirech'ye will then be considered with reference to this context, and finally the excavation history and current information about each of the three sites in this study will be provided.

I first look towards a comparative chronology in order to fix the period of study both chronologically and socio-culturally in its wider Central Asian context. Table 3.1. Comparative chronology shows the dating and phasing of the three sites that are employed in this study (using radiocarbon dates where available), and presents them together with a comparative chronology for Eurasia (after Christian 1998). As can be seen from the table, the three sites in this study represent three points in a long chronology, and as such are well placed chronologically to provide information on differences and continuities in land use and subsistence strategies during the period of transition from the Late Bronze to the Iron Age. However, while the time period of interest in this study is well represented in the spread of dates from the sites in question, it must be acknowledged that these sites represent three small pixels in a large picture which remains unclear in Semirech'ye, even beyond the limited scope of this dissertation. Nevertheless, the exercise of presenting the data in this study is a valid and a useful one, even given its chronologically 'patchy' nature, since it will facilitate future research into this period by enabling finer-grained chronologies to be built around these few points. While the data from each site is in some cases very fine-grained, it will be synthesised to obtain a broad impression of change and continuity over time in Semirech'ye, raising questions for future research and contributing to debates about broader patterns of stability and reorganisation in this corner of Central Asia.

Date	Period	Phasing of Sites in this study				General technological/cultural trends in Eurasia (after Christian, D. 1998)		
BC		Tuzusai		Tasbas	Turgen	West	Centre	East
3000	Middle Bronze Age			Phase 1: 2840 - 2496 cal BC		Pit-grave culture	Urbanization, Namazga Depe IV; pastoralism	Farming, Mongolia
2500						Wheeled vehicles	Afanasevo culture	
2000						Pastoralist migrations?		
	Late Bronze Age					Pastoralist migrations?	Pastoralist migrations? Sintashta; chariots	Tundra cultures; pastoralism in steppes, Okunev culture; Seima-Turbino
					Phase 1 (Level 5)			
					Phase 2 (Level 5?)			
1500				Phase 2a: 1491 - 1260 cal BC	Phase 3a (Level 4?): 1450-1400 cal BC	Steppe bronze cultures, timber-grave; 'Corded ware' cultures in woodlands	Steppe bronze cultures, Andonovo; Oxus civilization; Eurasian 'world system'?	
	Final Bronze Age			Phase 2b: 1254-1053 cal BC				Karasuk culture
1000				Phase 3: 899 - 831 BC	Phase 3b (Level 3)	Scythic cultures; Cimmerians; Greek traders in Black Sea	Scythic cultures; Arzhan tomb	Scythic cultures 823 pastoralists invade north China
	Early Iron Age/ Proto-Saka Period					Scythian invasions of Mesopotamia; first Greek towns by Black Sea	Urbanization in Khorezm	
		(522 - 383 BC:			Phase 4? (Level 2)		Achaemenid empire, *c.*539 conquers Bactria	
500		single date)	Phase 1 Phase 2		408 -200 cal BC	*c.*514 Darius invades Scythia	Zoroastrianism in Achaemenid empire	
		400 - 350 BC	Phase 3			Herodotus visits Olbia *c.*450; royal tombs	Pazyryk tombs Alexander in Central Asia 329 - 327	
	Iron Age/ Saka Period Wusun Period					Sarmatians enter Pontic steppes; Scythian war 346 - 339		Pastoralist confederations north of China
		200 BC - AD 1	Phase 4 Phase 5 Phase 6			*c.*238-140 Greco-Bactrian kingdom		
100					Phase 5? (Level 1)	*c.*238 BC-CE 226 Parthian kingdom		
AD100					Phase 6? (Level 1)			

Table 3.1. Comparative chronology of the sites in this study together with general technological/cultural trends across Eurasia (after Christian 1998)

The rise in the use of absolute dating techniques in recent years, in particular radiocarbon, has led to a revision of previously accepted dates and chronologies, pushing back many sequences further into antiquity, and refining our understanding of other sequences in the archaeological record (Chang *et al.* 2003; Hanks *et al.* 2007; Frachetti & Mar'yashev 2007; Frachetti 2008; Frachetti *et al.* 2010). The key dates to note for the purposes of this study are the dating of the Final Bronze Age to the fourteenth to tenth centuries BC by Hanks *et al.* (2007) from sites in the southern Urals, and by Frachetti and Mar'yashev (2007) to 1690–920 cal BC (2 sigma) from the settlement site of Begash in Semirech'ye.

Firm dating evidence of the Iron Age Saka period from settlement sites in Semirech'ye has been obtained by Claudia Chang from the sites of Tseganka, Tuzusai and Taldy Bulak, placing them between the eighth and the third centuries BC, with the earliest dates in this range falling between cal BC 780–370 at Taldy Bulak and cal BC 740–710 and cal BC 535–80 at Tseganka 8 (2 sigma; Chang 2007; Chang *et al.* 2003). Dates obtained from wood from Kurgan 11 at Berel in Eastern Kazakhstan range between cal BC 800 to 200 (2 sigma) (Vasiliev *et al.* 2005; Zaitseva *et al.* 2005), while a date from a fragment of a wooden table from a kurgan at the Issyk burial complex not far from the Talgar alluvial fan was between Cal BC 400 to 200 (Zaitseva *et al.* 2005). Hall (1997) has also used radiocarbon dates from Saka period burial mounds and tombs across Kazakhstan and north-western China to identify the *floruit* of the Saka phase as 750 BC to AD 1. This does leave a chronological gap between the end of the Final Bronze Age and the beginning of the Saka period. Frachetti and Mar'yashev (2007) have identified what they term a 'pre-Saka' period dating to 1010–510 cal BC (2 sigma), or 970–670 cal BC (1 sigma) at Begash, dated by a burial, although with other evidence of settlement at the site at this time. Hanks *et al.* (2007) have obtained a date of 910–800 cal BC from the Verbluz'yi Gorki cemetery, but early tenth and ninth century BC sites and absolute dates remain elusive, not only in Semirech'ye, but across the northern Eurasian steppe zone.

3.4.9. *Late Bronze to Iron Age transitions in Central Asia*

The transition from the Late Bronze to the Early Iron Age at the end of the second and the beginning of the first millennium BC in northern Eurasia is widely accepted to be a period of significant changes in the archaeological record (Hanks 2002, 183). In many ways, Semirech'ye shares much in common with the Eurasian steppe zone in terms of general trends in the archaeological record, but it does have some distinctive characteristics that mean it cannot be considered identical to the northern Eurasian steppes. As Frachetti (2008, 10) has pointed out, the physical geography of Semirech'ye is extremely varied both in geomorphology and vegetation cover, and affords an opportunity to study human activity across different environmental zones within a well-defined area. This combination of broadly shared archaeological heritage with the vast steppes, and unique local archaeological and varied geographical characteristics is one of the reasons that Semirech'ye was chosen for this research project.

The study of archaeological remains in the northern Eurasian steppe zone has a long and rich history, from the first investigations of researchers such as Viatkin and Pantusov in the 19th century and the foundation in April 1919 of the Soviet State Academy of the History of Material Culture (Field 1947), through to the post-Soviet international collaborative research projects of the last two decades. In Semirech'ye, archaeological surveys were first carried out in the 1950s, led by Bernshtam (1952, cited in Frachetti 2008, 10), and subsequent excavation of Bronze and Iron Age sites and monuments, including over one thousand burial mounds or kurgans (Russian *kurgani*), has been carried out by various researchers from the 1960s onwards (Akishev & Kushayev 1963; Chang *et al.* 2003; Chang and Guroff 2006; Frachetti 2008; Kuzmina 1966, cited in Kuzmina 2008, 82; Maksimova 1961; Yablonsky, 1994, 232). Archaeological sites in Semirech'ye include settlement sites, funerary structures such as kurgans and cist tombs, and petroglyphs.

The classification, chronology and interpretation of Late Bronze and Early Iron Age material has of course undergone many revisions over time, as new evidence has come to light and techniques such as radiocarbon dating have been applied in the past decade. Predominant in the development of archaeological theory in northern Eurasia has been a culture historical approach (Hanks *et al.* 2007, 355), fuelled by a desire to identify the origin and distribution of different ethnic groups through their material culture (Chang 2002, 80). This approach was favoured by Soviet archaeologists as it allowed the grouping of archaeological material into cultural representations of social groups, which could then be fitted into a Marxist framework of social and economic formulations (Chang 2002, 80; Kuzmina 2008, 6).

As David Anthony has argued, the employment of a culture-historical framework can have both advantages and disadvantages for archaeological interpretation. On the one hand, the equation of material culture with race and language (an approach often although not always encountered in archaeology of Soviet ancestry) can lead to erroneous interpretations about how groups interacted, missing the nuances involved in the expression of identity in the archaeological record (Anthony 2006, 44; Jones 1997). On the other hand, the predominantly Western school of thought which emphasises the ephemeral, fluid and dynamic nature of ethno-linguistic identities struggles to account for the stability and maintenance of cultural frontiers over many hundreds of years, many examples of which are found in Central Asia (Anthony 2006, 45). Although a traditional culture-historical approach in which distinct assemblages of material culture are taken to represent discrete ethno-linguistic groups, it is restrictive in its interpretive power because it does not take into account the negotiable nature of identity, the notion that cultural boundaries can be created, maintained and expressed through material culture is a useful one. The existence of a cultural boundary as expressed through material culture does not necessarily mean the existence of an ethnic or linguistic boundary. Differences in material culture could be an indication of different classes within society, or an expression of different economies. For example, a sharp distinction is seen in the material culture of the steppe zone herding communities and the forest zone herding communities of the Yamnaya period (3300–2500 cal BC), even though interaction between these groups is attested in earlier periods, and it can safely be assumed that such interactions did not cease simply because the material culture of the two groups became more distinctive over time (Anthony 2006, 47). Such examples serve to warn against conflating evidence for choices in material culture and economic strategies with ethnic and linguistic boundaries. Equally, a shared material culture does not necessarily mean the same identity and language were shared across a region.

If the complex nature of the interaction between material culture, ethnic identity and language is taken into consideration then using a culture-historical model to understand the archaeological record can be very useful to conceptualise, group and compare the material culture assemblages found in Central Asia. This is the dominant model found in Soviet-era archaeological research, and it continues to serve scholars today as a useful model with which to approach the prehistory of the region. If the limitations described above are included in archaeological interpretations then the process of cataloguing, classifying and comparing archaeological material can provide a useful starting point from which to ask more nuanced research questions. It retains a strong presence in archaeological thinking in Kazakhstan today, most notably employed by Kuzmina (1994; 2008) in her wide-ranging analysis of the archaeological record. Drawing on a vast body of research across northern Eurasia, Kuzmina (2008, 60) describes the development of the Andronovo cultural group in the eastern Eurasian steppe zone (east of the Urals to the Tien-Shan mountains) in the latter part of the Bronze Age, marked by a peak florescence in the fifteenth–thirteenth centuries BC with settlements far outnumbering those of previous periods.

The key features of the Andronovo culture are as follows: graves delineated by stone fences or burial mounds, and burials with rectangular cists covered with a capstone; burial practices that include inhumation or cremation, with inhumations buried in a crouched ‘sleeping’ position with head pointing to the west; richly decorated ceramics; large rectangular houses dug into the earth by approximately one metre; large numbers of domesticated animal bones of horses, cattle and sheep but never pigs; stone tools such as stone hoes and grinders; and the infrequent deposition in graves of high value objects such as bronze axes, celts, arrowheads, spearheads and knives or daggers (Frachetti 2008, 32–33; Sorokin & Gryaznov 1966, 5–7). Kuzmina (2008, 83) also stresses the fact that in Semirech’ye, archaeological monuments are clearly associated with petroglyphs (Mar’yashev & Goryachev 2002), meaning that although absolute dating of this artistic expression remains elusive, petroglyphs must be considered as part of the archaeological complex.

Kuzmina (2008, 63) argues that the unification of funeral rites and ceramic types across northern Eurasia indicates that the Andronovo communities were consolidated in the period 1500–1300 BC, and that stable landscape and climatic conditions meant that a settled way of life was possible, located on alluvial plains and terraces, and consisting of farming (wheat, millet, possibly rye) with a fundamental economic basis of animal husbandry (cattle, sheep or goat, three breeds of horse and Bactrian camel), including evidence of dairy farming. This stability led to a ‘population explosion’, resulting in increased pressure on environmental resources and the territorial expansion of Andronovo peoples into new ecological niches such as foothills and deserts. In the following period, from the thirteenth or twelfth to the ninth centuries BC, this ‘economic crisis’, as Kuzmina (2008, 65) terms it, was compounded by climatic cooling, flooding territories located on the flood plain. This resulted in the development of a ‘driving-to-pastures’ system of livestock herding, and an increase in the number of sheep and horses, which are both capable of accessing fodder from underneath snow. This period also saw the emergence of horseback riding, evidenced by the presence of bone bridle cheek-pieces (Kuzmina 2008, 65).

Kuzmina (2008) is keen to emphasise that these changes, although considerable, did not happen as one ‘leap’ as researchers such as Gryaznov (1957, cited in Kuzmina 2008) assert, but rather as a process over time that ultimately resulted, in the 8th century, in the adoption of nomadism. This mobile form of pastoralism (Kuzmina 2008. 66) is identified with the Saka culture in Semirech’ye, considered a regional culture contemporaneous with that of the nomadic Scythians and Sauro-Sarmatians to the west (Davis-Kimball 1995; Hanks 2007). It must be stressed here that patterns of subsistence in Semirech’ye have long been considered different from those of the western steppe, with the emphasis being on ‘vertical’ patterns of bi-annual seasonal transhumance in the piedmonts and alpine meadows of the Tien-Shan mountain zone, as opposed to the ‘horizontal’ transhumance of the steppe zone (Akishev 1972; 1977, cited in Yablonsky 1995, 196).

The use of the name ‘Saka’ to describe Iron Age peoples of the Eurasian steppe is first found on the Bisutun (6th century BC) and Persepolis (5th century BC) reliefs, and according to the Greek historian Diodorus (cited in Yablonsky 1995), the Saka belonged to the Scythian tribe and were shepherds who lived in grain-producing Asia (Yablonsky 1995, 194). Diodorus (cited in Yablonsky 1995) also cites Efor (405–330 BC), who states that the name Saka denoted Scythians who came to reside in Asia. In Semirech’ye, the name Saka is used to describe the Iron Age population and culture, and although exhibiting the so-called ‘Scythian triad’ of weaponry, horse harnesses and animal-style artefacts, it has long been understood that the Saka of Central Asia were not a homogenous group with a uniform, nomadic, way of life. Rather, each group had its own local variations of material culture and subsistence strategies, strongly influenced by the geographical particulars of the area they inhabited (Yablonsky 1995, 195). In the ancient delta of the Syr Darya river, for example, Saka populations were found to have been living in settlements and practising irrigation agriculture alongside stock breeding in at least the 6th century BC (Andrianov 1969), with evidence for agriculture relating to the ‘Tagisken culture’ (9th–8th centuries BC) found in the form of sandstone grinding stones and traces of irrigation ditches (Tolstov 1962). Similarly, in Semirech'ye Akishev (1972; 1977) emphasised the diverse economic models adopted by Saka groups, in particular the 'vertical' migration of the stock breeders of the Tien Shan foothills and the sedentary, agricultural lives of those occupying river deltas.

3.4.10. *Archaeology of Semirech'ye*

3.4.10.1.Saka culture

The Semirech'ye Saka culture has been characterised as including evidence of the use of the horse for individual mobility, indicated by the appearance of the complex horse harnesses (Christian 1998, 127; Hanks 2007, 183; Yablonsky 1995, 232); herding of cattle, sheep/goat and horse; large numbers of huge kurgans (burial mounds), some containing cist burials of very similar type to Bronze Age burials; a marked social hierarchy indicated through artefact rich burials with objects such as bronze and iron knives, beads imported from India, horse harnesses, bronze and bone arrowheads, and intricate gold clothing ornamentation and headdresses, such as those found on the famed 'Golden Warrior' burial located on the edge of a kurgan in Issyk (Akishev 1978; Yablonsky 1995, 238). Some of the social transitions from the Bronze to the Iron Age are reflected in changing burial practices, in particular the spatial organisation of burial mounds (Akishev 2002). Petroglyph styles attributed to this period include the widespread artistic stag motif, such as is found in the Koksu river valley of the Dzhungarian mountains (Alexei Rogozhinsky *pers. comm.*). Yablonsky (1995, 232) has stressed that these cultural attributes are very similar to those of central Kazakhstan, the Altai mountains and the lower Syr Darya River region, although Saka pottery from Semirech'ye has a distinct round-bottom shape.

3.4.10.2.Recent research

The archaeological 'facts' presented in the preceding paragraphs certainly raise many questions about the dynamics of change in the Late Bronze and Early Iron Ages, in particular regarding the development and nature of 'pastoral nomadism' and its use as a category in archaeology. Recent research projects in the region have attempted to ask and answer some of these questions, but before exploring these, we begin with an overview of the current understanding of the dating of this period.

With this chronology in mind, I will now move on to discuss recent archaeological work in Semirech'ye, and the questions behind such research. This discussion will focus on two international research projects, both run in collaboration with researchers from the A. Kh. Margulan Institute of Archaeology in Almaty. It is from sites excavated as part of these two projects that samples have been and will be taken for analysis. The first project is led by Dr. Claudia Chang of Sweetbriar College, USA in association with Dr. Fedor P. Grigoriev and Prof. Karl M. Baipakov of the Institute of Archaeology, Almaty, and has as its geographical focus the Iron Age sites of the Talgar alluvial fan (Chang *et al.* 2002; Chang *et al.* 2003; Chang & Guroff 2006; Chang 2007; Rosen *et al.* 2000). The second project is led by Dr. Michael Frachetti of Washington University in St. Louis, USA in association with Dr. A.N. Mar'yashev, and is based in the Dzhungarian Mountains, with a focus on Bronze Age sites (Frachetti 2006, 2008; Frachetti & Mar'yashev 2007; Frachetti *et al.* 2010a; Frachetti *et al.* 2010b; Mar'yashev & Frachetti 2007). As has been outlined above, traditional interpretations of the archaeological record in Semirech'ye have emphasised a move from sedentary pastoralism and agriculture in the Bronze Age to a bi-seasonal transhumant form of pastoral nomadism in the Iron Age. These recent research projects have sought to reach a more nuanced understanding of subsistence strategies in these two periods, and explore changes in site distribution, density and land use over time.

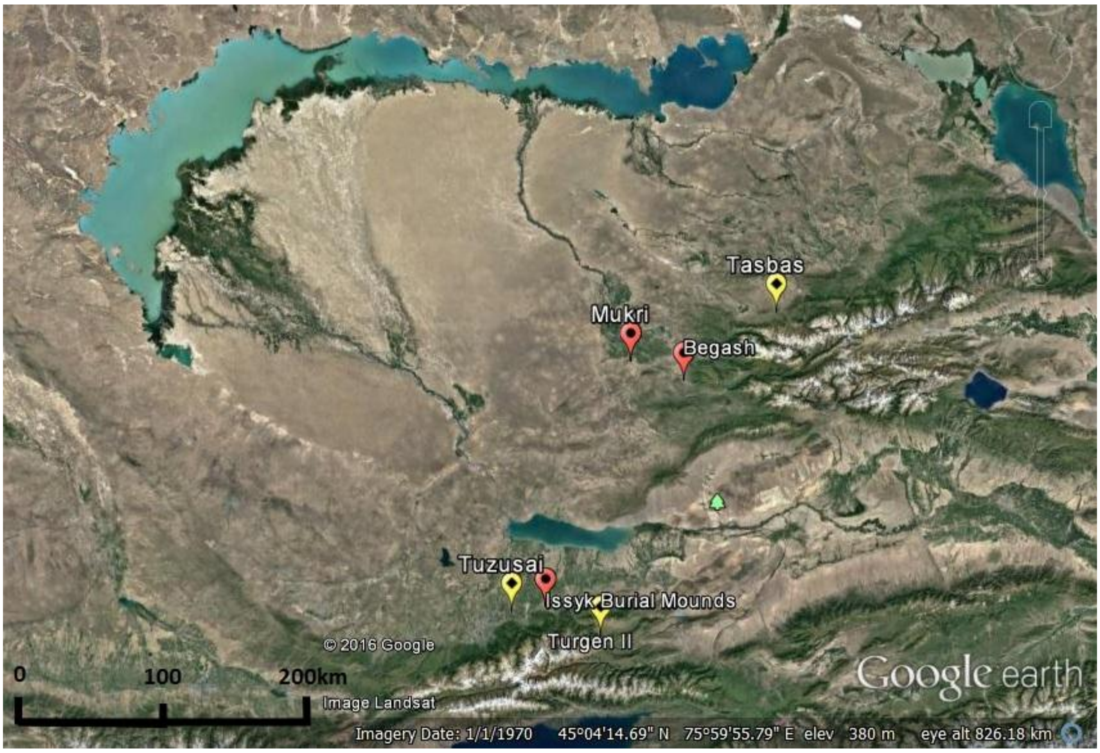

Figure 3.2. Location of the archaeological sites in Semirech'ye mentioned in this dissertation. The sites marked with yellow pins are those which were sampled for this research. Note that due to the scale of the map, the marker for Tuzusai also covers the locations of Taldy Bulak and Tseganka.

Claudia Chang's research in Semirech'ye spans over twenty years and has resulted in some major revisions to our understanding of Iron Age communities and their patterns of subsistence. For the purposes of this study, I will focus on her work on the Talgar alluvial fan, located east of Almaty in the ecotone between the piedmont zone of the Tien-Shan Mountains and the semi-arid and arid desert-steppe of the pre-Balkhash region. Chang's (Chang *et al.* 2002, 8) research has been driven by three main research aims: 1) to expand the number of known sites (burials, settlements, shrines, paths and routes) in the area through archaeological surveys and reconnaissance; 2) to reconstruct local environments and subsistence modes through the excavation of selected sites; 3) to develop a regional chronology through the use of radiometric dating in combination with typologies of material culture. To date, hundreds of burials and sites have been identified using a combination of field walking and remote sensing through satellite imagery (C. Chang and P. Tourtellotte pers. comm.). Of these sites, three settlements have been excavated, these being Tuzusai, Tseganka and Taldy

Bulak, all of which consist of semi-subterranean pit houses, pits and hearths (Chang *et al.* 2003).

The site of Tuzusai, which will be presented as a case study in this document, was first excavated by F.P. Grigoriev (1995). It is a large settlement, approximately 1 ha in size, and is located to the west of the ancient streambed of the Tuzusai channel (Chang *et al.* 2003, 301). Four to six cultural horizons have been identified, spanning from approximately 415 BC to 75 BC, and AD 1275 to 1950. Ceramics from the earlier occupation period are primarily utilitarian wares, with similarities to Saka-Wusun grave goods in Semirech'ye (*ibid.*, 204). Faunal remains are primarily of sheep/goat, cattle and horse, but camel, ass, dog and very low numbers of deer have also been identified. Phytolith analysis has revealed a dominance of foxtail millet (*Setaria italica*) with an additional presence of wheat, barley, and possibly rice. In later phases, the count of millet phytoliths decreases and rice phytoliths increase, with wheat remaining consistent (Rosen 2001).

The site of Tseganka 8 is located approximately 1.5 km to the north-east of Tuzusai on the east bank of the present-day Tseganka stream, which cuts the site. Six to eight cultural horizons have been identified, spanning the period 775–40 BC (Chang *et al.* 2003), with ceramics of both local Semirech'ye and imported Central Asian and Syr Darya regional origin. The faunal assemblage is similar to that at Tuzusai. Phytolith evidence from this site indicates a predominance of foxtail millet, with barley and wheat also present. Interestingly, one hearth sample was found to contain phytoliths similar to the complex hair base cells of *Cannabis sativa* leaves, the only sample of its kind (*ibid.*).

The final site of Taldy Bulak is located to the west of a dry stream bed, 3 km to the north of the village of Taldy Bulak (Chang 2007). Ten occupational horizons have been identified, spanning the period 780 BC–AD 960, dates secured by radiometric dating. Material culture from the site included iron artefacts such as knives, pins and hinges, and some fragments of bronze. Faunal remains consisted of sheep/goat, cattle and horse. Phytolith analysis revealed the presence of wheat, barley and foxtail millet (Chang 2007; Chang and Guroff 2006, 32). What is clear from the evidence presented here is that the economy of the Saka population extended far beyond a purely nomadic form of pastoralism. Further investigation into the dynamics of change and stability in the Early Saka period is needed to understand how mobile or sedentary the population was in this period, particularly with regards to agriculture and livestock foddering practices.

In contrast to Chang's economic-environmental research agenda, Frachetti (2009) takes a landscape approach to the archaeology of the Dzhungarian Mountain range, combining data from burials, settlements and rock art sites using GIS to infer patterns of landscape use and site interaction. Two settlements have been excavated as part of this research: the site of Begash, located on a flat ravine terrace in the piedmont zone of the Dzhungarian Mountains, which opens to a riparian terrace of the Zhalgyzagash River, an upland tributary of the Koksu River (Frachetti & Mar'yashev 2007, 224); and the site of Mukri, which is located approximately 850m above sea level in a narrow ravine on the western piedmont of the Dzhungarian Mountains (Frachetti *et al.* 2010a). Excavations of burials have also been carried out at Begash, and field surveys to locate archaeological monuments and rock art have been conducted in the region. Radiocarbon dating from Begash settlement has revealed a long chronology of site use covering the period 2460 cal BC–AD 1900, representing six phases of occupation.

The periods of interest for this study are phases 2 (1625–1000 cal BC) and 3a (970–400 cal BC). Phase 2 is characterized as showing a change in material culture, with ceramics and bronze metallurgy corresponding to those of the Final Bronze Age (Frachetti & Mar'yashev 2007, 233). This phase represented 600 years of occupation with no clear horizons, and it was therefore interpreted as demonstrating mixing of material from periodic revisitation of the site (*ibid.* 234). Faunal remains from the site indicate a predominance of sheep/goat. No domesticated cereals have been reported from macrobotanical analysis in this period, although broomcorn millet (*Panicum miliaceum*) and wheat have been identified in earlier levels (Frachetti *et al.* 2010b). Phase 3a has been identified by Frachetti and Mar'yashev as belonging to a pre-Saka and Early Saka phase of occupation, demonstrating periodic occupation of the site (*ibid*, 235). Foxtail millet has been identified in samples post-dating 1000 BC at Begash, although currently no context-specific archaeobotanical evidence is available on this time period.

Occupation levels at the settlement of Mukri have been identified as belonging to four phases, with a date range of 838 cal BC–cal AD 1953 (Frachetti *et al.* 2010a). Phase 1 represents Late Bronze to Early Iron Age occupation, and has been dated to 810–420 cal BC (*ibid.*, 632). Faunal remains indicate the presence of sheep/goat, cattle, horse and dog. No structural remains were found, and Frachetti proposes a 'pit house' dwelling, similar to those found by Claudia Chang on the Talgar alluvial fan. Stone hand grinders and polishers were found in addition to coarse-wear pottery of Early Iron Age type, and nearby petroglyphs reflect the typical Saka 'animal style' in depictions of predators and prey, in particular stags (Frachetti *et al.* 2010a, 633). In interpreting the changes seen in the archaeological record throughout the Bronze Age and into the Early Iron Age, Frachetti conceptualises 'nodes' of local interaction, represented by specific sites, which form a durable steppe-wide network of direct (personal) and indirect (material) communication (Frachetti 2008). Through a spatial approach to archaeological sites in the region, he argues for pastoral networks made up of these 'nodes' forming series of core-periphery relations between pastoralists through zones of interaction.

As can be seen from the archaeological background given above, approaches to understanding the changes seen in the archaeological record at the end of the first millennium BC in Semirech'ye are many and varied. While culture-historical approaches born from the Soviet archaeological tradition are limited in their explanatory power, they still provide researchers with useful systems of the classification and identification of archaeological material. However, as is demonstrated through new approaches to the archaeological record in the past 15 years, moving beyond a process of ethnic identification allows more sophisticated questioning of the archaeological record with regards to interactions between humans and the landscape.

3.4.11. ***Archaeology of the exploitation of plant resources in Central Asia***

The sites in this study are located in different ecological zones and at different elevations, with varying soils, hydrology, and annual temperature fluctuations. All these factors will of course lead to variations in the type of economy that it is possible to practise in each area. However, choices in subsistence strategies are not dictated by geographical and climatic possibilities alone. Two other important factors are firstly the physical availability of both wild and domesticated resources (plant and animal) in a region, whether controlled by human or natural means, and secondly whether an active choice has been made to exploit certain species in a given location. The current evidence from Bronze and Iron Age sites throughout the Central Asian steppe zone indicates that stockbreeding was the most important component of the subsistence strategies in the region throughout the 2nd and 1st millennia BC (Kuzmina 2008), although the following section will place its emphasis on the evidence for the exploitation of plant resources in Central Asia, both domesticated and wild. The focus here will be on cereals and wild grasses since these are the most abundant producers of diagnostic phytoliths. This background will lay the foundation for interpreting the plant remains from the three sites in this study.

While direct evidence for the importance of stockbreeding in Central Asian economies in the form of animal bones is abundant (Kuzmina 2008), direct evidence for the importance of plants in the Bronze Age and Iron Age remains under-represented, a problem resulting from the fact that during the Soviet and early post-Soviet period the systematic recovery and analysis of palaeobotanical data was not routinely carried out during excavations. This is a widespread issue in the territory of the former Soviet Union (Anthony *et al.* 2005; Coolidge 2010, 62; Popova 2006). A major reason for this lack of consideration for archaeobotanical data was the dominance of the culture-historical approach in Soviet-era archaeology. Within this framework the typological and chronological classification of archaeological material culture took precedence over and above other forms of archaeological evidence as a means to make sense of the archaeological record. It is, therefore, difficult to assess the relative importance of plant-based foods in prehistoric Central Asian economies be they domesticated or wild, and even more difficult to locate reported evidence for the economic non-food use of plants, such as in basketry, interior furnishings and architectural uses from the archaeological literature. This is not to say that these data were excluded from archaeological analyses, or indeed that the archaeobotanical implications of material culture were not considered. There are of course exceptions where direct palaeobotanical evidence has been found, and indirect evidence for the cultivation and gathering of plants in the form of hoes, sickles and grinding stones has been widely reported. Many excellent typologies of agricultural tools such as sickles exist (Kuzmina 2007), detailed studies have been made of prehistoric irrigation networks (Andrianov 1969; Tolstov 1962) and the practice of cultivation in the Bronze and Iron Age communities of Central Asia has long been acknowledged by scholars working in the region (Akishev 1972, 1977; Andrianov 1969; Yablonsky 1995; Kuzmina 2007).

What is lacking in the majority of studies, however, is the systematic, numerical analyses of plant remains from archaeological sites. As well as a lack of quantitative archaeobotanical data, the high visibility and generally good preservation of animal bones as opposed to the small size and low preservation rates of plant remains has led to an imbalance in interpretations of prehistoric subsistence economies in Central Asia. A potential problem here is that the relative importance of plant resources, both domesticated and wild may have been underestimated, skewing and over-simplifying interpretations of agro-pastoral economies in Central Asia, from the desert oases of the south to the Eurasian steppe and forest-steppe zones of the north of the region. As Kuzmina (2003, 203) has pointed out, while herding was predominant on the steppes, terms such as 'pastoralism' and 'nomadism' are highly debatable in their interpretation. It is through a focus on plant resources that a more detailed understanding of the Bronze and Iron Age economies of Central Asia can be achieved.

Semirech'ye is located between three major centres of domestication. In the Near East, domesticated plants include wheat, barley, oats and rye and animals include sheep and goats and cattle, in China rice and millets, while northern Kazakhstan has been demonstrated to be the origin of the domestication of the horse at around 3500 BC (Outram *et al.* 2009). While detailed discussion of the origins of both plant and animal domesticates is beyond the scope of this study, the spread of the plant species and their known distribution at the time of this study is important to interpreting the findings of this project in as informed a manner as possible. The subsequent distribution of cereals across the Eurasian steppe zone from their centres of domestication is still unclear. While much excellent work has been carried out towards identifying the locations for the domestication of plant species, the pathways and mechanisms for their distribution remains poorly understood, particularly for the Central Asian steppe zone, including Semirech'ye. The following study will attempt to draw together the current evidence for the spread of domesticated cereals in Central Asia. Of course, these cereals were part of a broader Neolithic 'package' of domesticates which included other economically important plant families (e.g. Fabaceae) and domesticated animals such as sheep, goat, cattle and horses. As stated above, the focus here is on the cereals and other grasses due to their production of diagnostic phytoliths, although hemp (*Cannabis sativa* L.) should also be considered since it produces distinctive multi-celled phytoliths from its hair bases that can contribute to a tentative identification in a sample.

Recent archaeobotanical research at the site of Jeitun in Turkmenistan has yielded important evidence for the earliest spread of domesticated cereals from their centre of domestication in the Fertile Crescent. Jeitun is a tell site located in modern day Turkmenistan, which is part of a complex of tells of varying sizes. It has been dated to between 6100 and c.4500 cal BC (Gosden and Meadows 2010). Archaeobotanical analysis has identified glume wheat (*Triticum monococcum* (einkorn) being dominant, also *T. dicoccum* (emmer) and a 'new' Jeitun-type), naked six-row and hulled varieties of barley (*Hordeum* sp.), and possibly free-threshing wheat (*T. aestivum/durum*) (Charles and Bogaard 2010, 152). Cereal chaff and culm nodes point to local cultivation of these cereals (Charles and Bogaard 2010, 164), and together with the presence of late-maturing wild plant species in dung samples this indicates that the site was occupied year round by at least part of the population. In addition to cultivated grains, the wild taxa were dominated by *Aegilops* sp. (goat-face grass) and *Capparis* sp. (caper), the presence of caper indicating that wild plants were also gathered as part of the spectrum of plant use. The data from Jeitun indicates that the spread of domesticated cereals (and goats and sheep) from the fertile crescent into western Central Asia began in the late 7th millennium BC, with cattle joining the repertoire later in the Neolithic, the earliest being recorded at c.5700 cal BC (Harris 2010, 236). It is suggested by Charles and Bogaard (2010, 162) that the narrow range of cereals, and in particular the minor presence of emmer, ubiquitous in Southwest Asia, may indicate that the einkorn and barley were chosen for their tolerance to low soil fertility and low water availability. If this is the case, then it is useful here to employ Flannery's concept of a 'spectrum' of food sources, where rather than forming a discrete and uniform 'package' of domesticates, plant and animal species were exploited to varying degrees at different times and in different places depending on a variety of locally and regionally driven factors (Flannery 1969). These components formed the basis of the agro-pastoral range of domesticated species that spread throughout Central Asia, however the current evidence suggests that this spread and the adoption of these new species was by no means a steady, uniform affair across the steppe zone (Matyushin 2003).

Evidence for the spread of agriculture in west Central Asia has been found at three sites: the Chalcolithic and Bronze Age sites of Anau North (3000–1700 BC) and Anau South (3000–1000 BC) located just north of the Kopet Dag; and the 2nd millennium BC sites of Gonur, located in the Murghab delta of Turkmenistan and Djarkutan, located on the alluvial fan of the Surkhandarya river in the north Bactria region of Uzbekistan (Miller 1999). Archaeobotanical evidence from these sites shows that the predominant crop was 6-row barley (*Hordeum vulgare*), followed by bread wheat (*Triticum aestivum*). A few grains of *Setaria* sp. or *Panicum* sp. were identified at Djarkutan, but are not considered to have been cultivated (Miller 1999, 16). From the Bronze Age onwards, grape (*Vitis vinifera*) was found at all three sites, and shell fragments from *Pistacia vera* were found at Djarkutan. Pits from *Prunus* were also identified at Gonur and Anau North, having close similarity with plums grown in the region today, and a single possible seed of *Malus* was identified at Gonur (Miller 1999, 18).

While the evidence for the spread of domesticated cereals and other plants into the southwestern regions of Central Asia is well attested, there appears to be a gap in the archaeological record for domesticated cereals further north and east into the Eurasian steppe zone in Kazakhstan until the 3rd millennium BC, and even then the evidence is scattered. Whether this is due to a real absence of these cultigens or a product of lack of data and available published material remains to be seen. Grains of both wheat (*Triticum aestivum/turgidium*) and broomcorn millet (*Panicum miliaceum*) have been identified from a cremation context from the site of Begash, located in the foothills of the Dzhungarian Alatau mountain range in Semirech'ye, with seeds being directly dated to between 2460–2150 cal BC (Frachetti *et al.* 2010). In the lower Zeravshan valley, at the cemetery and settlement of Zaman-Baba, imprints of wheat and barley grains have been found, together with querns and sickles (Gulyamov *et al.* 1966, 118–86; Kuzmina 1958; Kuzmina 2003, 205). Kuzmina (2003) dates these sites to the turn of the 3rd to the 2nd millennia BC, based on ceramic typologies. Evidence for irrigation agriculture in the 2nd millennium BC is found at the sites of the Tazabagyab and Suyargan cultures in the southern delta of the Akchadarya river in the form of irrigation channels (Andrianov 1969). A later find of *P. miliaceum* is that at the site of Tahirbaj Tepe in Turkmenistan, dating to the mid-second millennium BC (Nesbitt 1994). *Panicum* sp. is also reported at the sites of Arkaim and Alandskoe (c.2200–1800 BC), along with *Triticum* sp., however the dating and species identification of these grains is unconfirmed (Frachetti *et al.* 2010). At Chust in the Fergana valley, dating to the late 2nd to early 1st millennia BC, the seeds of an 'unknown plant similar to millet' were noted, along with grains of wheat and barley and sickles, grinding stones and pestles (Andrianov 1969).

Evidence for the origin of the domesticated millets *Panicum miliaceum* (broomcorn millet) and *Setaria italica* (foxtail millet) strongly suggests a centre of their domestication in the Yellow River valley in China (Song et al 2012). *P. miliaceum* has been identified from sites dating to the 9th to 7th millennia BC (Lu *et al.* 2009), while both species are attested at sites in the Yellow River valley and other sites in northern China dating to the 7th and 6th millennia BC (Hunt *et al.* 2008). *P. miliaceum* has also been identified at broadly contemporary sites in Eastern Europe and the Caucasus, indicating that it was the first millet to have been domesticated and to have spread west, while *S. italica* is found in the western Eurasian steppe zone from around the 5th to 4th millennium BC (Hunt *et al.* 2008). Although it seems that millet spread west from China from at least the 6th millennium BC, evidence for the route it followed remains unclear, especially with regards to the Eurasian steppe zone where evidence is sparse.

In his work on the ancient irrigation systems of the Aral Sea region, Andrianov (1969) speculates that millet could have been the main crop cultivated in the Bronze Age irrigated fields of the Akchadarya delta, stating that millet is 'typical for the Eurasian steppes in the Bronze Age', but he cites no archaeobotanical examples upon which this claim is based. The above evidence shows that documentation for the spread and relative importance of millets (and indeed other grains) in the diets of the peoples of Bronze and Iron Age Central Asia is extremely fragmentary at present. Further detailed searches of locally published journal articles and unpublished site reports from excavations around Kazakhstan during the Soviet era and beyond could be potentially fruitful in identifying further findings of millets and other grains in excavations from a time where systematic archaeobotanical sampling was not the norm. Such a survey of this 'grey literature' was outside the scope of this research project; however, it could certainly be a fruitful exercise for future research, and may have the potential to shed more light on what is currently a very patchy picture of the spread of domesticated cereals throughout the steppe zone of Central Asia.

Lack of evidence for cultivated grains does not necessarily mean that food and fibre from plants played an insignificant part in prehistoric economies of Central Asia. Conversely, the presence of agricultural tools and cultivated grains does not equal a reliance on cultivation for the provision of the majority of diet. Pollen, phytolith and macrobotanical analyses at the settlement site of Krasnosamarskoye in the Samara river valley, acknowledged to be an important east-west corridor between the Asian and European steppes dated between 1950–1700 cal BC, have yielded no cultivated grains (Anthony *et al.* 2005). Settlements in the valley at the beginning of the Late Bronze Age (c. 1900–1800 BC) consisted of permanent timber buildings with significant midden accumulations, with indications that the sites were occupied year round (Anthony *et al.* 2005, 396). Detailed palaeobotanical analysis from a waterlogged well deposit, dated 1950–1800 cal BC, yielded high numbers of seeds and pollen of *Chenopodium album* (goosefoot) and *Amaranthus* (amaranth), with lesser amounts of *Polygonum* (knotweed) (Anthony *et al.* 2005, 408). As stated above, no cultivated grains were identified. Being high in nutritional value, it seems that these wild seeds were collected for food. Other economically significant plants identified at the site through pollen analysis include *Allium* (garlic), *Urtica* (nettles) and *Gallium* (Lady's Bedstraw, used for bedding and for the curdling of milk products). It would appear that at Krasnosamarskoye, a wide variety of wild plant resources were exploited, and cultivation was not a part of the economic strategy adopted at the site, an interpretation further bolstered by the low frequency of caries in dental samples (Anthony *et al.* 2005, 409). It is interesting to note that at the slightly later settlement of Russkaya Sel'itba II, dated 1650–1500 BC and located in the northern part of the Samara oblast, a variety of cereal grains were identified (*Hordeum vulgare*, *Triticum dicoccum* and *compactum*, and *Panicum miliaceum*). The presence of cultivated grains at this site, only a little later than the settlement at Krasnosamarskoye, tends to indicate that choices were being made in the Bronze Age about the relationship between herding and the exploitation of plant resources, with both wild and cultivated grains appearing to be equally viable means of supporting settled populations.

Although located many hundreds of kilometres from Semirech'ye, the example of the Samara river valley serves to demonstrate the fact that the subsistence economy in the Bronze Age in Central Asia was a complex interplay between the exploitation of wild and domesticated species, both plant and animal. The absence of cultivated grain from the settlement does not necessarily mean that such grains were not known to the people of Krasnosamarskoye, rather it could indicate that the local wild plant resources were sufficient to serve the needs of the population without the need to expend additional energy on the cultivation of domesticated grains, allowing greater attention to be paid to herding. Anthony *et al.* (2005 409) even suggest a religious or social restriction to the cultivation of grains at the site, suggesting that perhaps ritual specialists or priests occupied the site. Whatever the reasons for the people of Krasnosamarskoye not cultivating grains, it seems that a purely environmental or technological reason is insufficient to explain the choice of subsistence economy at the site. Similarly, earlier indirect evidence for agriculture in the form of hoes and grinding stones at the site of Sintashta (2800–1600 BC) has now been re-evaluated and these objects are just as likely to be tools used for wood and metal working (Epimakhov 2010; Ventresca Miller 2014). These examples serve very well to illustrate the many different forms that the Late Bronze Age subsistence economy took across the Eurasian steppe zone.

To consider the evidence from Kazakhstan in more detail, some direct evidence for cultivated grain has been recovered, but the majority of interpretations for agricultural activity have been based on finds of agricultural tools such as hoes, sickles and grinding stones. As stated above, the presence of these tools does not necessarily mean that agriculture was taking place at the sites in question, and ore extraction, woodworking and the exploitation of wild plant resources cannot be excluded from interpretations of the use of these tools. Carbonised stalks and grains of wheat were found in a ritual context at the Bronze Age Andronovo site of Alekseevka (Krivtsova-Grakova 1948, 73), a find analogous to that of carbonised wheat and broomcorn millet from the site of Begash in Semirech'ye, where the grains were found in a cremation burial pit and associated funerary fire pit (Frachetti *et al.* 2010; Kuzmina 2007, 141). Rye and millet have been identified at Bronze Age settlements in Kazakhstan (Minaeva and Fursaev 1934), and wheat and millet have been found in settlements of the forest zone of the Ural region (Lebedeva 1996, 54). In central Kazakhstan, Margulan *et al.* (1966) argue that the cultivation of crops was of secondary importance in food production compared to the raising of livestock throughout the Bronze Age in Central Kazakhstan. Evidence for agriculture in the form of agricultural tools is absent in the Early Bronze Age, but they speculate that digging sticks could have been used in the earlier period for the preparation of soil. Direct evidence for plant foods has been found burnt inside pots from several sites in Central Kazakhstan, and although archaeobotanical analysis was not carried out, it has been reported to be a type of porridge made from either millet, wheat or barley (Margulan *et al.* 1966, 260). Archaeobotanical analysis from the site of Begash in the Dzhungarian Alatau mountain range of Semirech'ye has yielded grains of *Triticum aestivum/turigidum* and *Panicum miliaceum* (Frachetti *et al.* 2010). In the Middle Bronze Age period secondary evidence for agriculture is found in the form of hoes and sickles (Margulan *et al.* 1966, 260). Pleshakov and Zakharov (2012) argue that farming became widespread in Kazakhstan from the middle of the 2nd millennium BC from its origins in northern Kazakhstan, with wheat, rye and millet being the staple crops. The majority of known Andronovo sites in Kazakhstan are located on flood plains in fertile river valleys (Kuzmina 2007; 141), indicating a preference for cultivable lands, although varying site preservation and surface visibility must be considered for more geologically active zones such as the high foothills, which may account in part for this pattern of site distribution.

Kuzmina argues that the Bronze Age economy in Semirech'ye was based on farming and stockbreeding, as it was for the majority of Andronovo sites, with local variation in the emphasis on these activities (Kuzmina 2007, 141). While direct archaeobotanical evidence for plant-based economic activity in Semirech'ye in the Bronze and Iron Ages is rare in the archaeological literature, combining the few exceptions to this situation together with evidence from neighbouring regions allows a patchy picture to be built of the types of economies that may have been present in the region in the 2nd and 1st millennia BC. The emphasis here is placed on *economies*, since it appears from the current evidence that economic subsistence activity throughout northern Eurasia was varied, with sites of the same archaeological culture (in the culture historical sense) providing evidence for different economic strategies, such as in the example of the Samara river valley (Anthony *et al.* 2005).

The presence of wheat and millet at the Bronze Age site of Begash stands as the earliest firm archaeobotanical evidence for these cultigens in Semirech'ye (Frachetti *et al.* 2010). Evidence for Iron Age agriculture in Semirech'ye was first identified at the site of Tuzusai (410–150 cal BC), through macrobotanical and phytolith analysis (*Chang et al.* 2003; Rosen 1997; Rosen *et al.* 2000; Spengler *et al.* 2013). The first macrobotanical analysis carried out by Naomi Miller in 1996 (reported in Spengler *et al.* 2013) identified probable bread wheat (*Triticum aestivum* s.l., a hexaploid), barley (*Hordeum vulgare*), millet (unidentifiable as either broomcorn or foxtail), grape (*Vitis vinifera*), nut shell, probably almond (*Prunus* sp.), and a possible hawthorn seed (*Crataegus* sp.) (Spengler *et al.* 2013). Phytolith analysis carried out on samples from Tuzusai and the nearby contemporaneous settlement of Tseganka 8 identified wheat

(*Triticum* sp.), barley (*Hordeum vulgare*), millet (*Setaria* sp.) and possible rice phytoliths (*Oryza sativa*) (Chang *et al.* 2003; Rosen *et al.* 2000). The most recent macrobotanical analysis, carried out by Robert Spengler, has identified seven domesticated species: hulled barley (*Hordeum vulgare* var. *vulgare*); naked barley (*H. vulgare* var. *nudum*), free-threshing compact wheat and free-threshing lax-eared wheat (*Triticum aestivum/turgidum*); broomcorn millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), and grape (Vitis vinifera) (Spengler *et al* .2013).

From their first appearance in western Central Asia and origin in China from the end of the 7th millennium BC, the spread of domesticated cereals and their pathways to Semirech'ye remains unclear, and evidence from across the Central Asian steppe zone is at present far from complete. What is apparent is that by the Bronze Age, cereals were being exploited by stockbreeders in Semirech'ye (either cultivated or imported), and in the Iron Age a wide diversity of species were being cultivated in the foothills of the Tien Shan mountains. While present evidence points to the fact that stockbreeding remained the dominant economic activity, the role of domesticated and wild plant species in Bronze and Iron Age diets cannot be disregarded. The example from the Samara River valley, although distant, serves to illustrate the fact that the exploitation of plant species for human food is not limited to cultivated species alone, and that domesticated and wild species of both plants and animals may have been exploited to varying degrees across the Central Asian steppe zone. It is helpful to think of the resources available as part of a spectrum, in which the individual components may have become more or less important to the populations exploiting them according to a variety of factors such as local geography, climate, social pressures, seasonal habitation or religious restrictions. The evidence presented above illustrates the diversity to be found in the Central Asian steppe zone, which like the grass itself appears uniform in its make-up from afar, but on closer inspection is revealed to be composed of many different species.

3.5. Palaeoclimate

3.5.1. *Geography and geology*

The region of Semirech'ye (in Kazakh *Zhetysu*) in south-eastern Kazakhstan is perhaps best described geographically as the Tien-Shan-Balkhash region (Aubekerov *et al.* 2003), comprising as it does the area between the northern Tien-Shan mountains to the South and East, and Lake Balkhash to the North (Figure 3.3). Meaning 'seven rivers' in both its Russian and Kazakh form after the main rivers that flow into Lake Balkhash, Semirech'ye encompasses a variety of landscape zones. These include the high mountain meadows of the Tien-Shan, piedmonts, and the desert pre-Balkhash region (see Figure 5.1, Figure 5.2, Section 5.1 this thesis).

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Figure 3.3. Map of the Ili-Balkash basin, showing the catchment area of Lake Balkhash, and the main river and lake systems (adapted from Petr and Mitrofanov 1998, 146).

Lake Balkhash is the second largest lake in Kazakhstan, and its basin system is made up of more than 45,000 rivers, creeks and temporary streams (

Figure 3.3), the largest of which is the Ili River, which accounts for around 75% of the basin's waters (Beardmore 2007b; CAREC 2000, 2; Petr 1998, 147). Of the 413 thousand square kilometres of the Ili-Balkhash basin, 15% (60 thousand km2) is located in China's Xinjiang region (CAREC 2000, 2). The Ili River (or Kunes He) rises in the Xinjiang, with around 34% (55,300 km^2) of its basin located in Chinese territory. In addition, over 5% (8,800 km2) of the Ili basin is located in Kyrgyzstan (Beardmore 2007b; Transboundary Freshwater Dispute Database 2002). Describing the region in this way serves to illustrate how modern geopolitics has the potential to greatly influence the 'connectedness' of archaeological research, particularly in this case, where linguistic and ideological differences can lead to a divergence in methodology, interpretation, presentation and accessibility of the archaeological record. In the case of Semirech'ye, the term describes an area within the south-eastern corner of Kazakhstan, but from a geographically-informed perspective, the importance of the fertile Ili River basin as a 'corridor of contact' cannot be forgotten in any archaeological interpretation (Frachetti 2008).

The landscape zones of Semirech'ye can be divided into two broad areas: 1) the desert and deltaic area of southern Balkhash (or pre-Balkhash) in the North-West of the region, bordered to the West by the Chu-Ili mountain range, and 2) to the South-East, the semi-desert and forest-steppe piedmont zones of the Dzhungarian Alatau, and Tien-Shan mountains, and the semi-desert Ili River valley (ANKSSR 1982, 78; Walter & Box 1983, 44). The Quaternary sediments of the first region are located on the low plain of the Balkhash-Alakol depression, defined in the north by the arc of Lake Balkhash, in the West by the Chu-Ili mountains, and contains the delta of the Ili and other rivers. (Dzhurkashev 1972). Sediments in the Balkhash-Alakol depression consist primarily of

Middle- to Upper-Quaternary aeolian deposits, with alluvial deposits in the deltaic areas dating from the Middle-Quaternary to the present day (ANKSSR 1982, 22–23).

The Chu-Ili Mountains, rising between the Ili and the Chu rivers and forming the western boundary of Semirech'ye, are characterised in their piedmont zone to the East as having Upper-Quaternary to modern alluvial sediments (ANKSSR 1982, 22–23). Starting in the Tien-Shan high piedmont zone to the South and working North to the Dzhungarian-Alatau, the sediments of the second region are deposited in bands running roughly southwest to northeast, and are as follows: high piedmont zone, eluvial-diluvial undistinguished Quaternary sediments; mid-piedmont zone, Lower- to Middle-Quaternary proluvial sediments; low-piedmont zone, Middle- to Upper-Quaternary proluvial sediments; Ili River valley, alluvial-proluvial Middle-Quaternary to modern sediments; and the Dzhungarian-Alatau piedmont zone, Middle- to Upper-Quaternary proluvial sediments.

This study focuses on the south-eastern corner of Semirech'ye, in particular the high- to low-piedmont zones of the northern Tien-Shan (comprising the Zailiisky Alatau and Kungey Alatau ranges) and the Dzhungarian-Alatau range. Semirech'ye is located in a seismically active zone, with the potential of seismic force ranging from 5–9 points on the Richter scale (Merzlyakova 2002, 381). The Tien-Shan mountain chain, which joins the thick mountain junction of the Pamir, is characterised by high seismic activity (Koronovsky 2002, 31). Earthquakes are often accompanied by land subsidence (Merzlyakova 2002, 381).

3.5.2. ***Modelling climate mechanisms***

Northern Eurasia, comprising the mostly landlocked territory of the former Soviet Union, has a climate with a high to very high degree of continentality (Shahgedanova, 2002, 70). With the absence of orography, the vast Eurasian steppes display a classic pattern of climatic zonality; in contrast, the precipitation and temperature regimes of the mountainous regions are affected by altitude and topography (Shahgedanova, 2002, 70), resulting in the presence of a number of microclimates within the geographically diverse area of Semirech'ye that forms the basis of this study. An appreciation of this diversity is important when collating and presenting research on Holocene climate changes in Northern Eurasia, particularly with reference to the scale of the research area, and the location and type of data being analysed.

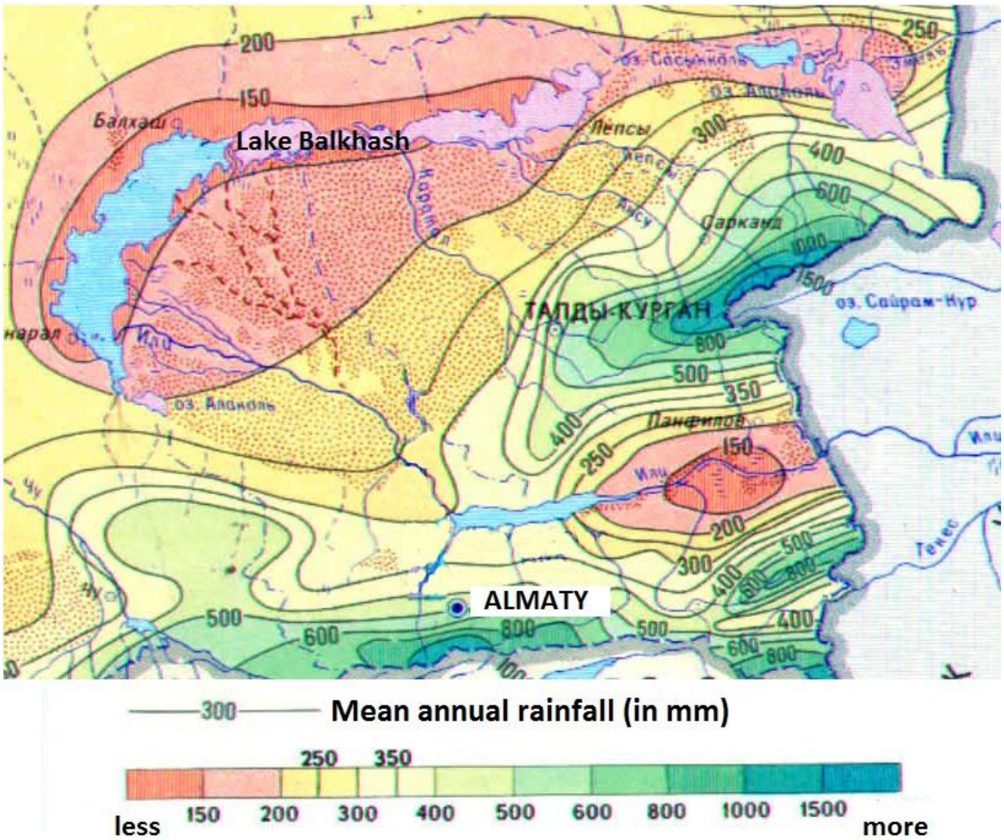

Figure 3.4. Map of the modern (1982) average annual rainfall for Semirech'ye, showing the sharp contrast in precipitation regimes between the mountainous regions to the south and east, and the plains to the north and west (after ANKSSR 1982).

In order to make sense of palaeoclimatic studies of the region, it is first important to understand the geographical context of the study area and the implications for climate dynamics. As detailed above, the sites in this study all occupy different environmental zones with varying elevations, topographies and orogprahic relationships, which will of course result in localised responses to region-wide changes in climate. This interplay between fluctuating local micro environments and broader regional changes in climate is complex, and will be explored here as far as is currently possible with the available data. It is argued here that this relationship between regional and local climate fluctuations opened the possibility for a variety of landscape uses and subsistence strategies to be practised simultaneously in Semirech'ye, leading to a diverse, resilient pattern of landscape exploitation.

Before exploring these relationships, I will first outline the characterisation of Northern Eurasia from a climatic perspective and place Semirech'ye within this context. This will provide a framework for understanding the inclusion of palaeoclimatic studies from further afield in this study. A widely accepted model of (modern day) climate regionalisation for Northern Eurasia has been produced by Alisov (1956, cited in Shahgedanova 2002, 75). This model is based on the radiation regime and atmospheric circulation, with climatic boundaries drawn in agreement with the distribution of soil and vegetation cover (Alisov 1956). As stated, this characterisation is based on modern day data, and it is presented here as a model to show how various climatic zones and subzones are present within the region. This emphasizes the point that any large-scale reconstruction of Holocene climate change is not modelling a vast and uniform expanse of steppe, but rather a complex mosaic of environmental zones whose boundaries doubtless shifted and blurred with climate changes over time. Having an appreciation of the complexity of the modern climatic zonation of the region paves the way to understanding the complexities of Holocene climate reconstruction, particularly when considering the ecotone positions of the sites in this study.

In Alisov's (1956) model, four climatic zones are identified – arctic, subarctic, temperate, and subtropical – and these are further divided into climatic provinces, subzones with different characteristics. Semirech'ye is classified as belonging in the Temperate zone, which encompasses most of the territory of Kazakhstan, southern Siberia, continental Eastern Europe, and the Caucasus, the Tien Shan and the Altai & Sayan mountains.

This zone is broadly characterised as consisting of taiga, mixed and broad-leaved forests, forest-steppe, steppe, semi-deserts and deserts, with temperature and humidity descriptors ranging from relatively warm to very warm and dry to very humid. It is bounded to the north by the subarctic zone characterised by tundra and sparse forests, and to the south by the extremely arid and warm Southern deserts, and the mountainous regions of Transcaucasia and the Pamirs (Alisov, 1956). The region of Semirech'ye itself falls into two provinces, or sub-zones, these being the eastern extreme of the Continental Northern Turanian province and the Tien-Shan province, the former described as consisting of dry and very warm Northern deserts (Alisov 1956). As can be seen from this brief overview, Semirech'ye falls climatically into a broad zone with much variation in vegetation, temperature and humidity, and any further discussion of palaeoclimatic studies is given with this context in mind.

As Shahgedanova (2001, 76) has pointed out, the emphasis in Alisov's (1956) model is on the prevalence of different air masses, with soil and vegetation zones forming a background to the climatic scheme. The model does not incorporate local and macroclimatic effects of mountains, however these effects will be considered later in this chapter with reference to localised studies of the Late Holocene climate. For now, the present the model provides a useful focus with which to consider the mechanisms of air mass climatology, an important forcing factor in the climate of the region and therefore a good basis for highlighting the mechanisms behind palaeoclimatic reconstructions, and their relative impact on the Semirech'ye region. According to Shahgedanova (2001, 76), the two most important features of the air mass climatology of Northern Eurasia are the transformation of air masses from temperate maritime and arctic maritime into temperate continental over the land mass, and also the seasonal reversal of the characteristics of temperate continental air.

Throughout the year, temperate continental air dominates Northern Eurasia. In winter, temperate maritime air of Atlantic origin is the main warm and humid air mass. It is associated with cloudy weather that prevents the rapid loss of heat and slows the transformation process to temperate continental air which is usually cold and dry. In summer, temperate continental air is formed of temperate maritime and arctic maritime air, but with different sources and characteristics. In the process of transformation over the continent, arctic maritime air masses gain moisture through evaporation enhanced by forests, while at the same time becoming less saturated as their temperature increases, resulting in warm temperate continental air with varying humidity, with very low humidity resulting from transformation over forest-steppe, steppe and semi-desert zones (Shahgedanova 2001). Central Asia also experiences tropical air masses throughout the year, arriving from the Middle East, Iran and Afghanistan (Shahgedanova 2001, 77). Temperatures across Northern Eurasia are generally low, but with large annual ranges, and they are affected by atmospheric circulation and the energy balance of the underlying surface, with snow cover contributing to a feedback effect on temperature (Shahgedanova 2001, 91), a factor that has implications for choices in agricultural practices, particularly with regards to sowing periods and the length of growing seasons. The above is by no means an exhaustive account of all the factors contributing to the climate of the study region, however it does serve to highlight some of the key mechanisms behind climate change and variability.

Chen *et al.* (2008) state that the Holocene climate patterns in arid central Asia are generally poorly documented and understood. This is in part due to the fact that there is a complex interplay of competing forcing factors that control the regional climate, which include: low-altitude summer monsoonal circulation; mid-latitude Westerlies; and the orographic influences of the Tibetan plateau. Therefore, any palaeoclimatic study of a wide scope in this region must contain both the presentation of the available evidence and a model of which forcing mechanisms might be responsible for effecting the climate changes evidenced. Climatic and environmental change during the Holocene in Northern Eurasia has been intermittent and non-uniform, characterised by abrupt shifts alternating with periods of relative stability (Khotinskiy 1984, 305). The correlation of multiple proxy data is key to interpreting and modelling changes in climate during the Late Holocene in Semirech'ye.

In their review of the primary data from previous studies, consisting of 11 lake cores, Chen *et al.* (2008) sought to assess the changing effective moisture in the area they call arid central Asia (ACA), the mid-latitude arid Asian region dominated today by Westerlies, and in particular to explore its relationship with the Asian monsoon. They state that the western part of ACA saw a wet Mid-Holocene, and dry early and Late Holocene, as evidenced from lake level changes in the Aral Sea, whereas eastern ACA saw variable wetness throughout the entire Holocene, with some possible drier intervals in the Mid Holocene (Chen *et al.* 2008, 252). Evidence from the lake core data suggests that during the Holocene the moisture history of ACA appears to be similar to the pattern of the Holocene sea-surface temperatures of the North Atlantic and Norwegian Seas, with precipitation depending mainly on the amount of water vapour transported by mid-latitude Westerlies (Chen *et al.* 2008, 359; Tarasov *et al.* 2007). In their model, the sea surface temperature of the North Atlantic and the high-altitude air temperature increased during the Mid-Holocene, leading to more water vapour from the North Atlantic and high continental temperatures, inducing high humidity available for local recycling over the Eurasian continent, and therefore more precipitation in ACA (Chen *et al.* 2008).

After the Mid-Holocene, effective moisture decreased, matching a temperature decrease relating to decreased summer insolation. The role of the Tibetan plateau is also considered, upon which strong insolation leads to the strong uplift of air mass which then results in low pressure near the land surface. This in turn leads to the large-scale convergence and enhancement of the Asian summer monsoon and the intensified subsidence of air mass to the north of the plateau, leading to a dry climate in ACA. It therefore seems that a strong summer monsoon correlates to a dry climate in ACA (Chen *et al.* 2008). Overall, Chen *et al.*'s (2008) study showed that throughout the

Holocene moisture changes in Central Asia were mostly influenced by sea surface temperatures of the North Atlantic, and the corresponding Westerlies, with distinct spatial patterns shown between arid central Asia and monsoonal Asia, although the orographic influences of the Tibetan plateau are important in influencing the aridity of the region. This modelling of the Holocene climate shows that, as in the present day, it is the movement of air masses that are the dominant mechanism for climate change in central Asia, although the orographic influence of the various mountain ranges in the region is still poorly understood. This is a particular problem for Semirech'ye, which is bordered by mountains on one side, and yet which is also open to the moisture and vegetation changes brought by shifting patterns of climate across the vast temperate zone of Northern Eurasia.

This interpretation is further developed by Cheng-Bang *et al.* (2011), who propose that in addition to the mechanisms outlined above, climate changes during the Mid to Late Holocene were a function of a chain reaction where changes in temperature led to changes in evaporation rates, which in turn affected effective moisture, changing thermal gradients and resulting in altered levels of precipitation. They conclude that changes in temperature played a more important role than has previously been understood, leading to feedback processes from local environmental factors such as vegetation, albedo, soil moisture status and elevation (Cheng-Bang *et al.* 2011, 50). This refinement of the model allows for localised feedback effects, and also opens the possibility for human-induced environmental change to be considered as part of the overall processes of climate fluctuation in the Mid to Late Holocene. While far from complete, the models detailed above provide a basic framework with which to approach the available data on climate reconstructions for the Mid to Late Holocene.

Considering the models for climate mechanisms outlined above and their regional effects in Eurasia, it can be seen that the climate in Semirech'ye has been influenced by a variety of forcing factors, the most prominent among these being the movement of air masses. Being located at the eastern edge of the arid Central Asian steppes and bounded by mountains along its easterly and southerly borders, the climate in Semirech'ye is expected to be primarily influenced by Westerlies caused by changing sea surface temperatures of the North Atlantic, although the effect of the Tibetan plateau and its interplay with the Asian monsoon with regards to fluctuating aridity is also an important factor. To date, the orographic influences of the Tien Shan and other mountain ranges are poorly understood, although it can perhaps be safely assumed that the Tien Shan range in particular has local influence on climatic regimes in Semirech'ye which may result in outcomes somewhat different from those outlined in the models above. What is clear is that Semirech'ye in general and the sites in this study in particular occupy a climatically interesting position in central Eurasia with regards to models for climate forcing mechanisms. On the one hand, climate in the region is influenced by the same large-scale forcing factors such as the mid-latitude Westerlies, while on the other hand the corner of Semirech'ye explored in this dissertation is nestled against climate modifying mountain ranges which form a barrier between the arid central Asia climatic zone and the Asian monsoon system beyond.

3.5.3. ***Late Holocene climate***

To begin with a very broad and long-term view of climate change in Northern Eurasia during the Mid to Late Holocene, Chen *et al.* (2008) conclude that there has been a general decrease in moisture into the present from a maximum effective moisture between 8000 and 4000 BP. Velichko and Spasskaya (2002) state that since the Late Atlantic warming period (occurring at 5500–5000 BP) when temperatures were marked by a 3–4°C rise in both summer and winter, the general trend towards the present day has been one of climatic cooling and increased moisture (Tarasov *et al.* 2007, 295). They note some exceptions to this, such as during the Subboreal between 4000 and 3500 BP (Velichko & Spasskaya 2002, 63). Chen *et al.* (2008) suggest a moderately humid climate during this period, however they highlight that there were large regional variations in this period, much more so than in the Early and Mid-Holocene.

As an interesting point to note, Velichko and Spasskaya (2001, 67) emphasise that plant communities respond most quickly to changes, whereas soils are more conservative and some soil profiles may integrate processes of the whole Holocene history, and it therefore may be difficult in some cases to correlate regional variations seen in vegetation proxies such as pollen data with geomorphological data such as soil profiles. Further refining this broad view, Khotinsky (1984) has summarised palynological data to produce a more detailed climatic history of the Subboreal. According to Khotinskiy's (1984, 196-197) summary of palynological data from across the former Soviet Union, three distinct environmental changes are evident in the latter part of the Holocene: a cool-dry Early Subboreal from c. 4600 BP (3357 cal BC) to 4100 BP (2600 cal BC); a warm, moister Middle Subboreal from 4100 BP (2600cal BC) to 3200 BP (1440 cal BC); and another cool Late Subboreal episode from 3200 BP (1440 cal BC) to 2500 BP (c.660 cal BC) (cal BC dates provided by Rosen *et al.* 2000).

As Khotinskiy (1984, 196) himself has pointed out, the Subboreal period was a very complex stage in the vegetation and climate history of Northern Eurasia, and this summary of data from a wide geographical range requires correlation with other more detailed studies to provide a more accurate picture, particularly when seeking to assess its relationship to the archaeological record. Van Geel *et al.* (2004) have proposed just such a relationship with regards to the expansion of Scythian culture in the early 1st millennium BC. They highlight the climatic shift in northwest Europe to cooler, wetter conditions after around 2800 BP (850 cal BC), marking the beginning of the Subatlantic period, concluding that a climatic shift to cooler and less dry conditions also occurred in southern Siberia and Central Asia, based on pollen data from a lake core (Van Geel *et al.* 2004, fig. 2), which is shown here in Figure 3.5. They propose that such a shift in Europe was triggered by a decline in solar activity and caused enhanced westerly winds, which have a strong influence on central Asian climate patterns. Focusing on radiocarbon data from the republic of Tuva that appears to show an increase in population, they argue that such a shift would have increased the biomass production of the region and thus the carrying capacity, allowing the increase and expansion of mobile populations. This hypothesis has not gone unchallenged, and Riehl and Pustovoytov (2006) have questioned the interpretation of the pollen diagram as showing a shift from semi-desert to steppe indicating a marked shift in vegetation, questioning the climatic zoning applied to genera such as *Artemisia*, *Cannabis* and *Betula*, rather suggesting that the data be re-evaluated and the nature of anthropogenic influences considered.

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Figure 3.5. Pollen diagram showing a selection of taxa from a sediment sequence from Kutuzhekovo Lake, located in south-central Siberia (vanGeel *et al.* 2004, fig. 2)

Although van Geel *et al.*'s (2004) conclusions may require further development, there is other evidence to support their proposal of a climatic shift at the beginning of the 1st millennium BC in Northern Eurasia and its impact on human populations. This view is reinforced by Shlütz and Lehmkuhl (2007), who conducted a palynological and geomorphological study in the southern Siberian part of the Russian Altai. In their study of a pollen from a core from the Kuray Range (2330m asl), they identify higher values of Poaceae, *Artemisia* and Chenopodiaceae during the later Subboreal period (c.3400 BP), indicating a spread of mountain steppe under a semi-humid climate (Shlütz & Lehmkuhl 2007, 108). This is also coupled with an abrupt end in woods with *Larix sibirica* and taiga with *Picea obovata*. This could be in part due to human exploitation of resources already under climatic pressure. Additionally, this change is reflected in the presence of buried fossil soil A-horizons overridden by solifluction debris in alpine meadows, which indicate periods of relatively weak geomorphological processes occurring before climatic deterioration at 3450± 125 BP and 2265± 70 BP (Shlütz & Lehmkuhl 2007, 111). They conclude that human impact in the Altai started with the Scythians in the 1st millennium BC, however they state that until the 20th century humans did not much alter the vegetation, with climatically driven changes having a far greater impact on human societies than the reverse (Shlütz & Lehmkuhl 2007, 114).

Hsü (1998, 683) likewise points to a period of global cooling at around 800BC. His interpretations of the effects of this climatic event are important because he highlights the effect of such changes at different latitudes, a factor that must also be considered when attempting to understand the palaeoclimatic history of a region. He states that middle- to low-latitude temperate lands (such as China) will become wetter during warmer epochs, while high-latitude regions such as Europe will become drier, and likewise during colder periods middle- to low-latitude lands will become drier, and high-latitude lands will become wetter. Such a consideration encourages any analysis of the complex responses of human groups to climate change to encompass not only the region being studied, but also neighbouring regions that may suffer a 'domino effect' in either direction. In the case of the Xinjiang region, Hsü (1998) emphasises the effect that such cooling and drying would have on harvests and other food procurement strategies in the affected areas.

The studies presented above indicate that the Late Holocene in Northern Eurasia has a complicated climatic history, with the Subboreal period in particular witnessing several shifts in climate between c.4600 and 2500 BP (Khotinskiy 1984; van Geel *et al.* 2004; Shlütz & Lehmkuhl 2007; Velichko & Spasskaya 2002). Most notably for this research project is what appears to be a relatively abrupt shift to cooler and wetter conditions at around 2800 BP (c. 850 cal BC) from warm and moist conditions in the preceding centuries. This shift appears to coincide with the expansion of Scythian populations across Eurasia, although as Riehl & Pustovoytov (2006, 44) argue, the peak in radiocarbon dates at around 2500 BP could be an artefact of research aims to refine the chronology of the Scythian age, and may therefore not represent a true increase in the number of sites dating to this period. While acknowledging this very real possibility, it is still reasonable to assert that the earlier half of the first millennium BC saw many changes in the archaeological record that occurred at the same time as shifts in climate. However, the proxies for climate change such as palynological and geomorphological records can also indicate anthropogenic influences on the landscape, however weak these may be during this period, and therefore establishing a causal relationship between climate change and human population growth, movement and landscape use is inherently complicated by the nature of the datasets involved. The potential to extricate human and climate-induced changes in the proxy data may come from records of glacial activity, which can be considered a pure climatic proxy signal (Shlütz & Lehmkuhl 2007, 111). Records from the Aktru valley indicate glacial advances at 430 BP, 1440–1640 BP and 6060 BP, with bulk material from an ice-dammed lake in the Ak-Kul valley dating to 3200 BP. These later phases can be correlated to the so-called Neoglacial period (Little Ice Age) from about 3000 BP (Shlütz & Lehmkuhl 2007, 111). From the glacial evidence, it would appear that the climatic shift to cooler conditions preceded the changes from the Bronze Age to the Early Iron Age seen in the archaeological record. Given the patchy and poorly understood nature of the climatic record, it would be rather a leap to suggest that this was the primary driving force behind the social and cultural changes, however it is possible that these changes enabled or perhaps encouraged a more diverse exploitation of the landscape, especially with regards to different elevations in the mountain and piedmont zones. The varying effects of wider-scale climatic change in different environmental zones across a vertical gradient is something that requires more careful exploration, as the sites in this research project occupy a variety of elevations and environmental zones. With this in mind, the current evidence for this localised effect of larger-scale environmental change will be considered here.

Studies of lake level changes of Lake Balkhash through submerged peat layers have been used to indicate changes in precipitation and humidity, showing that its water level was not stable during the Holocene (Kremenetski 2003, 23). Three phases of lake level change are of relevance to this study. The first is the Balkhash regression, which occurred after 3200 BC following a trangressive phase, as a result of increased climate aridisation. This regression is dated to 2990±150 BC (4960±150 BP), with submerged peat layers relating to this phase dated to 2314±120 BC (4264±120 BP) (B.G. Venus 1983, cited in Kremenetski 2003, 23). The lake level in this phase was 2–3 m lower than present (Kremenetski 2003, 23). This period was followed by the Novobalkhash transgression, resulting in a lake level 2–3m above that of the present day, which started after 1910±120 BC (3860±120 BP), indicating a change to moister conditions. Finally, the Novobalkhash regression began after 821±120 BC (2771±120 BP), marking an increase in aridity in the Balkhash basin (Kremenetski 2003, 23). This can be compared to the study of the lacustrine record from Lake Manas in northern Xinjiang, by Rhodes *et al.* (1996, 117), which identified indications of an arid period from around 1850–1550 BC, interrupting the general trend in increased carbonate sedimentation from 2550–550 BC.

The lake level changes of Lake Balkhash appear to contradict the other data presented above which show an increase in moisture and a more pluvial environment at the beginning of the 1st millennium BC in other areas. However, these other data come from upland and mountain zones, and this apparent contradiction in the climatic conditions in these areas and those in the low lying Lake Balkhash region serves as an excellent illustration of the varying effects that climatic change can have on different environmental zones within a single region. Available moisture can be calculated using a moisture availability index (MAI), which incorporates both moisture and heat factors (Zlotin 2002, 173):

$$MAI = P/E$$

$$E = 0.2\ (\Sigma t) + 306$$

where P is the annual amount of precipitation in mm, E is potential evaporation (mm) and t are temperatures exceeding 10°C. As can be seen from this equation, mountain zones would have a higher available moisture value as orographic influences would result in greater precipitation, while lower temperatures would mean that potential evaporation is also lower. Conversely, a low lying area such as that around Lake Balkhash would have higher thermal resources, which would meant that even with higher precipitation, available moisture would stay lower due to higher evaporation (Zlotin 2002, 173). That the alpine region can have a higher effective moisture while lower altitudes remain arid is also pointed out by Shlütz & Lehmkuhl (2007). They show that higher orographic precipitation combined with colder winters, leading to wetter conditions, is indicated by increasing values of Cyperaceae, while lower steppe and desert areas show increasing drought indicators such as *Artemisia* and Chenopodiaceae (Shlütz & Lehmkuhl 2007, 112). They are, however, careful to state that *Artemisia* and Chenopodiaceae also include several pasture weeds, and therefore this change could also indicate anthropogenic or zoogenic influences (Shlütz & Lehmkuhl 2007, 112).

This disparity of localised responses to climate change across a vertical gradient has also been observed in palynological data from across Semirech'ye including the environs of all three of the sites in this research project, where Aubekerov *et al.* (2003) have compared data from sites in the semi-desert zone of the Chu-Ili low mountain range, at Talgar, near the site of Tuzusai in the piedmont steppe zone, at Turgen in the high mountain meadow zone of the Tien Shan, and at Tasbas in the middle mountain steppe zone of the Dzhungarian mountain range. Their research found that in general the local climatic fluctuations indicated are largely in agreement with larger scale global estimates, however they identified sub-regional differences between the lower-lying steppe and semi-desert zones and mountain zones (Aubekerov *et al.* 2003, 24). They conclude that such differences, when experienced at the borders of different landscape zones (ecotones), were strong enough to influence human landscape use (Aubekerov *et al.* 2003).

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Figure 3.6. Reconstruction of average temperature and precipitation in Semirech'ye during the last 3200 yrs (150 yrs temporal resolution; based on palynological analyses). a) In the plains (Tamgaly, 800 m asl, semi-desert landscape); b) In the mountains of Semirech'ye (Turgen, 2300 m asl, alpine meadows). Temperature (T) is indicated by red lines, precipitation (P) by blue dashed lines. The absolute chronology is provided by EPR and 14C analyses (dots) and archaeological correlation (segments) (Aubekerov *et al.* 2003, fig. 2)

Their study allowed climatic reconstruction for around the last 3000 years, which is illustrated here in Figure 3.6 (Aubekerov *et al.* 2003), the most relevant periods for this study being the Late Subboreal period from 3200–2800 BP (c. 1250–850 BC, considered the Final Bronze Age) and the Early Subatlantic from 2800–2000 BP (c. 850–50 BC, which includes the Early Iron Age). Their data suggest that in the Late Subboreal (Late–Final Bronze Age), the steppe zone was warm and arid, while the mountain zones were humid, cooler and wetter than present. Glaciers in the northern

Tien Shan mountains contracted to less than 2km in length (Aubekerov *et al.* 2003, 25). The borders of vegetative cover in all landscape zones remained close to those of the present day, a conclusion also reached by Frachetti in relation to the Dzhungarian Mountains in this period (Aubekerov *et al.* 2003; Frachetti 2008, 80).

During the Early Subatlantic period (Early Iron Age onwards), Aubekerov *et al.* (2003) argue that the average climate was pluvial, being cooler and wetter than the present day, with larger seasonal amplitudes of temperature and humidity. They conclude that both the steppe and the mountain zones had cold-wet conditions, however it seems that the zones had some difference in periodicity. On the steppes humidity and cold peaked at around 2400 BP, whereas in the mountains this occurred later at around 2200 BP, a difference that they attribute to prolonged ice accumulation with Tien Shan glaciers growing to over 2km in length (Aubekerov *et al.* 2003). Vegetation zone borders changed in response to climatic fluctuations, with alpine zones becoming glaciated, and the semi-desert plains becoming steppe zones (Nigmatova 2008, 14).

These studies illustrate the increasingly complicated picture that can be obtained by targeted local studies across a region, and shows that while broader climatic trends in Semirech'ye may be consistent with those for Northern Eurasia and globally, the effect of such changes on local microenvironments can be very different, particularly between low steppe and semi-desert zones and higher mountain meadows and alpine zones.

A further example of this can be found in the study carried out by Cheng-Bang *et al.* (2011) of the pollen record from Lake Balikun in the eastern part of Xinjiang, the pollen diagram for which is shown here in

Figure 3.7. The lake is situated between branches of the Tien Shan mountains at 1575m asl. Modern vegetation ranges from alpine meadow at 2900-2800m asl, coniferous forest (*Larix sibirica* and *Picea schrenkiana*) between 2900 and 2100m asl, to desert steppe (*Stipa glaerosa*, *Festuca suleata*, *Allium polyrrhizum*) in the piedmont

zone (Cheng-Bang *et al.* 2011, 44). The pollen data is supplemented by evidence from grain size analysis as a proxy for past changes in transport capacity, but the authors are careful to point out that variations will occur, for example when the lake is shallow coarse material may be carried directly to the coring site, but this may also happen when the river carrying capacity is increased (Cheng-Bang *et al.* 2011, 45). The data from Lake Balikun show that during the Holocene the lake saw a period of fluctuating lake level, and the authors conclude that as a closed lake basin, the lake is very susceptible to climate change, and is therefore well placed to provide high resolution data about environmental changes (Cheng-Bang *et al.* 2011, 43).

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Figure 3.7. The percentage pollen diagram for Lake Balikun (Cheng-Bang *et al.* 2011, fig. 4)

In the period of interest to this study, the Mid to Late Holocene, records show three periods of change between 4300 and 0 BP. The first of these, from 4300 to 3800 BP, indicates a phase of increasing desertification, which appears to be a centennial-scale event during which the climate deteriorated and effective moisture decreased (Cheng-Bang *et al.* 2011, 47). This is shown through the pollen record in which percentages of Chenopodiaceae dramatically increased while *Artemisia* and arboreal elements, in particular *Betula*, decreased sharply (Cheng-Bang *et al.* 2011, 46). The Late Holocene, from 3800 to 2300 BP saw a fluctuating lake level. Percentages of Cyperaceae increased while that of Chenopodiaceae decreased, with a gradual increase in the *Artemisia*/Chenopodiaceae ratio. The general picture from the pollen data in this period is one of the expansion of meadows and the recovery of steppe from a previous period of low effective moisture and increasing desertification (Cheng-Bang *et al.* 2011, 47). From 2300 BP to the present day the lake has been shallow with the extent of steppe at a maximum and stable. Cyperaceae reached its highest values, implying the expansion of meadows, and the authors highlight the conflicting lines of evidence in this period, such as reduced runoff into the lake, indicating the impact of human activity (Cheng-Bang *et al.* 2011, 48).

The evidence here for a Mid–Late Holocene drought is broadly in agreement with the other data presented above. Cheng-Bang *et al.* (2011) suggest that this period of drought could have been the result of the high temperatures documented in other studies from across Eurasia, when precipitation could not compensate for the increase in evaporation. This study of the local effects of Eurasia-wide changes in temperature and precipitation shows that although general trends are reflected in local proxy data, the reaction to these trends can occur with varying levels of severity and over different time scales at the local level. Sensitive environments such as the closed system of Lake Balikun may record such changes at a higher resolution but with a much smaller focus than larger, more open systems such as those of Lake Balkhash, where deposits such as pollen may be washed in from a wider catchment area. In this case, the Lake Balikun system indicates some fairly sharp transitions from desert to steppe vegetation in the Mid to Late Holocene, and it would seem that local conditions such as elevation are a strong factor in how local environmental systems react to changes in temperature and precipitation, amplifying or absorbing these effects and therefore modifying the signal that is recorded in the proxy record.

Given the above data, it would seem that Semirech'ye is best conceptualised as a patchwork of micro-environments that were available for exploitation by human groups, all influenced by the same broad climatic shifts, but reacting in a variety of ways to different stresses and stimuli. The extent of human and climatic impact on these micro-environments was most likely variable, with some areas more prone to degradation and collapse than others. This would necessitate a variety of strategies for successful occupation, which may have been practised at different times by the same human group, or perhaps by the same group. What seems clear is that following the drought conditions of the 2nd millennium BC, the first millennium witnessed an increase in available moisture, occurring at around 800 BC, which seems to have resulted in many different environmental zones becoming more habitable, or perhaps habitable for longer time periods throughout the year. This would increase the options available to the Early- and Mid-Iron Age populations of Semirech'ye, perhaps enabling a greater diversity of landscape use.

The impact of human action on these environments must also be considered, and human influence such as deforestation or grazing of livestock can also modify local environmental responses to climate change by reducing or amplifying natural processes such as vegetation change, and erosional and depositional rates. The implications of this for human choices in land use and subsistence strategies are such that even at a time of environmental stress such as the Mid to Late Holocene period of drought, small-scale systems would have seen varying degrees of change in vegetation and effective moisture, meaning that not all areas were affected negatively to the same degree. Human interaction with natural processes and its consequences can be intentional or unintentional, and must depend in part on how the landscape is conceptualised by the human group in question, and the way in which the group wishes to use the land. This type of information can be accessed through studies of evidence for food use such as micro- and macrobotanical remains, animal bones and related tools such as grinding stones and sickles. When combined with local environmental data, the varying causes and effects of human–landscape interactions can be accessed.

All these studies are of course reliant on accessing proxy data for the reconstruction of past environments. While the results from these data can be very high resolution and accurate in terms of time and species/sediment origins etc., there are some caveats that must be considered if the data is to be used in an effective and accurate way. Different proxies for climate change may reflect such changes according to varying timescales and degrees of reaction. For example, glacier retreat and expansion can have a time lag ranging from a few decades to a few millennia because of the time it takes for the increase or decrease in ice volume in the accumulation zone to be felt at the snout (Roberts 1998, 46).

Pollen records are also susceptible to bias, as pollen may be deposited from both air and water action in lakes and bogs, which in addition to subsequent bioturbation can blur the stratigraphic integrity of a deposit (Dinacuze 2000, 345). Due to these reasons, pollen diagrams do not represent a direct record of the vegetation from the period and therefore do not directly relate to changes in climate. However, despite these shortcomings, palynology remains a useful tool in low-resolution identification of climatic change (Dinacuze 2000, 346). As argued above, it can also be difficult to extricate the anthropogenic from the natural in proxy records such as palynological and geomorphological records. This has implications for reconstructions of past climate in two ways. Firstly, the speed and severity of a change in climate may be overestimated due to anthropogenic influences on the landscape and the way in which they are reflected in proxy records. An example of this can be seen in Shlütz and Lehmkuhl's (2007) study in the Russian Altai, where an abrupt reduction in *Larix sibirica* in the pollen record could indicate an abrupt change in climate, but this change may have been amplified by human pressure through deforestation, even if, as they argue, human influence is relatively weak during the later Subboreal period.

The second implication for climate reconstruction is that anthropogenic influences may alter the composition and nature of deposits, especially with regards to the transportation or removal of plant material, for example through selective grazing by livestock (Miehe *et al.* 2009). The pollen record may in these cases present a skewed picture indicating a different set of climatic conditions to those actually present at the time. This illustrates the importance of integrating different types of proxy data in order to identify those changes in the landscape that were the result of human influence and those that were influenced by climatic shifts, and also to determine the scale, speed and extent of these changes.

3.6. Research aims and original contribution of research

Located in south-eastern Kazakhstan on the edge of the northern Eurasian steppes, the often steep environmental zoning of the Semirech'ye 'land of seven rivers' encompasses high mountain pastures, rich alluvial fans and semi-desert steppe. This varied and complex landscape offers the opportunity to gain a deeper and more nuanced understanding of the interface between the archaeological sites and the landscape in which they exist, and in doing so be able to draw conclusions about the human activity through which this interaction was mediated. As detailed earlier in this chapter, recent research in Semirech'ye and the northern Eurasian steppe zone is providing many new absolute dates from sites in order to refine chronologies, challenging previous assumptions about the nature of nomadic pastoralism and the economic strategies adopted in this period of transition, and working towards a model of population interaction across northern Eurasia. What remains underdeveloped in these approaches is consideration of the dynamics underlying social and environmental change and stability across the transitional period from the Late Bronze to the Iron Age, specifically human-environment interactions.

As demonstrated above, the archaeological archive of the Semirech'ye region is rich. Of special interest are the often deeply buried and near-invisible settlement sites of the

Late Bronze and Early Iron Ages, whose excavation is providing valuable data to deepen our understanding of the people who created the well-documented, highly visible and easily accessible funerary monuments and petroglyph sites abundant in the region. The emergence of the Saka culture at the beginning of the 1st millennium BC has been heralded as the advent of true nomadic pastoralism, dominated by horse-riding mobile herders with a strict social hierarchy. In this research I seek to understand the nature of this transitional period, asking whether the dramatic cultural and social changes seen in the archaeological record really were accompanied by equally dramatic changes in subsistence strategies and land use, and how this might affect our understanding of 'nomadic pastoralism' in relation to Semirech'ye and the Eurasian steppe zone.

The research also aims to investigate the nature of subsistence strategies in the region in order to further develop new understandings of the relationship between agricultural and pastoral modes of subsistence in Semirech'ye that have been proposed in recent years (Chang *et al.* 2003). The principal methodological approach in this case will be phytolith analysis, which will generate new data in order to understand the links between the exploitation of plant resources, and how this relates to human land use. The use of phytolith data allows more detailed questions to be asked of human and plant interactions, and by inference human and environment interactions. This research will seek to use phytolith analysis in two ways: firstly to understand human plant exploitation as evident within specific archaeological contexts, and secondly to provide models of past landscape characteristics, land use, and depositional environments. Through investigating specific contexts within archaeological sites, phytolith data has the potential to identify the cultivation of cereals, livestock foddering strategies, fuel use, and craft activities. By correlating off-site phytolith data and relevant on-site indicator genera, environmental characteristics can be accessed through the relative presence of grasses of differing drought tolerance, and the presence of water-loving species such as members of the Cyperaceae family (sedges).

At the heart of the research agenda is the view that archaeological sites are a point of interaction between humans and their environment, and that there is a need to find a suitable theoretical model which can be employed to explain the dynamics underlying these interactions. As has been shown in the case of both archaeological and palaeoclimatic data, the history of Semirech'ye is best understood at two levels. The first being the changes seen in a wider Eurasian context, and the second being the localised responses or non-responses to such changes. Such localised responses on an environmental level can include changes in humidity, the nature and manageability of water courses, the reliability of water sources (through changes to the water table, changes in seasonal temperature and evaporation rates), the extent and duration of ice and snow cover, and changes in insolation. All these factors can cause changes to vegetation cover, and the nature and rate of the deposition of sediments. It is through these proxies that the majority of the palaeoclimatic data for Central Asia is accessed, and it is important to consider how anthropogenic influences such as deforestation and the management or mismanagement of water courses might affect this record. This is why the comparison of data from different sites is essential in building an understanding of local responses to regional and global shifts in climate, society and culture.

Of course, this is not a one-way or top-down process, and therefore a theoretical model must account for this multi-level and dynamic process of change, stability, and interaction. To this end, this research will test the model proposed by resilience theory, and investigate whether this model is suitable for explaining the processes underlying the events recorded in the archaeological archive. The aim of this approach is to work towards a suitable model of human-environment interaction that can both explain the dynamics seen in the archaeological record and provide a framework for future research.

The original contribution of this research lies in the generation and synthesis of new phytolith data for the region of Semirech'ye, and the interpretation of these data within the theoretical framework of resilience theory. The research aims to propose new directions for the future study of Late Bronze and Iron Age populations in Central Asia by demonstrating the application of phytolith analysis in answering questions of human land use and subsistence strategies. The work builds on a foundation of phytolith and geoarchaeological work carried out by Arlene Rosen at the sites of Tuzusai and Taldy Bulak (Rosen *et al.* 2000), but greatly expands the geographical and temporal scope of these preliminary studies to include more sites and a greater time depth. Further to this, the project uniquely applies resilience theory to this geographical region, and explores its application in understanding the dynamics of change and stability in the Semirech'ye region.

Chapter 4: Theoretical approach

This chapter will explore the theoretical framework that will underpin the approach to, and interpretation of, the data and inform how these data are used to answer the research questions. This study employs resilience theory, as this theoretical model is interdisciplinary in its development and well suited to the integration of environmental and social data sets. I hope that this research project will not only 'take' from an established theoretical model, but will also 'give back' to the development of the theoretical model some of the unique insights that the time depth of archaeology can offer, as proposed by Redman and Kinzig (2003).

The following section will outline resilience theory, exploring and defining the supporting concepts that underpin key aspects of the theory, and assessing its strengths and weaknesses for informing the interpretation of the data in this study. I will also explore the mutual benefits of engaging archaeology and resilience theory, and seek to address some areas that require further refinement. Following this general introduction, I will present the applicability of this theory to the study of the Semirech'ye region with reference to other models that have been proposed for interpreting the archaeology of this region. Finally, this chapter will look specifically at how this theoretical framework can be used to inform the research methods of phytolith analysis, including sampling strategies and approaches to interpretation.

4.1. The purpose of archaeological theory

As Schiffer (1988) has pointed out, the diverse nature of archaeology as a discipline is such that a single hierarchical structure of archaeological theory is neither feasible nor desirable. Schiffer (1988) defines a theory as "a series of basic premises, postulates or assumptions that specify certain fundamental entities, processes or mechanisms". Considering the many facets of archaeological research, covering all aspects of human social, cultural, and technological existence over thousands of years, it can safely be argued that any theoretical approach in archaeology must necessarily be selective in its scope and approach in order to be useful. Unlike theories in other disciplines, direct monitoring of phenomena that may be explained by a theory is often not possible due to our inability to travel back in time and make observations, and therefore much archaeological knowledge is built through the indirect observation of often invisible processes (Chang and Beardmore 2015; Schiffer 1988; Turner 2007, 115). In his analysis of the differences between the study of the tiny and 'invisible' in other scientific disciplines and the study of the 'invisible' past in the historical sciences, Turner (2007, 24) has argued that in contrast to the study of unobservable entities and processes in other scientific fields, such as that of quarks or electrons, the study of the past suffers from an "asymmetry of manipulability" in that we cannot intervene in and manipulate the invisible processes of the past in the way that we can, for example, manipulate electrons so that they become tools in the creation of new data rather than a theoretical category of analysis (Hacking 1983, 263). This asymmetry between the scientific study of 'invisible' phenomena in the present and the study of the past further affects the role of background theories in archaeology, in particular often having what Turner (2007, 25) terms a "dampening role" on scientific ambition, restricting the scope for the creation of new evidence by which to test claims and theories. For example, in this study theories about the formation, deposition and taphonomy of phytoliths, such as the role of genetics or soil chemistry, have a dampening effect on the expectations and interpretation of the knowledge generated through their study, acknowledging as they do the limits of the potential for phytolith research and the amount of evidence that has been destroyed and is no longer available for analysis. Of course, some theories in archaeology have an "enlarging role", informing how new lines of empirical evidence might be created, however Turner (2007, 25) argues that these are much less common in the study of the past.

While at first glance Turner's (2007) thesis appears to be rather negative about the potential of archaeological theories to generate and prove new predictions about the past in a scientific way, it is rather a positive affirmation of the status of the historical sciences as being “as scientific” as the “hard” sciences. Acknowledging these limitations of archaeological theory allows us to be more rigorous in identifying what the purpose of a particular theory is, and its potential to inform research into the past. By accepting Turner’s (2007) argument that any theory relating to the study of the past is subject to an “asymmetry of manipulability” when it comes to testing that theory, and that the “role asymmetry of background theories” often means that there is a “dampening role” of many background theories in archaeology, we can think critically about the role of that theory in the creation of new knowledge about the past and its potential to make new predictions about the past.

For these reasons, it is important to identify the aim and purpose of a theory in archaeology, and to acknowledge its limitations as well as the contribution it makes towards answering a particular archaeological question. In the case of this research, there are several levels of analysis that are employed in both the asking and answering of the research questions. These range from the extraction and quantification of microscopic phytoliths from sediments, the analysis and interpretation of these data within their site-wide context, inter-site comparisons between the three sites in this study, and the placing of these results within current regional models and debates about land use, climate change, and social dynamics over time.

The purpose of the theory in this study is to explore an underlying mechanism by which the different scales of analysis can be understood in how they relate to one another. The aim is to utilise a theoretical model that will allow a coherent understanding of the large scale spatial and temporal changes that are evidenced in this study through small scale observations. As Kohler and van der Leeuw (2007, 3) argue, “a good model is not a universal scientific truth, but fits some portion of the real world reasonably well, in certain respects and for some specific purpose”. This view is coherent with the “series of basic premises, postulates or assumptions that specify certain fundamental entities, processes or mechanisms" through which Schiffer (1988) defines a theory. Both outline an approach that requires a clear assessment of the specific purpose of that theory and how it relates to the data in question, but which also emphasises the fundamental real world mechanisms or processes to which the theory relates these data. This is a fine balance to attain, and while I will attempt to achieve this balance and outline a strong case for my theoretical approach, I also hope to do so critically, acknowledging the weaknesses as well as the strengths of resilience theory with regards to this thesis.

4.2. **Resilience theory**

Resilience theory, as applied to the study of human social and cultural change, developed from observations and growing concerns about changes in ecosystems around the world in the present day, and how these are affected by and affect human behaviour, both economically and socially in an integrated system of interaction (Holling 1973, 1978; Holling *et al.* 2002; Gunderson and Holling 2002; Walters 1986). Besides its application in the study of ecosystems (from which stems its application in archaeology), the concept of resilience has been applied in many different disciplines, ranging from psychology to social work and economics (e.g. Arrow *et al.* 1995; Greene 2004; Hill 1958; Werner 1993), and it has a range of meanings according to the context in which it is used. It is therefore necessary to define the basic understanding of the term as it is used in this study. Both Davidson (2010) and Martin-Breen and Anderies (2011) have highlighted the roots of the concept of resilience in mathematical ecology, from which much of the language surrounding resilience theory stems (Carpenter *et al.* 1999; Carpenter *et al.* 2001). Central to this understanding of resilience is the role of attractors in determining the behaviour of a system, whereby a system defined by a single attractor behaves in a linear fashion, and the level of resilience of the system determines the likelihood that the system will return to the same domain of attraction after an external disruption (Davidson 2010). The more attractors that are present in complex systems such as those found in socio-ecological systems, the more complex the behavioural response, with the emphasis being on nonlinear dynamics, stable attractors and the transitions between them (Martin-Breen and Anderies 2011). Thus, resilience in this case is understood to be the ability of a system to return to the same domain of attraction after a disruption. As Holling (1973) defines it:

> "Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist" (Holling 1973, 17).

As mentioned in the previous paragraph, the central understanding of resilience is tied to the concept of attractors influencing the state of a system, which has its roots in mathematical ecology (Davidson 2010). In order to understand resilience theory as it is used in this study, it is necessary to outline the central concepts that have their origins in ecology, and to trace its development into the realm of archaeology. In doing so I hope to demonstrate that although resilience theory retains much of the ecological and mathematical language of its roots, it is actually very much a human-centred approach. Resilience theory as it is employed in this study developed from a growing realisation in the latter half of the 20th century of the need for sensitive and flexible resource management if the human population is to sustain itself on this planet. In his early research on resilience in ecosystems, Holling (1973; 1978) argued that it is an emphasis on fostering change and heterogeneity within ecosystems rather than optimisation and stability which leads to more flexible resource management and better outcomes in the face of unknown future stressors. Holling's (1973; 1978) focus is on ecosystems being continually in a transient state, and this emphasis on the uncertainty of future events and the effect this has on ecosystem management was further developed by Walters (1986, 9), who outlined a process for the adaptive management of renewable resources (in this case fisheries). In addition to the arguments that ecosystems face constant uncertainty and change, Arrow *et al.* (1995) argued that it is the abrupt nature of change that often causes catastrophic disruption, and the more heterogeneous a system is the better it is able to cope with such change through adaptation.

Having outlined the origins of the notion of resilience as applied to ecosystems, it is now useful to explore briefly what is understood by the term 'ecosystem,' since many of the key concepts underlying its definition are further developed in the human-centric resilience theory that is employed in this study. Pickett and Cadenasso (2002) offer a concise yet multi-dimensional explanation of what is meant by an 'ecosystem', starting with Tansley's (1935, 299) definition that it is "a biotic community or assemblage and its associated physical environment in a specific place". This definition also rings true with archaeological research, where communities and assemblages of people and objects are investigated within their physical environment. In describing the nature of an ecosystem Pickett and Cadenasso (2002) state that since Tansley's (1935) definition describes interactions between biotic and abiotic features, which themselves are complexes within which interactions take place, a nested hierarchical structure is implicit within the definition. Further to this, ecosystems are scale-independent, since they can be as small as a garden pond or as large as an entire rainforest, but they do have a specific spatial extent, even if this extent is the entire Earth (Pickett and Cadenasso 2002). Finally, ecosystems are free from 'narrow assumptions' such as equilibrium or stability (Pickett and Cadenasso 2002), as outlined above and argued by Holling (1973) and Walters (1986).

As can be seen from this definition of ecosystems, underlying the construction of resilience theory is the concept of complexity, specifically the notion that the systems described in the model are complex adaptive systems. A human-environment ecosystem consisting of multiple actors, is considered to be a "complex adaptive system" (Gumerman and Gell-Mann 1994, 4), characterised through the complexity of both its structural qualities and its dynamics (Abel and Stepp 2003). Of course when talking about human-environment interactions, the systems being considered are not just biotic and abiotic as understood in a biological definition, but also social, cultural and technological, taking into account the ability of humans to transmit survival information through a variety of means (Gumerman and Gell-Mann 1994, 4). 'Resilience' as applied to these systems is understood to include three key features:

1.) The amount of change the system can undergo and still retain the same controls on function and structure

2.) The degree to which the system is capable of self-organization

3.) The ability to build and increase the capacity for learning and adaptation (Gunderson & Holling 2002; Holling 1973; Resilience Alliance website; Walker *et al*. 2004).

As can be seen from these three features, reconciliation between the anthropological systems of human-environment interactions and ecosystems ecology (the 'environmental' component of the systems) is at the core of resilience theory, and its usefulness lies in acknowledging that these two elements are part of the same sphere of interaction rather than operating as separate bodies exerting a gravitational pull on each other. In exploring the potential for this reconciliation Abel and Stepp (2003) highlight some of the structural qualities of the systems involved, which include: resilience, hierarchy, scale, nesting, dissipative structures and autocatalytic design. They summarise the descriptors of the system dynamics as being: nonlinearity, irreversibility, self-organization, emergence, development, directionality, history, co-evolution, surprise, indeterminism, pulsing, and chaotic dynamics (Abel and Stepp 2003). These describe the truly complex nature of the systems being studied, and further emphasise the chaotic and non-stable nature of human-environment systems that were also highlighted by the earlier studies of ecosystems (Holling 1973; 1978; 1987; Walters 1986). Of particular relevance to archaeology is the assertion of the irreversibility and directionality of these system dynamics (Abel and Stepp 2003). This supports Turner's (2007) argument that prehistory is an experiment that cannot be repeated, and indeed Abel and Stepp label the prehistoric environment as a 'moving target' (Abel and Stepp 2003). A further level of complexity is proposed by Gumerman and Gell-Mann (1994, 5), who define a complex adaptive system as consisting in many cases of smaller complex adaptive systems interacting with one another. These definitions of the core terms in resilience theory move us beyond the 'black box' analogy of past systems archaeology (Clarke 1968), and instead demonstrate that underlying the resilience theory model is a nuanced understanding of the nature and dynamics of complex adaptive systems that has evolved from decades of careful research into human-environment interactions.

With these definitions in mind, it is now possible to outline the mechanics of resilience theory and to explore how the drivers behind the dynamics of these complex systems can be understood. As has been demonstrated above, resilience theory is concerned with understanding change in systems, in particular the importance of episodic change (Gotts 2007) and how these systems cope. These changes are theorised to take place in an 'adaptive cycle' that has four phases (Holling and Gunderson 2002, 32). It is important to note that although this episodic change is conceptualised as a cycle, the human-environment systems hold the characteristics described in the preceding paragraph, most notably that their dynamics are irreversible and directional (Abel and Stepp 2003), and, therefore, the 'closed loop' diagram is a neat and clear way to demonstrate the concept, rather than an argument that systems return to their same previous state. Even if the characteristics of the system return to their previous state in terms of attractors, the temporal aspect of change means that a complete return is impossible.

The first phase in the adaptive cycle is a period of exploitation and growth (the 'r-phase'). This is followed by a period of conservation and stability (the 'K-phase'), then a period of release (through creative destruction, the 'Ω-phase'), followed by a renewal phase (the 'α-phase') (Holling and Gunderson 2002, 32). As Figure 4.1 below illustrates, movement between these phases relies on the potential and the connectedness of the system, and resilience is found in the third dimension of this model (Gunderson and Holling 2002, 41).

Image removed from online version of thesis for copyright reasons

Figure 4.1. The 3D Adaptive cycle. Phases of rapid growth (r), conservation (K), release (Ω) and reorganization (α). Dearing (2008, Figure 1), adapted from Gunderson and Holling (2002).

Core here is the concept of *panarchy*. Panarchy is a term that was created from the identification of the linkages between system dynamics and scale as the antithesis of hierarchy (Gunderson *et al.* 1995; Gunderson and Holling 2002). The term emphasises that systems of human-environment interaction form nested sets of adaptive cycles as part of a framework that has connectedness between levels, with larger, slower cycles generally constraining the smaller, faster cycles, but with the potential for cross-scale interactions (Gotts 2007; Gunderson and Holling 2002, 26; Resilience Alliance 2002). Key understandings within this model are that change is episodic – caused by the interaction between fast and slow variables, spatial attributes of ecosystems are not uniform and the gradients between them at different scales are neither scale-dependent nor 'smooth' but rather patchy and discontinuous, and finally ecosystems do not have a single equilibrium (Holling and Gunderson 2002, 26–27). In other words, ecosystems are moving targets with multiple features that are uncertain and unpredictable, a sentiment echoed by Abel and Stepp (2003, 8) in their consideration of prehistoric environments.

The description of resilience theory given above outlines the mechanism by which humans can be considered as part of wider systems of interaction as mammals in an ecosystem, but this goes only part of the way to offering a model satisfactory for answering archaeological questions. While concepts of complexity and nested hierarchy, the varying scale and pace at which change occurs, and the uncertain and unpredictable nature of such change provide an invaluable way of understanding the structure of human-environment interactions on a biological level; this framework requires a more sophisticated theory of how humans behave, not just as biological organisms, taking into account human agency with regards to reactions to change beyond a rational or passive ecological decision (a prime example of this being current debates on climate change, and the emergence of such terms as 'climate denier'). Such an approach has been proposed by Westley *et al.* (2002), and consists of four dimensions of human interaction in relation to the environment and to each other. The first dimension is that of human symbolic systems, which they argue allows social systems to abstract from local environments, most obviously through the use of language to define and categorise what is perceived as the 'natural world' (Westley *et al.* 2002*,* 105), allowing a large amount of uncertainty to be absorbed. Linked to this is the second dimension of reflexivity, the ability of humans to self-organise, and create and internalise multiple 'virtual realities' that allow them to move between hierarchies and systems (Westley *et al.* 2002, 110). This is similar to Gumerman and Gell-Mann's (1994, 4) proposal that schemata are used in society to transmit survival information. This, they argue, offers a degree of flexibility when faced with change, however humans are poor at dealing with multiple time scales, and tend to operate within a single time-scale at a time (Westley *et al.* 2002, 113, citing Dörner 1996). The third characteristic of human systems is that they are forward-looking. Humans employ models of the past and use them to build models to predict the future (Westley *et al.* 2002, 114). This encompasses activities from sowing crops to financial forecasting. Interesting here is the task of identifying which filters might have occurred to produce bad modelling, leading to onset of the Ω-phase of creative destruction (Westley *et al.* 2002, 116). The final dimension of human interaction with ecosystems is that of the externalisation of logic through technology. It is through technological innovation that adaptation can be enhanced (Westley *et al.* 2002, 117). These four dimensions of human system-building allow more sophisticated interpretations of human action within the framework of adaptive cycles, and allow the archaeologist to ask questions of both cultural and ecological change whilst still holding these potentially quite different aspects of human life within an integrated framework of interaction.

It is noteworthy that in presenting their theory of how human social and cultural systems can be understood, Westley *et al.* (2002) turn to an archaeological question (the collapse of Easter Island society as posed by Redman (1999)) in order to illustrate their research question. This point will be elaborated upon in more detail in the following sections, where I will discuss the applicability of resilience theory to archaeology, and more specifically its applicability to understanding the changes seen in the archaeological record in Semirech'ye.

Of course the resilience model is not without its weaknesses, and it is not adopted here as a complete explanation for all the archaeological phenomena observed in the Semirech'ye region and beyond. Indeed, one of the difficulties in employing resilience theory is that in its widest and most abstract sense the resilience theory framework can be used as a model for all observable and unobservable systems and therefore loses its power as an explanatory tool with which to explore the mechanisms of human social, cultural and technological change and stability. Further (constructive) criticisms of the use of resilience theory as applied to human-environment systems have been highlighted by Davidson (2010), who states that "the panarchy model implies that in the absence of disturbances, systems will tend towards increasing complexity". Using contemporary global society as an example, she argues that this assumption is difficult to transfer to a social model since many trends are towards simplification, for example a single free market or a single energy source, and in many cases increasing diversification may in fact result in a reduction in complexity (Davidson 2010). She further argues that the deterministic nature of the relationship between complexity and disturbances in ecological systems in the resilience model requires refinement when applied to social systems, in particular the feedback processes in social systems are not comparable to those in ecological systems since both individual and collective human agency plays a large role in shaping outcomes (Davidson 2010). This is particularly pertinent to archaeological research, where it may be very difficult to disentangle human agency from environmental variables. For example, in the case of this study, evidence for choices in land use may reflect environmental pressures such as the physical availability of certain ecological niches, or it could be an indication of a socially or culturally-led decision. Although it might not be possible to identify the underlying mechanism behind such choices, acknowledging and actively including human agency in the resilience model steers us away from environmental determinism.

4.3. Resilience Theory and Archaeology

There are two aims in employing resilience theory for the purposes of this study. The primary aim is to build a theoretical framework that will inform the nature of the investigation and aid in reaching theoretically robust interpretations of the archaeological record. The secondary aim is to use these results and interpretations to offer suggestions of refinements to the resilience theory model and its applicability to the Semirech'ye region in the Late Bronze to Early Iron Ages.

I will first examine why resilience theory is a useful theoretical model for archaeologists. In their article discussing the two-way benefits of archaeologists engaging with resilience theory, Redman and Kinzig (2003) have argued that resilience theory offers a rich perspective on social and ecological change and stability by emphasising the integrated nature of underlying processes, and the varying 'speeds' at which they operate. Such an approach in archaeology allows us to account for the varying degrees of connectedness between social and environmental elements, but more importantly enables explanations of the variation observed in change and stability across time through an understanding of the interaction of ‘fast’ and ‘slow’ processes (for example in the case of this study it might be necessary to consider fast events such as flooding and slow processes such as the management of irrigation systems). In addition to enabling sophisticated explanations of systems change and stability, the roots of resilience theory lie in complexity theory, concerned with the complex adaptive and survival systems of human knowledge creation, management and retrieval in the face of social and environmental pressures (Dean 2000, 90; Gumerman & Gell-Mann 1994; Shennan 2007). This dimension of human behaviour includes cultural, religious, economic and social strategies, which are often difficult to access archaeologically, but which nonetheless form a very large component of the choices and adaptation strategies that humans employed in prehistory. This approach is useful to this research since the evidence presented here may be the result of choices determined by both environmental and cultural/social pressures. However, the temptation is to focus solely on the environmental aspect as an explanation since this is the most readily available data. By appreciating the relationship between these factors in shaping choices relating to land use and subsistence strategies, a more nuanced interpretation can be achieved. For example, phytolith evidence for the exploitation of a particular ecological zone might indicate that this was the most easily accessible resource, however, in an area such as Semirech’ye - with its mosaic of different environments in close proximity - there may be other factors affecting these choices such as familial, political or religious restrictions on land use, culturally defined subsistence strategies, or logistical but not environmentally determined limitations on activities such as irrigation (e.g. not enough available workers to maintain irrigation ditches).

In addition to the recognition of the different ‘speeds’ of various social, cultural, technological and environmental processes, resilience theory also emphasises the diversity and multiple temporal and spatial scales of analysis (Peeples *et al.* 2006). This aspect of resilience theory has been highlighted by Peeples *et al.* (2006), who argue that using a resilience theory framework allows us to structure descriptions of the dynamics in complex systems. The scalar aspect of the model is particularly useful when considering human land use in prehistory, since the same human group can simultaneously exploit resources of different spatial and temporal (i.e. cycle length) scales; for example, upland and lowland resources (Peeples *et al.* 2006). This approach encourages an interpretation of the data that considers the overall dynamics behind the 'snapshot' pictures that make up much of the archaeological data (Peeples *et al.* 2006). This is particularly relevant for this research, where the three sites in this study represent only a very small amount of the total number of sites in Semirech'ye, many of which remain either undiscovered or undocumented (Frachetti 2008, 10). By interpreting the data using the resilience theory framework, I hope to acknowledge the different scales at which human groups who occupied these sites may have operated. In particular, I want my interpretations to be mindful of the fact that the results from a single site may not represent the whole range of activities by the humans who occupied that site. Although this might seem like a very basic point, it is especially relevant to Semirech'ye, where modern ethnographic analogy demonstrates that traditional modes of land use in the region include biseasonal transhumance between uplands and lowlands, with temporary summer camps in high mountain pastures and more durable winter dwellings in lowlands (personal observations). Further to this, current archaeological research points to a varied use of the landscape, with a 'mosaic' pattern of land use proposed by Spengler *et al.* in the Bronze Age (Spengler *et al.* 2013b). Employing the resilience theory framework allows this varying use of the landscape to be taken into account, particularly with regards to the very different ecological zones that may have been exploited by the same group of humans, each with their own temporal and spatial scale of management, for example patterns of field management may take place in a very clearly defined space and have a complex temporal pattern of use with both a year-long and multiple-year cycle of use through irrigation, choices of crop, annual rainfall averages etc. On the other hand, the use of summer pastures might have a largely geographically undefined pattern (within certain limits, such as available pasture, political and social boundaries), but its temporal scale may be highly predictable and constricted, defined by the retreat of snow and the onset of the autumn frosts.

Redman (2005, 72) has argued that by engaging with resilience theory archaeologists can work across disciplines to participate in debates relating to the future of human society. As was demonstrated above, resilience theory has been used to inform policy in many important areas relating to the future of human-environment interactions (Martin-Breen and Anderies 2011), and by engaging with these policy debates within a single theoretical framework, archaeologists can make their arguments heard, integrating the important lessons of past mistakes and successes into future planning for such vital issues as water management, land use, and population dynamics to name but a few. This approach means that the researcher is required to think in complex ways, appreciating the place of one particular line of enquiry within the context of others. The concept of panarchy encourages thinking across different scales of interaction, meaning that one particular line of investigation is conducted not only within its own sphere of the specialism, but also with mindfulness of the 'bigger picture' of the human story that archaeology seeks to tell. For this study, conducted alongside ongoing research projects in Semirech'ye, such an approach is invaluable to integrating data and interpretations in a meaningful way. Since the three sites from which the data have been collected are all part of different research projects with different research aims and analysis timescales, it is useful to employ an interpretive framework that allows for these disparities in a constructive way.

4.4. **Resilience theory in the case of Semirech'ye**

As shown in Chapter 3, the archaeological record at the end of the first millennium BC indicates changes in the way social groups expressed themselves through their material culture and rock art, in how they occupied the landscape spatially and in how they altered their surroundings for the provision of shelter and sustenance. Radiometric dating of sites across northern Eurasia shows that dated sites tend to cluster in periods either in the Final Bronze Age before 1000 BC, or the Early Saka period in the late ninth and early eighth centuries BC, with fewer dates procured for the tenth and early ninth centuries (but they do exist, see Hanks *et al.* 2007; Frachetti and Mar'yashev 2007). This apparent fall in numbers of sites could be the result of the lack of recognition of sites of this period, an element of chance on the part of the researcher when choosing which contexts to date (perhaps due to lack of recognition of sites), a physical lack of sites of this date due to a fall in population through death or migration out of the region, or the location of sites in completely different places from the preceding and proceeding settlements. Although the reason behind this pattern in the archaeological record is unknown, conceptualising this change as part of an adaptive cycle helps us to approach this problem in a more nuanced way, considering the factors that may be driving the change, and thus getting closer to an explanation of why such change occurred.

Excavations at the site of Begash produced evidence of mixed pastoral and small-scale agricultural practices from 2200 BC, but no domesticated cereal crops have yet been identified for the Final Bronze period of 1625–1000 BC. Coupled with changes in the material culture at this site, it seems that the earlier period of occupation could correspond to a K-phase of relative stability and conservation, and therefore less resilience. The change noted in the Final Bronze Age possibly indicates the beginning of an Ω-phase of release or 'creative destruction' (Gunderson and Holling 2002, 41), when former strategies and systems of subsistence ceased to be viable. In this context, the pre-Saka period of the tenth and ninth centuries BC could represent the height of the Ω release phase.

The Saka period of Semirech'ye in the eighth century BC saw the emergence of new forms of social hierarchy, artistic expression and subsistence strategies, in particular an increase in agricultural activity, and it would be reasonable to identify this period as an α-phase of renewal and reorganisation, demonstrating high resilience. The later Iron

Age witnessed a r-phase of exploitation and growth, as evidenced on the Talgar alluvial fan (Chang *et al.* 2002). While this model of an adaptive cycle is tentative, and will be tested in this thesis, once in place it encourages an approach to the archaeological record that considers nested hierarchies of systems, the dynamics of fast and slow variables within these systems, the scalar nature of interactions, and the specific nature of human actions, as proposed by Westley *et al.* (2002), all of which contribute to answering the research questions about the nature of human-environment and human-human interactions over time.

The concept of panarchy, with its basis in complexity theory, is particularly useful in approaching the study of interactions between human groups, both within Semirech'ye and in the regions beyond. It was demonstrated in Chapter 3 that the archaeological record in Semirech'ye shares many characteristics in common with the northern Eurasian steppe zone, but that it is also characterised as having some unique material culture types (e.g. round-bottom ceramics (Yablonsky 1995)), and patterns of subsistence (e.g. 'vertical' as opposed to 'horizontal' transhumance patterns (Akishev 1972), and mixed agro-pastoralism (Chang *et al.* 2003)). Using the concept of nested hierarchies, we can see that there are at least two levels of interaction that need to be considered in an interpretation of the archaeological record. The first level is intra-regional, concerning the interaction between different groups of people engaged in different subsistence practices within the Semirech'ye region (i.e. bi-seasonal transhumance and sedentary or semi-sedentary agriculture). The second level is inter-regional, and concerns interactions between Semirech'ye peoples and groups occupying the neighbouring regions of Xingjian and the eastern Eurasian steppe zone. It may also be the case that a third level of interaction took place on a local scale, with different members of one social group practising different subsistence strategies within the same settlement, for example one half of the group taking livestock to high mountain pastures in the summer, while the other half tends to crops.

Using this model as a basis from which to approach the data, phytolith analysis will be used to identify modes of subsistence present at the settlement sites of the Talgar alluvial fan and the Dzhungarian piedmont zone, and these data will then be compared both within and between sites to identify patterns and trends in subsistence choices. Agricultural practices can be inferred through the identification of domesticated cereals to genus, and sometimes species, level, including millets (*Setaria italica* and *Panicum miliaceum*) (Lu *et al.* 2009), wheat (*Triticum* sp.), barley (*Hordeum vulgare*) (Rosen 1992) and rice (*Oryza sativa*) (Pearsall *et al.* 1995). The laboratory methodology for the extraction of phytoliths from sediment aims to calculate the mass of phytoliths extracted from a known mass of sediment, and therefore the absolute abundance of different cereals can be inferred in addition to their presence or absence from a sample. This could be particularly useful for the sites of Semirech'ye, where the changing significance of farming across sites might imply differing reactions to social and environmental pressures. Different cereal crops have different demands of care; millet, for example, is a good environmental stress crop with a short growing season and low moisture requirements, whereas if rice is being cultivated on the Talgar alluvial fan in the Saka period then the implication is that intensive, irrigation-based agriculture with a large time commitment was being practised (Chang *et al.* 2003).

In addition to providing evidence of agricultural practices, phytolith data can also give an insight into choices of pasturing of livestock, and this is accessed through contexts containing phytoliths from their dung, usually found in hearths after the dung was used as fuel. Hearth contexts with large numbers of grass stem phytoliths are usually indicative of the use of dung as fuel. Rosen's identification of the lack of correlation between quantities of weed and cereal phytoliths in the earlier levels at Tuzusai led her to conclude that the weeds were being brought into the site in the form of animal dung (Rosen *et al.* 2000), and that the animals were grazing away from the fields. Rosen was also able to identify the ecological zone in which the animals were grazing, which is possible through obtaining ratios of phytoliths diagnostic of C3 Pooid grasses (cool-moist adapted, ‘rondel’ phytolith type) and C4 Panicoid grasses (warm-dry adapted, ‘bilobate’, ‘polylobate’ and ‘cross’ phytolith types) (Rosen, 2001, 187). In addition, ratios of C4 Panicoidiae grass phytoliths can be distinguished from C4 Chloridoideae grass phytoliths, giving a further indication of aridity (Piperno 2006, 32–34; Strömberg 2009). Since the sites in this study are located on the ecotone between the semi-desert steppe and cool high mountain pastures, differences in grass types will indicate different choices of where to graze animals. This information will be used in a comparison between sites and across time, to inform about herding choices. The correlation of phytolith data with other data such as faunal remains will allow for an assessment of the relative significance of agricultural practices compared to pastoralist activities. This will enable the extent and nature of the interaction of these two systems of subsistence to be identified. The ‘nested hierarchy’ model of panarchy is invaluable here as it enables us to conceptualise the multi-level nature of differing systems of subsistence across space and time, and the ways in which they might interact and change.

While the concept of panarchy aids in conceptualising how changing systems interact, in order to understand and explain the dynamics of change within these observed systems, it is necessary to consider the slow and fast variables that interact to cause episodic periods of change (Holling and Gunderson 2002, 26–27). The variables in this case are those factors which have the power to affect human choices of land use and subsistence and therefore the systems in which they operate, and they can be both environmental and social in origin. I identify the following four variables as being significant factors in human decision-making about subsistence choices: 1) climate, which can act as both a fast and a slow variable, depending on perspective; 2) hydrology, including seasonal stream variability, flooding events; 3) social and demographic pressures, again these can be both fast and slow acting variables. For example, steady population growth can be considered a slow variable, whereas war or political upheaval can be very fast acting; 4) human land exploitation and its consequences, including factors such as deforestation and water management, which can be slow or fast acting depending on the type of change being made to the landscape. Information about these variables is accessible in the archaeological record, in this case phytolith analysis, and I will outline how this will be achieved below. Before outlining how these variables will be accessed within the scope of this project, I would like to stress that while these variables have the potential to alter the systems in which they operate, they also affect, and are affected by, each other, and therefore should not be seen as factors to be 'plugged into' an equation, but rather as part of dynamic processes of change and stability.

1.) Climate. As I outline in Chapter 3 above, general trends of climate change in Semirech'ye and the northern Eurasian steppe zone have been identified through the use of various palaeoclimatic proxies (Alisov, 1956; Aubekerov *et al.* 2003; Khotinskiy 1984; Kremenetski 2003). Although the picture is far from complete, it is possible to identify changes in climate on a regional and continental scale. This macro scale data can be complemented with site-specific phytolith data to further inform about the nature of this variable, and the relative speeds at which it might act. As discussed above, phytolith data can be used to indicate vegetation cover and therefore the types of environments that were being exploited, which may be a reflection of the climate. Through a comparison of samples taken both on and off-site, and in and near specific contexts, a picture of the site's 'background noise' of plant types can be built up (Piperno 2006, 83), and this used to inform about the vegetation cover of the surrounding area, and therefore infer the type of climate. Periods of climate instability will result in changing patterns of aggradation of sediment as factors such as changing levels of moisture and the presence of ice affect the way in which sediments are transported and deposited. Periods of climatic stability are just as important as periods of change, and these can be identified through the evidence for soil formation, the consequence of a period of nonaggradation (Rapp & Hill 1998, 32), in geoarchaeological sections.

2.) Hydrology. The availability of moisture in a climatic system can affect the nature of sedimentation both on archaeological sites, and in the landscape surrounding them. Such changes are most evident in hydrological systems, such as alluvial fans, where the changing energy of a stream channel due to fluctuating amounts of water flowing in it is reflected in the deposition of sediment (Goldberg & Macphail 2006, 85–98). Hydrological regimes can have a great effect on human choices of land use and subsistence strategies, as unpredictable or high energy stream patterns may be unmanageable and therefore not conducive to settlement or agriculture. Conversely, the deposition and accumulation of fine silty alluvium, such as that seen on the Talgar alluvial fan, is highly advantageous for agricultural activity (Rosen *et al.* 2000, 615). Of course, humans are not completely at the mercy of hydrological systems, managing them intentionally through the building of dams and drainage channels, and affecting them unintentionally through landscape changes such as deforestation, or the unintended consequences of damming. These aspects will be considered as part of variable 4. Phytolith data can also be used to infer local microenvironments and the availability of water within a system. For example, a high number of phytoliths from water-loving species such as sedges (Cyperaceae) and reeds (*Phragmites australis*) can indicate a high water table, and therefore a tendency towards marshy and swampy environments (Rosen *et al.* 2000, 612).

3.) Social and demographic pressures. The variable of social and demographic pressure is certainly the most difficult to interpret in the archaeological record as social pressure such as political change may not be evident at all in the prehistoric period, leading the researcher to place more emphasis on environmental variables as the underlying causes of change. Demographic pressure is also a difficult variable to measure when not all the sites of a period have been identified in an area, leading to a skewed picture of land use. This is evident on the Talgar alluvial fan, where Chang *et al.* (2002) have identified hundreds of Iron Age sites, but very few from the Bronze Age. They argue that this could be due either to a lack of sites, or the fact that these sites are buried beneath several metres of sediment, and are therefore not visible through current methods of surface survey and the use of satellite imagery (Chang *et al.* 2002, 135). This variable also involves those behaviours described by Westley *et al.* (2002) such as the use of symbolic systems, the ability to plan for the future, and the creation of 'virtual realities' allowing movement between different hierarchies. Forward planning through the need to sow, tend and harvest crops in the right season can be implied from evidence for the intensification of agriculture, although pastoral activities equally require foreknowledge of pasture availability, for example through the ability to predict when snows will melt making high alpine meadows available. Likewise, evidence of the creation of 'virtual realities' to enable movement across various systems and hierarchies can be accessed through the evidence for differing subsistence practices outlined above, as intra- and inter-regional interactions require the creation and use of different social systems to cope with changing scales of interaction. Although difficult to access archaeologically, especially within the scope of this project, it is nonetheless necessary to account for this variable of human population and social dynamics, and to build it into the resilience model as far as is possible.

4.) Human land exploitation. The exploitation of the landscape by humans is a variable that can result in both intended and unintended consequences, and can be thought of as both a variable driving change as well as a response to other variables causing it. Intended consequences of landscape exploitation such as the control of streams through channelling and irrigation ditches include periods of stability and soil formation, a slow-acting variable that allows the expansion and growth of agriculture. At the same time, the increasing exploitation of this system, and the maintenance of a stable state, reduces the resilience of the system, and leads to the slow process of soil deprivation. A reaction to this may be the clearing of forested land to create new areas for agriculture, itself leading to what may be a very fast process of soil erosion (Dearing 2008, 120). Overgrazing is another expression of this variable. Evidence for deforestation and subsequent erosion can be found through phytolith evidence. By analysing counts of ligneous dicotyledon phytoliths and grass phytoliths (the 'tree cover index'), ratios of vegetation cover can be expressed as a ratio, which might indicate periods of deforestation (Bremond *et al.* 2008). The erosional consequences of deforestation and overgrazing can be identified through evidence of erosion of sediment, characterised by abrupt and uneven interfaces between horizons, or evidence for the erosion of sediment upstream, and the resulting high sediment load of waters producing flooding events in which a large amount of sediment is deposited in a single context (Dearing 2008, 120; Rosen *et al.* 2000, 617). Again, as has been emphasised throughout this section, these human-induced variables do not exist in isolation, and must be seen as part of a range of interacting processes that all lead to changes in land use choices, subsistence practices, and the resilience of human systems.

The resilience model is a useful framework for informing methodological approaches to answering the research questions. By building a working hypothesis conceptualising change in the archaeological record as being part of an adaptive cycle, research methodologies can be applied in a focused and ordered way to answer specific questions relating to the variables acting within that system. The integration of phytolith data within this theoretical framework allows for the testing of the hypothesis in a sophisticated way, appreciating the interconnectedness of the systems, hierarchies and variables within a complex system of human adaptation through economic, social, technological and cultural means.

Reversing the question to ask what archaeology can offer to resilience theory, the strongest consensus among researchers is that archaeology's unique 'time depth' perspective allows the resilience model as it relates to human societies to be tested over a period of hundreds of years, something that is not possible from historical records alone (Berger *et al.* 2007; Dearing 2008; Redman 2005; Redman and Kinzig 2003). In his analysis of palaeoenvironmental change during 3000 years of human occupation in Yunnan, South-West China, Dearing (2008, 118) emphasises the role of archaeological data in helping to distinguish between *ultimate* and *proximate* causes of collapse in socio-environmental systems. He demonstrates that by correlating multiple data relating to environmental change such as monsoons and human land use, long term trends in processes can be identified as part of an adaptive cycle, many of which might in the short term appear to show the movement from one state to another (e.g. K-phase to Ω-phase) but are in fact merely variations within a larger pattern of change. This highlights another contribution of archaeology to resilience theory, which is the ability to identify episodic behaviour caused by the interaction between fast and slow variables through an approach that employs multiple scales of analysis (Redman 2005). For example, archaeological interpretations of a settlement site will generally include considerations of individual, familial, settlement and regional interactions. This research project also adopts a multi-scalar approach, and will therefore seek to offer refinements to the resilience model through a more nuanced interpretation of how fast and slow variables interact over time. Analyses such as these aid in the refinement of the resilience theory model, and improve its power to predict and inform human adaptive behaviour in the future.

Chapter 5: Background to the sites in this study

This chapter will provide more specific background information for the sites in this study. The first section gives an overview of the soils and vegetation to be found in Semirech'ye. As well as providing contextual information for the phytolith assemblages and site locations, it also demonstrates the steep environmental zoning that is found in the foothills of the Tien Shan and Dzhungarian-Alatau mountains. The ability to access a wide range of environmental zones within a very short distance is important to bear in mind when considering how the landscape may have been used by humans over the course of a year. Evidence of agricultural activity does not necessarily mean that occupation was year-round, and evidence for seasonal occupation at a site does not mean that all members of a community were mobile.

The second part of this chapter provides details about the three sites from which phytolith samples have been analysed. Each site is introduced in its geographical context, and a brief description of key features is given. The site phasing and where available absolute dating is then summarised, together with key artefactual and faunal remains. The archaeological information is then followed with site-specific palaeoclimatic reconstructions where such data are available.

5.1. Soils and vegetation in Semirech'ye

This section considers the distribution of soils and vegetation in Semirech'ye today. The different vegetation zones to be found in the region are outlined, together with a brief summary of their most significant species. The following data are provided in order to demonstrate the large diversity in vegetation to be found in Semirech'ye today, as demonstrated in Figure 5.1, which shows the 'modern' (1982) vegetation zones of

Semirech'ye and provides a model with which to understand how past landscapes may have looked under different climatic conditions.

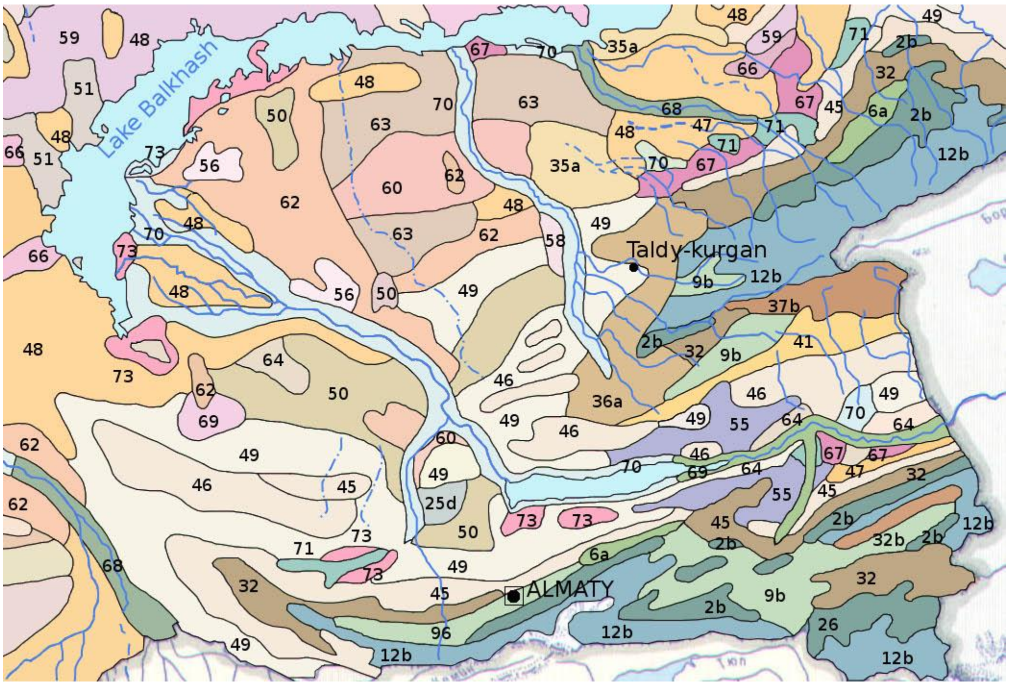


Figure 5.1. Modern vegetation map of Semirech'ye, showing the many different vegetation zones in the region. Each colour-coded number represents a different classification of vegetation, with the key to those numbers on this diagram given below (after ANKSSR 1982, translations from the original Russian my own):

No. on map	Vegetation description
2b	Spruce forests, dominated by *Picea Schrenkiana* and admixed *Abies sibirica*, combined with shrub thickets (*Rosa plathyacantha*, *Spiraea lasiocarpa*, *Cotoneaster melanocarpa*) and meadows (*Ligularia macrophylla*, *Bupleurum aureum*, *Aconitum leucostomum*)
6a	Wild apple forest (*Malus sieversii*) combined with shrub thickets (*Rosa plathyacantha*, *Cotoneaster melanocarpa*, *Acer semenovii*) and shrub-grass steppes
9b	Rose forb-grass (*Rosa plathyacantha*, *Lonicera tatarica*) combined with forb-grass meadow (*Dactylis glomerata*) and shrub-grass steppe (*Helitotrichon desertosum*, *Stipa kirghizorum*)
12b	Alpine meadow (*Kobresia capilliformis*, *Alhimilla retropilosa*, *Abies sibirica*) and steppe (*Festuca alatavica*, *Festuca valesiaca*) sometimes with sub-alpine Tien Shan meadows (*Alopercurus songoricus*, *Alchimilla retropilosa*, *Geranium collinum*)
25d	Artemisia-Stipa (*Artemisia marschalliana*, *Artemisia sublessinqiana*) sandy steppe
32	Shrub (*Spiraea hypericifolia*, *Cerasus tianschanica*)-Helictotrichon (*Helictotrichon desertorum*)-Kyrgyz feather grass (*Stipa kirghisorum*) and shrub-steppe fescue-Stipa (*Stipa capillata*, *Stipa valesiaca*) Tien-Shan steppe sometimes in combination with shrub thickets (*Rosa plathyacantha*, *Cerasus tianschanica*, *Spiraea hypericifolia*)
35a	Sandy steppe (*Agropyron fragile*, *Artemisia arenaria*, *Ceratoides papposa*, *Callidonum* sp.)
36a	Rocky steppe - Shrub (*Spiraea hypericifolia* in the west, *Caragana frutx* in the east) fescue (*Festuca valesiaca*) and lessingiana (*Stipa lessingiana*)-fescue
37b	High-mountain steppe - Fescue, Helictotrichon-fescue (*Festuca valesiaca*, *Festuca*

No. on map	Vegetation description
	tianschanica, *Helictotrichon tianschanicum*)
41	Mountain steppe - Blue-stem and shrub-sagebrush-blue-stem (*Bothriochloa ischaemum*, *Artemisia sublessingiana*, *Spiraea hypericifolia*)
45	Desert - Grass-sagebrush (*Artemisia sublessingiana*, *Stipa sareptana*, *Stipa lessingiana*)
46	Desert - Sagebrush (*Artemisia sublessingiana*)
47	Desert - Grass-white-wormwood (*Artemisia terrae-albae*, *Stipa sareptana*, *Stipa richteriana*)
48	Desert - White-wormwood (*Artemisia terrae-albae*) with in some places *Salsola arbusculaeformis* and *Salsola rigida*
49	Desert - Ephemeroid-white-wormwood (*Artemisia terrae-albae*, *Poa bulbosa*, *Carex pachystillis*)
50	Desert - White-wormwood and Yermakovo-white-wormwood (*Artemisia terra-albae*, *Agropyron fragile*)
51	Desert - *Artemisia turanica* and *Salsola arbusculaeformis*
55	Desert - complex of Nanophyton erinaceum and *Anabasis salsa*
56	Desert - *Salsola rigida*, *Salsola laricina*, *Artemisia terrae-albae*)
58	Desert - Grass (*Stipa sareptana*) -white-wormwood (*Artemisia terrae-albae*) -*Salsola arbusculaeformis*
59	Desert - *Salsola arbusulaeformis*, *Artemisia turanica*)
60	Desert and white-wormwood-desert (*Ceratoides papposa*, *Agropyron fragile*, *Artemisia terrae-albae*)
62	Desert - black saxaul (*Haloxylon aphyllum*) sometimes with *Salsola rigida*
63	Desert - white saxaul (*Haloxylon persicum*) sometimes with *Calligonum* sp., ephedra (*Ephedra lomatolepis*), wormwood (*Artemisia arenaria*, *Artemisia leucodes* in the east)
64	Desert - saxaul (*Haloxylon aphyllum*, *Haloxylon pericum*) sometimes with *Ceratoides papposa*, wormwood (*Artemisia terrae-albae*), *Calligonum* sp.
66	Desert - *Atriplex cana*, *Artesmisia pauciflora*, *Suaeda physophora*, *Anabasis salsa*
67	Desert - *Halocnemum strobilaceum*, *Halostachys caspica*, *Kalidium foliatum*, *Kaldium caspicum*, *Atriplex verruciferae*
68	Riparian woodland (*Elaeagnus angustifolia*, *Populus pruinosa*, *Populus diversifolia*) and shrubs (*Halimondendron halodendron*, *Tamarix ramosissima*)
69	Forb-grass meadow (*Agropyron repens*, *Bromus inermis*, *Calamagrostis epideios*)
70	Reed (*Phragmites australis*) and bulrush (*Bolboschoenus maritimus*) meadows
71	Needlegrass (*Achnatherum splendens*), Altai wildrye (*Leymus angustus*), *Aeluropus littoralis* meadows, sometimes with communities of sagebrush (*Artemisia nitrosa*)
73	Seral (unformed) vegetation of coastal and lake shores (*Climacoptera* sp., *Salsola nitraria*, *Petrosimonia sibirica*, *Atriplex verruciferae*)

(after ANKSSR 1982).

The purpose of exploring vegetation zones with an emphasis on elevation and aspect is to show that these factors give rise to a wide variety of habitats. While the modern boundaries of these zones are not the same as they were in the late 2nd and early 1st millennia BC, the data below serves to illustrate the patchwork nature of habitats, and how small changes in moisture availability can have a dramatic impact on the natural vegetation cover of this region. Of course, humans have a great ability to modify the landscapes they encounter, and I am not implying here that human occupation of a particular area was a one-way process dictated solely by the available habitats. However, an understanding of the natural vegetation of the region provides a basis with which to approach the occupation and exploitation of a particular area. It also serves to illustrate the many factors that can affect the viability of various types of vegetation, both wild and domesticated.

A study by Funakawa *et al.* (2010) found that modern soil and vegetation zonation for the Transili-Alatau (the region which includes the sites of Tuzusai and Turgen) and the Dzhungarian-Alatau (where the site of Tasbas is located) are similar, although for the Dzhungarian-Alatau borders are 200m lower. It is therefore possible to describe the zonation of soils and vegetation in these two regions together. This similarity in the vertical distribution patterns of soils and vegetation further demonstrates the appropriateness of comparing data from these three sites together. It appears that these two regions are affected by soil formation and vegetation distribution factors in the same way, and therefore the landscapes available for human exploitation would have presented the same vertical gradient in both areas.

In general, soil formation in Semirech'ye falls into two broad categories, with desert calcisols forming in the pre-Balkhash and other desert areas, and grey earths of piedmont semi-desert forming in the Tien-Shan–Dzhungarian-Alatau zone (Zamotaev, 2002, 105). The typical parent rocks of grey earth soils are loesses and loess-like loams, often underlain by gravels. They have a low humus content (1–4%), and are rich in carbonate (*ibid.*, 117). The modern day distribution of soils in Semirech'ye is illustrated in Figure 5.2, which shows the mountain and foothill soils to the south and east giving way sharply to the desert soils of the pre-Balkhash region to the north and east. The altitudinal zonation of these mountain chains is steep and well-defined, as demonstrated by Frachetti (2008) with the lower altitude zones tending towards semi-desert and desert vegetation, while meadow steppes and coniferous forest can be found at higher altitudes.

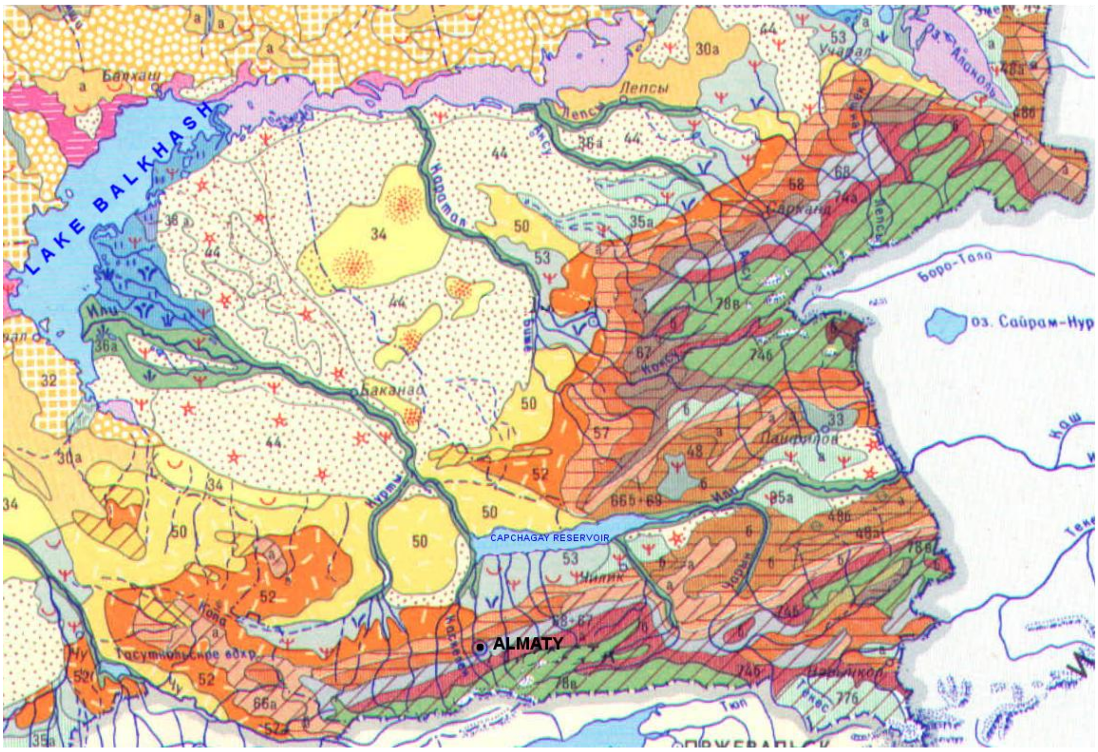


Figure 5.2. Modern soil map of Semirech'ye, showing the distribution of soils in the region. Each colour-coded number represents a different soil classification, and the key to those numbers on this diagram is given below (after ANKSSR 1982, translations from the original Russian my own):

No. on map	Soil type
30	Grey-brown with residual takyr in places
32	Grey-brown underdeveloped gravelly
34	Takyr-like and takyr
35	Meadow
36	Floodplain meadow
38	Marsh (a) and marsh saline (b)
44	Sandy
48	Foothill brown (a) and grey-brown (b)
50	Northern light grey soils (calcareous)
52	Ordinary northern grey soils (calcareous)
53	Meadow-grey soil
57	Foothill light brown carbonate (grey-brown)
58	Foothill dark-brown, sometimes with mountain brown
66	Mountain brown (a), sometimes with mountain black earth (b)
67	Mountain black earth with mountain-steppe xeromorphic

No. on map	Soil type
68	Mountain black earth with mountain-steppe xeromorphic
69	Mountain-steppe xeromorphic with mountain black earth (a), sometimes with mountain-forest black earth-like
74	Mountain-forest dark-coloured and dark-grey with mountain turf and mountain-steppe (a) or with mountain-meadow-steppe and mountain-steppe (b)
77	Mountain-meadow-steppe alpine and subalpine (a), sometimes with mountain-meadow alpine and subalpine (b)
78	Mountain-meadow alpine and subalpine (a), sometimes with mountain-tundra alpine and subalpine (B)
78	Mountain-tundra

(after ANKSSR 1982)

Using the World Reference Base for Soil Resources (WRB), the following is a brief description of the vertical distribution of soils in the study area (IUSS Working Group WRB 2006). At lower altitudes, below 700m (1000m for south-facing slopes), calcisols are found in what are desert regions. From around 700m dark-coloured soils with mollic horizons start, and are found into the high mountains. Kastanozems are found in the north-facing foothills up to 1000m, and up to 2000m in south-facing slopes. The steppe zone begins at around 1000m for northern slopes, with chernozems supporting broad leaved forests from around 1400m. From around 1800m pheozems are found in the coniferous forest zone (dominated by *Picea*), predominantly on north-facing slopes. Above 2500m are found umbrisols, which support highland grassland (Funakawa *et al.* 2010). Overall, soil pH demonstrates a decreasing trend with increasing elevation due to precipitation and decreasing temperature (*ibid.*, 45).

As can be seen from the above data, the aspect of slopes in foothill and mountain zones is very important in determining the soil, and subsequently the vegetation type to be found in a particular area. This must be borne in mind when considering the location of the sites in this study, and subsequently the local vegetation that may have been present at the time. While the above overview is one of modern soil distribution, it serves to demonstrate the often clearly demarcated patterns of vertical zonation that are found in the mountain and foothill regions of this study. This is of importance when considering the various landscapes that were available for occupation and exploitation, not only in terms of the vegetation that they carried, but also their physical presence as visually distinct zones, which may have had more than ecological significance to the human groups that occupied them.

Having considered the distribution of soils, I will now summarise the vegetation to be found in the various landscape zones described above (see also Figure 5.1). It should be noted that the moisture regime is the main factor that influences the location of these different vegetation belts, and this is determined by the aspect of the slope, the closeness of the valleys, and the character of the bedrock (Kotov 1960, 231). When these factors are taken into account, it can be seen that even one hill may support a variety of different vegetation groups, and that while broad groupings are a useful way to approach large landscapes, each zone must be considered as a mosaic of many different plant colonies. The vegetation of the Tien Shan and foothills can be grouped into five main belts (after Kotov 1960, 231). The altitudes detailed in parentheses below reflect data from the central Tien Shan region, and are given as a guide. When compared with the altitudes for the soil zones from local data given above (presented here below in square brackets), it would appear that the vegetation bands for the Transili-Alatau and the Dzhungarian-Alatau are most likely to be a few hundred metres lower than those of the central Tien Shan region, however the general vegetation bands are comparable:

Desert and desert-steppe (1600m–2000m) [<700–1000m] (Figure 5.3).

Figure 5.3. Desert/semi-desert steppe vegetaion of the pre-Balkhash region (author's photograph)

Steppe belt (1700-2600m) [1000–2000m] (Figure 5.4).

Figure 5.4. Vegetation of the steppe belt (c.1000m asl), showing mixed grass/forb meadows and deciduous woodlands. The foothills of the Tien Shan mountains are visible in the background (author's photograph).

Subalpine belt 2160-3200m [1400–2500m] (Figure 5.5).

Figure 5.5. Subalpine high mountain meadows near the site of Turgen, elevation c.2200m asl, showing mixed forb/grass meadows and *Picea Schrenkiana* forests (author's photograph).

Alpine belt 2800-3300m [2500m–glacial and moraine belt] (Figure 5.6 and Figure 5.7).

Figure 5.6. Assy plateau, elevation 2600-2800m asl, located at the alpine/subalpine ecotone, showing low-grass meadow vegetation (author's photograph).

Figure 5.7. View of the ecotone between the alpine and the glacier and moraine belt. Alpine vegetation cover is shown in the background, consisting of low-grass meadows, and in the foreground is glacier and moraine belt vegetation, consisting of single-standing species in the stony substrate (author's photograph).

Glacier and moraine belt, from 3300-4000m (Figure 5.8).

Figure 5.8. Glacier at the head of the Small Almaty Gorge (c.3400m asl), showing sparse glacier and moraine belt vegetation in the foreground (author's photograph).

Within each of these vegetation groups a variety of plant colonies can be found which reflect differences in the moisture regime caused by the influencing factors described above. Some of these colonies and the significant species found within them are detailed below.

Desert and desert-steppe. Vegetation in the lower foothills of the northern Tien-Shan is characterised as temperate wormwood desert-steppe. The dominant species here is *Artemisia tinschanica*, with admixed prostrate summer cypress (*Kochia prostrata*), *Eurotia ceratoides* (important use as forage (Uniyal *et al.* 2005)), *Carex duriusculiformis*, *Festuca kryloviana* and the feathergrasses *Stipa caucasica* and *Stipa bungeana* (Kotov 1960, 233).

Steppe belt. Characterised as cereal-feathergrass-desert-steppes, feather-grass (*Stipa* sp.) steppe, with a widespread distribution of shrubs (e.g. *Rosa* spp.) (Merzlyakova 2002, 396). Found here are wild fruit forests composed of *Prunus racemosa* and *Malus sieversii*. Other woodlands represented are poplar (*Populus densa*), found up to 2600m, intermixed with willow (*Salix przewalskii*), buckthorn (*Hippophae rhamnoides*) and sweetbriar (*Rosa beggariana*), and birch forests (*Betula tianshanica*). The birch forests are admixed with willows, and among the grasses is found wild barley (*Hordeum turkestanicum*) (Kotov 1960, 232).

Subalpine belt. The dominant forest here is spruce (*Picea schrenkiana*). The diverse subalpine tall-grass meadow zone, which is interspersed with juniper thickets (*Juniperus turkestanica*), is dominated by sedges and cold-tolerant flowering species (*Helictotrichon asiaticum*, *Alopecurus songoricus*) (Merzlyakova 2002, 396). Also found are Shagspine Peashrubs (*Caragana jubata*, can be used for medicine, fibre and hedging (PFAF 2013)), Meyer currant (*Ribes meyeri*) and honeysuckle (*Lonicera microphylla*) (Kotov 1960, 232). Widespread are the mountain meadows, found in the alpine and subalpine belts. These steppes are important for grazing, and also provide a valuable source for hay-cutting (Kotov 1960, 233). At lower elevations are the cereal subalpine meadows, found above the juniper thickets. The average height of the grass stand is 50-60cm, and these grasses develop during the short summer period. On higher, marshy ground sedges and dicotyledons dominate (Kotov 1960, 234).

Alpine belt. Alpine low-grass meadows. Widespread on syrts (elevated flatlands found in high mountain areas) are fescue steppes, up to 3200m on northern slopes, and 3600m on southern slopes. These steppes are located on high-mountain subalpine-steppe-meadow soils and carbonated chocolate-grey soils (Kotov 1960, 233). The background is formed of *Festuca kryloviana*.

The high mountain glacier and moraine belt consists of single standing species dispersed among the stony substrate (Kotov 1960, 234).

As can be seen from the above description, the distribution of vegetation in Semirech'ye, and in particular in the foothills of the Tien Shan and Dzhungarian-Alatau, is not uniform. Elevation, aspect and parent material all influence moisture availability, which in turn affects soil type and vegetation cover. Even at similar elevations, the varied topography of the region means that many different habitats can be found within a relatively small area, and this is even more marked by moving between elevations. Between semi-desert, steppes, woodlands and alpine meadows, humans are presented with a wide variety of vegetation zones available for exploitation. Even before cultigens are taken into account, it can be seen that Semirech'ye is a diverse landscape with a wide variety of economically valuable plants for humans to exploit, either through direct consumption, the grazing of livestock, or for non-food uses such as fuel, construction and craft. Since aspect appears to be a key factor in moisture availability and subsequently the natural vegetation cover for a particular area, it must also be taken into account when interpreting evidence for the cultivation of domesticated plant species, and choices in human landscape use in the past. Understanding the natural vegetation of Semirech'ye provides insight into interpreting evidence for the cultivation of plants, and what is most clear is that the region is not uniformly suited to agriculture.

Evidence of human occupation at various elevations and on slopes of various aspects may therefore in part reflect the type of subsistence that was most important to that settlement, given that a very small change in elevation or aspect can dramatically alter the available moisture and therefore vegetation of an area. When considering the placement of settlements, this choice can perhaps in part be seen as relating to the distribution and diversity of vegetation in and around a given site, as well as other important factors such as the availability of potable water, fuel and protection from threats, natural or human.

Figure 5.9 shows the location of the three sites in this study in the context of the Semirech'ye region. This region is bordered to the north and west by Lake Balkhash, to the east by the Dzhungarian Alatau mountains, and to the south by the Tien Shan mountains. As can be seen from the map, the three sites all occupy locations in either the mountain or foothill zones of the region.

Figure 5.9. Map of the three sites in this study

5.2. **Tuzusai**

The site of Tuzusai is located on the Talgar alluvial fan, which is situated in the northern foothills of the Tien-Shan Mountains at an elevation of 723m asl, around 25 km east of the city of Almaty (Figure 5.10). The Talgar alluvial fan is a strip of land located on the ecotone between the two very different environmental zones of the semi-desert plains of the pre-Balkhash region and the high mountain region of the Tien-Shan (Rosen *et al.* 2000). It is approximately 30 km wide, and is composed of distinct sedimentary units of coarse gravels, reworked loess and poorly sorted sandy silts and gravels (Rosen *et al.* 2000; Figure 5.11).

Figure 5.10. Google Earth image showing the location of Tuzusai on the Talgar alluvial fan

Figure 5.11. Talgar river

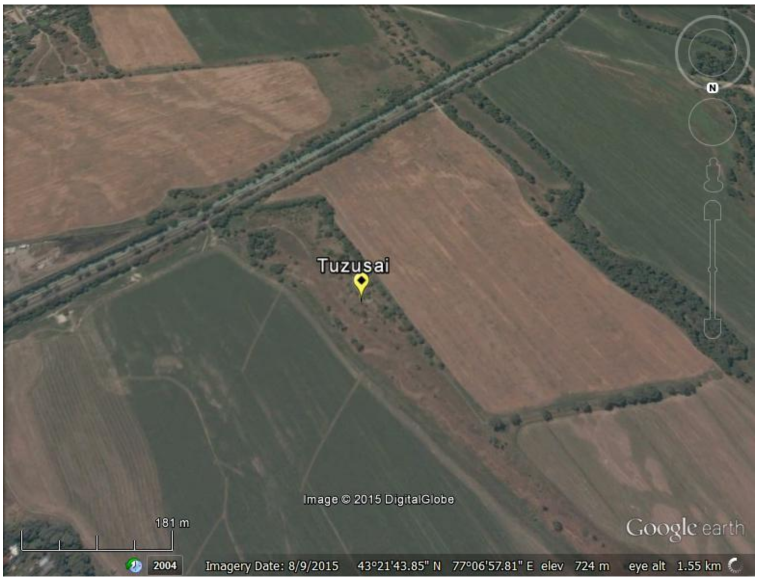


Figure 5.12. Google Earth image of the Tuzusai settlement located to the west of the Tuzusai ancient stream channel

5.2.1. ***Archaeology***

Tuzusai is a large village settlement, extending over an area of around 1 hectare, which is situated to the west of the ancient stream channel of Tuzusai (Chang *et al.* 2003, 301; Figure 5.12 and Figure 5.13). Excavations have revealed gravel-lined circular and rectangular storage pits, house architecture, floors, ovens, and hearths (Chang *et al.* 2003).

Figure 5.13. View of the Tuzusai settlement from the opposite bank of the Tuzusai channel

Four to six cultural horizons have been identified, spanning from approximately 415 BC to AD 1 and AD 1275 to 1950. Ceramics from the earlier occupation period are primarily utilitarian wares, with similarities to Saka-Wusun grave goods in Semirech'ye (Chang *et al.* 2003, 204). Faunal remains are primarily of sheep/goat, cattle and horse, but camel, ass, dog and very low numbers of deer have also been identified (Chang *et al.* 2003).

Excavations at Tuzusai were first conducted in 1992–1993 by Fedor P. Grigoriev (1995), and subsequent excavation has been carried out by the Kazakh-American Archaeological Expedition (KAAE) in the periods 1994–1996 and 2008–2010 (Chang *et al.* 2003; Chang & Tourtellotte 2008; Rosen *et al.* 2001). Excavations have revealed circular and rectangular storage pits, house architecture, floors, hearths, and a Mongol-period burial (Chang *et al.* 2003). The Iron Age deposits are over 1.5m thick, and Chang and Tourtellotte (2008) suggest that continual occupation is indicated, possibly from the 8th century BC, although the earliest radiometric date from this site is from the mid to late-fifth century BC.

Tuzusai has a very complex stratigraphy, with many pits and pit houses cutting one another throughout the occupation layers. In addition to this, the presence of mud brick architecture that has in many places 'melted' can make it very difficult to distinguish features within the site before removing them through excavation (Chang & Tourtellotte 2008; Figure 5.14). To compound these issues, due to the colour and texture of the sediments, both archaeological and natural, the distinction between contexts and stratigraphic relationships is often extremely difficult to determine visually during excavation, especially when the sediment has begun to dry out. To compensate for these difficulties, excavations from 2008 onwards have been conducted using arbitrary levels of 10 cm, in addition to single context recording when possible on site. This allows for accurate three dimensional recording of features and artefacts during excavation when stratigraphy and phasing is unclear, but with the ability to establish stratigraphic relationships during post-excavation analysis.

Figure 5.14. Tuzusai mud brick

Although post-excavation analysis by Chang and Tourtellotte of the most recent excavations is still in progress, six strata that appear to indicate different periods in the occupation history of the site have been provisionally identified:

Stratum 1 (Phase 6): 150-200 cm below datum. Features include a kitchen area, hard packed and mud brick floors, a house (House 9), a tandoor, and ‘melted’ mud brick.

Stratum 2 (Phase 5): 207-260 cm below datum. Lower occupation levels of House 9, a living surface, a tandoor, floors, post holes and collapsed mud brick.

Stratum 3 (Phase 4): 210-260 cm below datum. This is possibly the phase where the hiatus in occupation occurs (see below). Fireplaces, floors, two semi-subterranean rooms, a storage pit (feature 68, context 143), post holes.

Stratum 4 (Phase 3): 250-300 cm below datum. Kitchen floors, ash dump, tandoor, fireplaces, rooms and associated floor levels.

Stratum 5 (Phase 2): 308-317 cm below datum. Rooms, floors, and walls.

Stratum 6 (Phase 1): 317-350 cm below datum. Floors at sub-soil level.

(Chang 2012)

Previous radiometric dating and correlation of occupation phases of Tuzusai indicated four to six different cultural horizons at Tuzusai that span from approximately 415 BC to AD 1, and two later phases consisting of a burial dated to between AD 1275 and 1410, and a fire pit and yurt base outline dating between AD 1650 to 1950 (Chang *et al.* 2003). Research by Irina Panyushkina at the Laboratory of Tree Ring Research, University of Arizona has indicated that the earlier occupation of Tuzusai took place in two phases; the first being 415 to 350 BC and the second from 200 BC – AD 1 (Chang 2012). More recently, AMS dates obtained from archaeobotanical samples yielded a date range of 450 to 150 BC, with a single earlier date of 522–383 BC at 2σ (Spengler *et al.* 2013). The exact correlation of the archaeological phases with the radiometric dates has not yet been resolved for this complicated site, but the evidence at present points to two main phases of occupation in the Iron Age, with a hiatus of around 150 years in between (Chang 2012). There appear to be six main phases of activity at Tuzusai (*ibid.*).

The animal bones from Tuzusai indicate a dominance of sheep and goat (67.5%), in addition to cattle (19.5%) and horse (9.8%) (Lyublyanovics in Chang 2012). Interesting to note is the lack of butchering cut marks on the bones, with bones rather being smashed with stones and other heavy objects, but not butchered with metal tools (Lyublyanovics in Chang 2012). Other domesticated species identified in the animal bone assemblages are camel and dog. Wild species include deer, pig, fox, hare, and vulture (Chang *et al.* 2003).

Ceramics from Tuzusai include mould-formed and handmade red wares, with surface treatments such as buff and red slips and red paint (Chang *et al.* 2003). These were primarily utilitarian vessels, including bowls, jars, pitchers, and storage vessels made with local clays (Chang *et al.* 2003). Imported ceramics were also recovered, consisting of burnished and polished black ware, and red-slipped wares with a fine sand temper, most likely from the Syr Darya region and Central Asia proper (Grigoriev 1995; Change *et al.* 2003). Other artefacts include grinding stones, large burnt stones presumably used as fire shields or cooking stones, and a bronze bracelet (Chang 2012).

Macrobotanical analysis carried out by Naomi Miller in 1996 (reported in Spengler *et al.* 2013) identified probable bread wheat (*Triticum aestivum* s.l.), barley (*Hordeum vulgare*), millet (differentiation between *Setaria italica* and *Panicum miliaceum* was not possible), grape (*Vitis vinifera*), a nut shell – probably almond (*Prunus* sp.), and a possible Hawthorn seed (*Crataegus* sp.) (Spengler *et al.* 2013). More recent work by Robert Spengler (Washington University in St. Louis) has identified hulled barley (likely all six-rowed *Hordeum vulgare* var. *vulgare*), naked barley (*H. vulgare* var. *nudum*), free-threshing compact wheat and free-threshing lax-eared wheat (*Triticum aestivum/turgidum*), broomcorn millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), and grape seeds (*Vitis vinifera*) (Spengler *et al.* 2013). Very low masses of carbonised wood fragments were reported from all samples, and many species of carbonised wild herbaceous seeds were also identified (Spengler *et al.* 2013).

Phytolith analysis carried out by Arlene Rosen (2000) (UCL, now University of Texas, Austin) reported a dominance of foxtail millet (*Setaria italica*), with the additional identification of wheat, barley, and rice (Chang *et al.* 2003; Rosen 2001; Rosen *et al.* 2000). The identification of rice in the phytolith samples is unique to this site for the Semirech'ye region in this period (Chang *et al.* 2003).

5.2.2. *Palaeoclimate*

Palaeoclimatic data for Tuzusai comes from the geoarchaeological work carried out by Arlene Rosen (1997) around the Talgar alluvial fan. A type-section from the Tseganka river (section GS-VI) revealed a depositional sequence from the Late Holocene to the present day (Rosen 1997). Deposits at the base of the section (Unit 4) appear to date to the Middle Holocene and consist of gravels graded from large 18cm cobbles at the base of the section to smaller pebbles, 2–5 cm in size near the top. The upper layer of this deposit fines to sands and forms a conformable boundary with the overlaying unit, Unit 3 (Rosen 1997), indicating little or no time lag between the two units. Unit 3 contains Saka period sherds, and so it is on this basis that Rosen suggests a Late Holocene date for the underlying and contiguous gravel deposit. The size, shape and material of the gravels in Unit 4 (well-rounded spherical and discoidal granites) indicate that they were transported in a fast-flowing stream channel of moderate competence over a long distance, suggesting strong drainages from the mountains (Rosen 1997).

It is possible that the smaller-graded gravels and sands in the upper section of this deposit correspond to the Late Subboreal phase identified by Aubekerov et al (2003), which would explain the lack of a time-lag between the gravel deposits of the lower levels, which appear to be Pleistocene in nature, and the overlying deposit, Unit 3. In their study, Aubekerov *et al.* (2003) concluded that during the Late to Final Bronze Age

(3200–2800 BP) the steppe zone was warm and arid, while the mountain zone was humid, being cooler and wetter than present, with glacial shrinkage. This glacial shrinkage has important implications for the amount of runoff from the mountains that would have occurred during the summer months with glacial and snow melt. The effect of this shrinkage has been modelled by Hagg and Braun (2005) in their comparative studies of glaciers in Central Asia and the Alps. Using their own precipitation-runoff model (HBV–ETH), they model the effects of glacial shrinkage and disappearance on runoff during the summer months for three glaciers in Central Asia and two in the Alps. Of relevance to this study is the Tuyuksu glacial area in Kazakhstan, which is located to the south of the city of Almaty in the Zailisky Alatau range of the Tien Shan mountains, the same range in which the site of Turgen is found and at whose foothills lies the Talgar alluvial fan. By inputting the distribution of the glacial area by altitude and topographic aspect, Hagg and Braun's (2005, 266) model uses daily means of air temperature and precipitation to calculate mean daily discharge, which when compared to contemporary conditions shows a good correlation. In their model, a 50% decrease in the glaciated area of Tuyuksu would result in around a 15% increase in early summer runoff (associated with snow melt) in the average summer, with an overall summer runoff increase of over 25% during a cool, wet summer (Hagg and Braun 2005, fig. 18.7).

It is interesting to note here that Nigmatova identified from the palynological record at Turgen a period in the middle of three Late Bronze Age phases during which conditions became cooler and wetter (Nigmatova 2008). It could therefore be argued that the smaller-sized gravel deposits found in the upper part of the base gravel layer of the Mid to Late Holocene profile on the Talgar alluvial fan are a result of the decrease in glaciation witnessed in the Turgen mountain area during the Late Bronze Age. This would account for the deposition of gravels in the upper part of this profile that appear to have a conformable boundary with the overlying Iron Age deposits.

In the same model of a 50% decreased glacial area, Hagg and Braun (2005, fig. 18.7) also show that while overall runoff increases for the summer period, the model predicts that runoff in August would actually decrease proportionately, resulting in lower water availability at lower elevations during the height of summer. This supports the assertion of Aubekerov *et al.* (2003) that while the mountain zone experienced higher moisture availability in this period, aridity in the low altitude steppe region at the foothills of the Tien Shan in Semirech'ye increased. As Hagg and Braun (2005, 263) state, when surrounded by arid regions, such as in Semirech'ye, the mountains are the most important and often only relevant water supplier to the lowlands, and therefore glacial runoff character is preserved further downstream. This is different for humid lowlands, where the mountainous runoff regime is overlaid by a pluvial one (Hagg and Braun 2005).

It seems, therefore, that the evidence for increased moisture in the Turgen region and the subsequent increased erosional activity in the mountain zone which would have resulted from these conditions can be correlated with the deposition of the smaller-grade gravels on the Talgar alluvial fan during the Late Holocene. These upper deposits could well have been laid down during the Bronze Age when glaciers had retreated by up to 2km. In addition, cooler, wetter summer months would have resulted in a surge in early summer runoff, forming channels of increased carrying capacity capable of transporting gravels down to the lowlands region. Furthermore, the contrasting aridity of the lowlands would have meant that pluvial runoff regimes would not have overlain those of glacial origin, meaning that the dominant depositional signature would be that of downwash from the mountain zone. This interpretation of the depositional character of the sediments on the Talgar alluvial fan is of course a conjecture based on the limited amount of currently available evidence, which has been presented here.

This interpretation will be further discussed and newly gathered information analysed later in the thesis with an aim to explore further the possible relationship between the mountain and the lowlands sediment regimes. One of the major problems is the lack of indirectly datable material such as ceramics included in these lower deposits, in contrast with the later sediments, which would allow an in-field estimate of the date of the sediment. A firm interpretation would only be possible through the direct dating of the sediments themselves using OSL, which would allow the refinement of the climate model for the Late Holocene and a more sophisticated assessment of the relationship between upland and lowland hydrological regimes. Such a study would also benefit from further analysis of the gravels to determine their origin, and thus the distance that they were transported before their deposition could be calculated. This would further add to the interpretation of the carrying capacity of the channels during each period.

Unit 3, which lies above the gravel deposits of Unit 4 was found to contain ceramics of Saka date, along with other inclusions such as land snail shells and bones (Rosen 1997). Rosen (1997, 6) identifies this deposit as consisting of well-compacted silt containing a small percentage of sand, with occasional iron and manganese strains indicating post-depositional rises in the water table. She interprets the sediment as indicating either stream overbank deposits or fine-grained sheetwash. Given the lack of stream channel gravels that appeared to be contemporary with the silty deposits in other sections across the fan, it would seem that these deposits are most likely sheetwash, consisting of reworked loess from the foothills. Rosen (1997, 7) tentatively suggests that these deposits suggest a moister environment than that of the present, with rainfall that was more evenly distributed throughout the year and well-vegetated hillslopes. This interpretation supports conclusions drawn from other palaeoclimatic studies of a more pluvial climate in the Iron Age, with higher available moisture and higher rainfall on the plains. This evidence suggests that during the Iron Age the Talgar alluvial fan was well-watered with a stable pluvial regime, and received plenty of soil-rejuvenating hillwash deposits, which would have made agriculture a viable long-term activity on the fan. It would seem that during the Bronze Age, the area around Tuzusai experienced an arid environment, with deposits dominated by gravels washed down from the high mountain area, although these gravels were not as large as those from earlier in the Holocene and Pleistocene, indicating an overall reduction in the carrying capacity of streams of mountain origin over time. The Iron Age saw a marked change in the nature of the deposits on the Talgar alluvial fan, with sediments bearing Saka period artefacts providing a provisional date for this change. During the Iron Age, the depositional regime was dominated by fine alluvium or sheetwash sediments, indicating a low energy depositional environment. As indicated by other data, the climate around Tuzusai at this time was largely pluvial, with larger seasonal amplitudes than the present day.

5.3. **Tasbas**

Figure 5.15. Tasbas location in the context of the Bayan-Zhurek low mountain range, the Kaskarau valley, and the foothills of the Dzhungar Alatau mountains

Tasbas is a highland summer campsite with four phases of occupation, dating from the Early Bronze to the Early Iron Ages, including ritual and domestic structures, an area of outdoor activity, and a foundationless encampment (Doumani *et al.* 2015). The site of

Tasbas is located at 1488m asl, on the south-facing slope of the eastern end of the Bayan-Zhurek low mountain range which defines the northern edge of the Kaskarau wide glacial valley (Baipakov and Mar'yashev 2008; Figure 5.15). On the opposite side of the valley to the south lie the foothills of the Dzhungar Alatau mountains (Figure 5.16). Evidence pointing to the glacial origins of the Kaskarau valley is found in the enormous boulders that lie across the landscape, amongst which the Tasbas settlement is located (Figure 5.17).

Figure 5.16. View to the south from above the Tasbas settlement looking towards the Dzhungar-Alatau mountains across the Kaskarau valley

Figure 5.17. Tasbas settlement amongst massive glacial boulders

The eastern end of the valley, near to the Tasbas settlement, is bordered by two rivers: the Berkutchi-Bien and the Saga-Bien (Baipakov and Mar'yashev 2008), and the valley is criss-crossed by many smaller seasonal channels (Figure 5.18, Figure 5.19). The settlement is located over three natural terraces, and vegetation around the site is a mosaic of grass-dominated and forbs/grass fields and low-growing shrubby forests (Doumani *et al.* 2015).

Figure 5.18. Tasbas location showing location in relation to rivers and seasonal channels


Figure 5.19. Seasonal watercourse near Tasbas settlement

5.3.1. ***Archaeology***

Following the discovery of the site in 2001, a small scale-excavation revealed multiple occupation phases from the Bronze Age to the Kazakh period (Doumani *et al.* 2015; Mar'yashev 2002). More extensive excavations were carried out in 2011 by Paula Doumani Dupuy (Washington University in St. Louis), under the directorship of Michael Frachetti (Washington University in St. Louis), with the aim of building a detailed chronology for the Bronze Age occupation phases through AMS dating (Doumani *et al.* 2015). These excavations revealed four chronological phases dating from the Early Bronze Age to the Final Bronze – Early Iron Age transition, which are detailed below:

Phase 1: Early Bronze Age (2840–2496 cal B.C.). Human activity in this phase consisted of a cremation burial cist next to a small house structure. Five grains of a highly compact form of free-threshing wheat (*Triticum* sp.) were recovered from floated sediment from inside the cist. Outside the cist, an ephemeral lens of ash and burned bone from caprine-sized grazers and a large mammal were found in association with three chert microliths and three in-situ carbonized conifer branches (Doumani *et al.* 2015). A stone-lined circular hearth covered in clay was associated with this phase (Mar'yashev 2002). Direct dates were obtained from the wheat seeds and charcoal associated with the cist (Doumani *et al.* 2015).

Phase 2a: Late Bronze Age (1491–1260 cal. B.C.). This phase consisted of a small circular dwelling with stone wall foundations. A stone-lined circular fire pit covered in clay and an oven built of mud brick were found within the dwelling. The macrobotanical assemblage included domesticated free-threshing wheat (*Triticum* sp.), naked barley (*Hordeum vulgare),* foxtail millet (*Setaria italica*) broomcorn millet (*Panicum miliaceum)*, and green peas (*Pisum sativum*) (Doumani *et al.* 2015). Direct dates were obtained from the barley grains. Other finds from this phase were ground stone tools, bones from both domesticated and wild animals, and coarseware and decorated pottery (Doumani *et al.* 2015).

Phase 2b: Late–Final Bronze Age (1254–1053 cal. BC). Phase 2b represented the continued use of part of the stone foundations of the dwelling found in Phase 2a, but with much lower architectural investment (Doumani *et al.* 2015). This phase is characterised by palimpsest of carbon-rich deposits together with artefacts such as ground stone mortars, potsherds, and the butchered bones of sheep, antelope, and goat with all components present, indicating on-site butchering. This phase has been interpreted as representing outdoor activity (Doumani *et al.* 2015).

Phase 3: Final Bronze–Early Iron Age (899–831 cal. BC). This phase has been interpreted as representing periodic habitation of the site, with ephemeral activity surfaces, small hearths and large deposits of refuse, although these deposits were disturbed by later rodent and human activity in the 18th–20th centuries (Doumani *et al.* 2015). Finds from the midden deposits included ground stone and polished stone tools.

Compositional analysis of the ceramics and mud brick from Tasbas revealed a high correlation in element composition, implying that local clay sources were used for both. In addition, artefacts suggesting onsite pottery manufacture were found, such as round flat pedestal stones to shape the base, modified animal bones to smooth and decorate, and smooth river pebbles for burnishing Doumani *et al.* 2015.

The majority of the faunal remains (92%) were from domesticated species, and six domesticated taxa were identified: sheep, goat, cattle, horse, ass, and camel. Wild species represented were gazelle, deer, and fish. Every occupation phase from Tasbas yielded processed, chopped, and burnt bones of domestic and wild species (Doumani *et al.* 2015). The presence of neonate caprines indicates habitation of the site in the spring and summer, however caprines that were less than a year old were also identified, which might suggest that the site was also inhabited during the winter months (Doumani *et al.* 2015).

5.3.2. ***Palaeoclimate***

Detailed palaeoclimatic research at Tasbas remains unpublished, however data from the site was included in the study published by Aubekerov *et al.* (2003), which outlined the climatic trends in the steppe and mountain zones based on data from palynological studies at 5 archaeological sites in Semirech'ye and geoarchaeological studies at a further 7 sites. In this model, Tasbas (located at an elevation of 1600m asl) would have experienced a more humid, cooler and wetter climate than present in the Subboreal period from 3200–2800 BP (c. 1250–850 BC, Final Bronze Age) with vegetation borders close to those of the present day (Frachetti 2008, 80). In the Early Subatlantic from 2800–2000 BP (c. 850–50 BC, Early to Mid Iron Age), the climate around Tasbas became cold and wet, with a peak cold and humidity at around 2200 BP (c. 250 BC) (Aubekerov *et al.* 2003). Vegetation borders shifted in response to this change, and the advance of glaciers in alpine areas would most likely permit only seasonal occupation in the higher mountain areas. Although Tasbas is at too low an elevation to have been affected directly by glacial advance, prolonged ice accumulation due to the colder and wetter conditions would have meant that the environs of Tasbas would have perhaps been inhabitable for shorter periods of the year in the Iron Age than in the preceding Bronze Age, although with greater moisture availability in the spring and summer months.

5.4. **Turgen II**

Turgen II is one of a number of Bronze and Iron Age settlements with associated funerary complexes to be found in the high mountain zone of the Zailiyskiy Alatau mountains, part of the northern Tien Shan range (Chang 2003). The samples discussed in this paper come from excavations carried out at the site of Turgen II under the direction of A.A. Goryachev (Institute of Archaeology, Almaty, Kazakhstan). The site itself is located at an elevation of 2283m asl next to the upper Turgen river (Kyzylbulak stream), and sits on an outcrop of moraine, which is overlain by up to 2m of Holocene diluvium (Nigmatova 2008; Figure 5.20, Figure 5.21, Figure 5.22). Palynological research at Turgen carried out by Saida Nigmatova has show evidence for a warmer drier climate in the Bronze Age layers, while Early Iron Age contexts were found to indicate a pluvial climate, with a high moisture content and lower summer temperatures (Nigmatova 2008).

Figure 5.20. Turgen II site location showing relation to the Asi plateau (to the North-East) and water courses

Figure 5.21. Turgen II site location, showing relation to the upper Turgen river and moraine outcrop

Figure 5.22. Photograph of Turgen II site, showing upper Turgen channel (Kyzylbulak stream) and site location, indicated by tall vegetation

5.4.1. ***Archaeology***

Excavations have revealed five phases of activity: two Bronze Age occupation layers, Early and Late Iron Age encampments, and Wusun period kurgans (burial mounds)

(Goryachev 2010). The site has been primarily dated through diagnostic ceramics from the occupation layers.

The following stratigraphic levels were identified (those of interest to this study are described in more detail):

Level 5: Late Andronovo settlement (Bronze Age). Series of dwellings with yards consisting of semi-dugout sub-rectangular huts with a pole and frame construction and central hearths (Goryachev 2010). Artefacts included stone pestles and mortars, spindle whorls, and ceramics. Faunal remains were dominated by cattle (96%), with horse (1%) and wild herbivores such as deer (3%) (Goryachev 2010). In a small pit or post-hole at the bottom of the sampled profile – attributed to this level – a worked stone object was found, carved with geometric shapes and a symbol that is very similar to the 'sun-head' figures from petroglyphs dated to the Bronze Age at the Tamgaly petroglyph site (Figure 5.23).

Figure 5.23. Worked stone object discovered at the base of a pit/post hole at Turgen-II, with carved triangular shapes, scratched lines, and 'sun head' symbol (author's own image of freshly-excavated find)

Level 4: Final Bronze Age. A series of religious-ritual buildings were identified at Turgen-II, while contemporary dwellings were discovered 400m upstream along the Kyzylbulak brook, a tributary of the Turgen river. Buildings at Turgen-II were rectangular in shape, with a similar semi-dugout pole and frame construction of the earlier period (Goryachev 2010). In the centre of one large room was an elevated rectangular platform with a stone-lined hearth in the centre with 40-50cm of ash deposit. Two large furnaces (max. 2m diameter) with associated air intake channels were found in an adjacent 'corridor' room, which had been dug into the ground and covered with clay (see also those at Tasbas) (Goryachev 2010). The furnaces were found to contain charcoal and fragments of human and animal bones. Three smaller furnaces were found to the northeast of these structures. Other finds from this period include ceramics with around 15% being ornamental ware, stone and bone tools, bronze jewellery, bone arrowheads, plaques of bone, and grinding stones with bowl-shaped cavities similar to the 'cup marks' found in petroglyph complexes (Goryachev 2010).

Level 3: Late Bronze/Early Iron Age. In this level, structures were discovered in clear alignment with those of the earlier period, which are circular and sub-rectangular in shape, with various animals interred within the perimeter. The structures had tightly packed clay floors, and were constructed on top of earlier structures, leaving a compacted layer of clay and charcoal (Goryachev 2010). Artefacts include bone, clay, and stone tools, some of which indicate that leather working was carried out on site, and a ceramic 'altar' (Goryachev 2010).

Level 2: Early Iron Age. This level consisted of oval or circular dwellings in a shallow cleared area (20–40cm), with one or two supporting central posts with posts around the perimeter. Ceramics suggest a long stretch of periodic occupation up to the 3rd or 2nd century BC (Goryachev 2010). Artefacts include ceramics, iron and bone tools, and a spindle whorl. An associated cemetery was located further upstream along the right bank of the Kyzylbulak stream (Goryachev 2010). Finds from the graves and associated 'feasting' deposits include the bones of sheep and goats, ceramic vessels (a cup for infants), stirrups, metal plaques, arrowheads, and pendants, earrings and beads in the graves of children (Goryachev 2010). Excavations in 2011 also recovered bone needles, scythes, and picks, grinding stones, and pestles (Goryachev pers. comm.). The settlement pattern has been interpreted as that of temporary dwellings due to the lack of evidence for permanent structures (Goryachev pers. comm.). In all domestic contexts on the site animal bones have been found, predominantly belonging to sheep and goats, with some bovines and very few belonging to horse. The presence of antler and hare bone fragments was also noted (Nurumov 1999) (Figure 5.24).

Figure 5.24. Turgen-II - Iron Age floor surface

Level 1: Wusun period burial mounds. These burial mounds overlie the site, and are constructed using glacial boulders (seen at the top of the profile shown in

Figure 5.26) (Goryachev 2010).

Phytolith samples analysed from Turgen come from two different locations: the floor of a temporary dwelling, dated through ceramics to the Early Iron Age, and a section in the excavation wall that was cleaned back to provide a full stratigraphic sequence for the site. The section in the excavation wall included a large ash and charcoal dump/fire pit and an associated spread of burnt earth mixed with ash that lies just below the upper floor surface of the dwelling (

Figure 5.25,

Figure 5.26).

Figure 5.25. Turgen-II site showing sampled profile in excavation wall to the left and the Iron Age occupation floor under excavation to the right

Figure 5.26. Turgen II profile in wall of excavations sampled for phytoliths. The large stones of the burial mound are visible in the top of the profile, and at the bottom of the profile is a small pit/post hole dug into the natural sediment which is pale yellow in colour. The large charcoal and ash deposit from which the radiocarbon date was obtained is visible in the centre of the profile.

Relative phasing for the levels identified at Turgen was assigned through consultation with the lead archaeologist (Dr. A. A. Goryachev) while in the field, and was based on visible contexts in the profile and the floor of the excavations from which the phytolith samples were taken, together with material culture associated with the contexts. The phases identified are detailed below with corresponding occupation levels included in brackets where possible. It should be noted here that exact correlation with the occupation phases identified by Goryachev (2010) was not possible due to a lack of relative and absolute dating material for all phases:

Phase 1 (Level 5): Pit and associated fill dug into sterile matrix.

Phase 2 (Level 5?): Layers of fill above the pit. Layers of clay/natural matrix appear to be interspersed with cultural fill.

Phase 3a (Level 4?): Spread of ash, charcoal, and burnt soil.

Phase 3b (Level 3): Fill above ash spread. Some charcoal flecks.

Phase 4 (Level 2): White clay and charcoal deposits. This phase appears to be contemporary with the floor of the Early Iron Age dwelling.

Phase 5 (Level 1): Fill under the burial mound stones.

Phase 6 (Level 1/Topsoil): Topsoil/stones of burial mound.

Absolute dating for all of the site phases was not possible, but thanks to the generosity of Claudia Chang, one AMS radiocarbon date was obtained from the profile from which the phytolith samples were taken. This date was obtained from charcoal extracted from the deposit of charcoal and ash visible as the black and orange layer in the middle of the profile pictured, and is labelled in Figure 5.27, assigned as Phase 3a. The radiocarbon date was 3,138 +- 52 BP. Calibration of radiocarbon dates for Central Asia through tree-ring analysis is still in its infancy, but work by Irina Panyushkina (University of Arizona) using wood preserved from archaeological contexts in Semirech'ye has indicated that the calibrated date for this sample is 1450-1400 cal BC (1 sigma, high peak; Irina Panyushkina pers. comm.). Using the OxCal radiocarbon date calibration programme with the IntCal 13 calibration curve yields a calibrated date of 1507 to 1268 cal BC (2 sigma, 95.4% probability; OxCal online, version 4.2; Bronk Ramsey 2009; Reimer *et al.* 2013), which supports Panyushkina's calibration. This context was overlain by a floor dated by Dr. Goryachev from ceramic typologies to the Early Iron Age (Goryachev pers. comm.).

Figure 5.27. Turgen profile showing the location of the sample (marked with the star) from which a radiocarbon date was obtained (1450-1400 cal BC (1 sigma, high peak).

In addition to this date, a radiocarbon date was obtained from charcoal recovered from kurgan 3, one of the burial mounds located to the east of the settlement structures, and denoted as Early Iron Age through ceramic typologies (Goryachev 2007). This was dated to 2300 +- 50 BP, 408 to 200 cal BC (Goryachev 2007).

5.4.2. *Palaeoclimate*

Palynological research at Turgen carried out by Saida Nigmatova has revealed eight different vegetation phases connected with climatological changes from the Bronze Age to the present day. The three earliest phases, corresponding to the Bronze Age, show evidence for a warmer drier climate in the earlier Bronze Age, with a predominance of pollen from Chenopodiaceae and sagebrush, a period of slightly cooler and wetter conditions in the middle phase indicated by an increase in tree pollen, and a return to warm dry conditions in the later phase, seen in a return to a mixed-grass high mountain forest pollen profile (Nigmatova 2008, 11). The overall vegetation during this period is characteristic of that of the mixed grasses in the forest high mountain zone. The three phases corresponding to the Early Iron Age show a general trend towards cooler and wetter conditions in the two earlier phases, with warm, dry conditions developing in the later phase. The earliest Iron Age phase in this sequence contained pollen indicating a sagebrush-Chenopodiaceae-mixed-grass signature with a significant proportion of *Ephedra* and a reduction in the quantity of tree pollen. During this time the climate probably became drier and colder (Nigmatova 2008). The middle of the three Iron Age phases shows a period in which temperatures became cooler and wetter, with the pollen record showing mixed grasses in a forest zone, with an increase in tree pollen (Nigmatova 2008).

The Final phase of the Iron Age represented at Turgen II shows a shift towards hotter and drier conditions, with a meagre component of a sagebrush-Chenopodiaceae association (Nigmatova 2008). The overall picture from Nigamatova's data is of this high mountain zone experiencing a warmer and drier Bronze Age with a cooler and wetter interval, followed by an Iron Age with a pluvial climate, higher relative moisture and lower summer temperatures (Nigmatova 2008, 11). However her data also illustrate the fluctuations in climate that the area experienced within these respective periods, showing that while wider-scale trends in climate identified from proxy records elsewhere in Eurasia are broadly reflected in the pollen record from Turgen II, the site has its own specific climate history. This shows how the elevation, aspect, topography, hydrological systems and exposure of a site can influence the ways in which climatic changes have an effect, meaning that each location may have its own unique response to Eurasia-wide changes in climate.

Chapter 6: Methodology

This chapter will detail the methodological approach employed in the collection and analysis of the phytolith and faecal spherulite samples in this study. The first section will outline the sampling strategy for the collection of phytolith samples in the field, followed by the method for the collection of sediment and extraction of phytoliths from the sediment. This is followed by a description of the phytolith counting process, and the identification criteria used in recording both single and multi-celled phytoliths. The final section details the preparation of slides for the collection of faecal spherulite data, and the method for their identification and recording.

In total 140 phytolith samples were processed in this analysis, and 20 spherulite samples. 50 sediment samples were collected from Tasbas, of which 36 were chosen for processing for phytoliths, and 4 were sub-sampled for faecal spherulites. In addition 3 phytolith samples were collected from test excavations at the site of Dali, located next to Tasbas. 54 samples were collected from Turgen, of which 43 were chosen for processing for phytoliths and 4 were sub-sampled for faecal spherulites. 198 samples were collected from Tuzusai, of which 58 were chosen for processing for phytoliths and 10 were sub-sampled for faecal spherulites. The database of samples, which includes context descriptions, can be found on the enclosed CD-ROM, in the file '04_Samples_DB'.

6.1. Sampling strategy

6.1.1. *Selection of samples*

6.1.1.1.Archaeological samples

The sampling strategy for the purposes of sediment collection for phytolith analysis was primarily determined by the desire to gain a wide-ranging overview of the phytolith assemblage at each site. For the archaeological samples, the sampling was context-led, with a single-context sampling strategy, the aim being to collect samples from each type of context at each site. The main contexts that were present and sampled at the three sites were hearths, the fills of features such as pits and houses, floors, and architectural features such as mud brick.

Of course, while excavating it is not always possible to determine the activity which led to a particular context being formed or the period of time over which the context was formed, and this is particularly relevant for at least two of the sites in this study: Tuzusai due to its complicated mudbrick stratigraphy; and Turgen due to the ephemeral nature of the occupation. For this reason, although as much contextual information was recorded as possible at the time of sample collection, when analyzing the data samples were assigned to one of four categories: hearths and burning contexts, floors, mud brick, and fill. While hearths, mud brick and living surfaces can be linked to specific activities, the broad category of 'fill' was chosen to reflect the uncertainty over the activity leading to other deposits, for example whether a pit house was deliberately infilled to make way for a new building, which may have been accompanied by the deliberate deposition of extra rubbish in a short time period, or whether it fell into disrepair and the accumulation rate of the deposit was a slow process with little deliberate human deposition. Similarly, in the case of Turgen, the base of a small pit/post hole was found to contain the broken remains of a carved stone object, the interpretation of which action is unclear. Was it a ritual deposit prior to the placing of a post, or was it a discarded item tossed into the bottom of a small rubbish pit? Using the broader term 'fill' therefore acknowledges the uncertainty over the depositional activity which led to the formation of the context, while describing its nature as a deposit within or between features on site.

In most cases one or two samples were taken per context in order to maximise the number of contexts that could be analysed, giving as broad a picture of the phytolith assemblage at each site as possible. There were exceptions to this strategy, such as in the case of some floor contexts, where samples were taken along two perpendicular transects at 50 cm intervals in order to identify any spatial differences in the distribution of phytoliths within the single large context (Figure 6.1).

Figure 6.1. Sampling a pit house floor at Tuzusai (1.4m in diameter)

The samples were collected over a period of two field seasons, the first season being at the site of Tuzusai in 2010, and the second season being at all three sites in 2011, during which time the majority of the samples were collected. Since the samples were collected from sites that were still under active excavation during a single season, the contexts available for sampling were dictated by the stage of the excavation at the time when sampling took place. Efforts were made to be present towards the middle and end of the season in order to gain access to the earliest contexts that were more likely to be of the time period of interest to this research. In addition, during time at each of the sites those archaeologists excavating were instructed on how to take a sediment sample for phytolith analysis so that any further contexts of interest could be sampled at a later date.

With samples being taken from three different sites with different archaeologists excavating, one of the main challenges was to take a range of samples that could be comparable during analysis with regards to their date and context. For this reason, many more contexts were sampled than were eventually processed in the lab. The decision as to which samples would be processed was made following discussion with the lead archaeologists from each site once the excavations were over and the site stratigraphy had been fully determined.

6.1.1.2.Non-archaeological samples

In addition to the samples taken from the archaeological sites, samples were also taken from non-archaeological sediments in order to provide information on the 'background noise' that might be present at a site, and also to compare the anthropogenic deposits with those of natural origin. The aim here was to compare both the density of phytoliths and the composition of the assemblage in each type of deposit. Topsoil and subsoil samples were taken from the walls of the excavations in order to identify the modern phytolith assemblage left by the current vegetation at the sites themselves. In addition to these samples, topsoil and subsoil samples were also taken from an offsite location that was determined as far as was possible to have had no direct anthropogenic disturbance, and which could therefore be said to be representative of the modern natural vegetation profile of the area. Were this a larger-scale project, it would have been ideal to explore the possibility of identifying ancient land surfaces, such as the buried soil identified by Arlene Rosen (1999) during her research in the region, and to firmly date these through absolute dating techniques in order to give a picture of the natural phytolith assemblage contemporary to the archaeological samples. However such an endeavour was outside the scope and excavation permits of this research project.

6.1.1.3.Tuzusai Mud brick

In addition to the sampling strategy outlined above, the mud brick at Tuzusai was subject to an additional sampling strategy in order to explore whether the different visual attributes of the mud bricks had any bearing on their physical properties. In this case, two different colours of mud brick were observed on the site: red/brown and yellow/green. A small sub-sample was taken of four different mud bricks from different areas of the site, with two samples of each colour taken. These data were used to feed into the wider interpretations of the site, but they also formed a small data set on their own, with potential for further sampling and a wider, more detailed study in the future with regards to the nature of the mud brick at Tuzusai and its different uses on the site.

6.1.2. ***Collection of samples***

In the majority of cases, the physical collection of samples was carried out in person directly from the archaeological context on the site. Exceptions included samples taken specifically for the purposes of phytolith analysis by archaeologists who had been shown the collection methodology, and in a few cases at the site of Tasbas, the sub-sampling of bulk samples that had been taken for macrobotanical analysis prior to their flotation. These cases adhered to the single-context sampling strategy.

For the physical collection of samples, the location of the samples was first determined on the site. Each sample was then assigned a unique sample number, and this number along with the site name, year and context number were recorded both in the field notebook and on a small slip of paper which was then placed over the collection site (affixed with a small, clean nail where necessary) and photographed with the whole context. For multiple proximate contexts and large contexts which were to be sampled in several places, all proposed samples were recorded together in order to record their spatial relationship. Where available, the level of the sample was recorded, and if not available a ranging rod was used to record the depth of the sample from the surface (Figure 6.2).

Figure 6.2. Recording samples at Turgen

In the case of samples taken from the excavation walls, sampling began at the bottom of the profile and worked up in order to avoid contaminating lower samples with sediment from samples dislodged from above.

In all cases, the surface of the context was cleaned using a clean stainless steel spatula, and the surface sediment removed in order to ensure that no contaminating sediment was present in the sample. A small clean stainless steel scoop was then used to extract around 20-30g of sediment from the context into a clean zip-lock sample bag. In between the collection of each sample the stainless steel instruments were cleaned with fresh water and wiped dry with a fresh piece of tissue, ensuring no sediment remained. The amount of sediment collected was rather large for a phytolith sample, since only around 0.8g of sediment is processed for phytolith analysis, however there were three reasons for this quantity. First, this quantity of sediment was collected in order to allow the sample to be divided in two at a later date, with half the sample being left in storage in Kazakhstan as a security measure should any problems be encountered when transporting the sediment out of the country. Secondly, it was deemed useful to have the possibility of taking further sub-samples for different analyses. This strategy proved useful, since it was later decided to explore the potential of identifying faecal spherulites in the samples, which would have had a high likelihood of having been destroyed during the phytolith extraction process (Macphail 2004) and would therefore be unlikely to appear in the phytolith slides. This sample size also allowed the extraction of charcoal pieces for AMS radiocarbon dating when the opportunity to secure an exact date for the Turgen site was very kindly provided by Prof. Claudia Chang. The final reason for this sample size was to allow the possibility of revisiting the samples in the future.

Samples collected in the field were first air dried off-site in Kazakhstan to ensure that no moisture was present prior to their transportation and storage, reducing the likelihood of microbial activity in the samples. This was particularly necessary for the higher mountain sites of Tasbas and Turgen, where the weather meant that collecting wet samples was often unavoidable. Once dry, the samples were divided in two using the cone and quarter method. They were then placed into plastic sample bags and transported to the Institute of Archaeology, UCL, for processing in the lab for the extraction of phytoliths.

In the case of the samples taken in 2010, the samples were partly processed at the lab in the Institute of Geology, Almaty, Kazakhstan (sieving, HCl, removal of clays and furnace treatment). This was due to the nature of the permits required to transport the sediment out of the country. In 2011 different permits were obtained which allowed unprocessed sediment to be exported. The extraction process followed the standard procedure for phytolith extraction used at UCL (Rosen 1999), which is detailed below.

6.2. Phytolith extraction methodology

The sediment was removed from the sample bag and was lightly ground using a pestle and mortar to break up conglomerates where necessary. It was then divided using the cone and quarter method to ensure a representative sub-sample would be taken. A sub-sample of the sediment was passed through a 0.25mm sieve, and c.800mg of this sieved sediment was taken for processing, the exact amount for each sample being weighed and recorded. The samples were each treated with 15ml of 10% HCl to remove pedogenic carbonates, and left until no further reaction was visible. They were then washed 3 times in filtered water, using a centrifuge to settle the sediment before pouring off the excess water. The samples were then left to sit overnight in a little distilled water to help disperse clays.

Once settled overnight, the excess water was pipetted from the samples, and 15-20ml of the dispersant Sodium Hexametaphosphate ($(NaPO_3)_6$, calgon) was added to each sample. The sample was then shaken vigorously and left to sit in the $(NaPO_3)_6$ for one hour. After an hour, the samples were shaken again and washed out into tall beakers. Filtered water was used to fill the beakers to a depth of 8cm. Each sample was stirred well and left to stand for 1hour and 10 minutes, after which the suspense containing the clays was poured off. The beakers containing the residue were re-filled with filtered water to 8cm depth, stirred, and left for 1 hour before the suspense of clays was again poured off. This step was repeated until the suspense became clear, whereupon the samples were transferred to ceramic crucibles and left in a drying oven at 40°C until completely dry.

When the samples were dry, a metal spatula was used to disaggregate the samples, and they were placed into a muffle furnace at 500°C for 2½ hours to remove any remaining organic matter. Once cool, the samples were scraped out of the crucibles and onto glossy paper using a metal spatula, taking care to ensure the whole sample had been transferred. The samples were then added to 15ml centrifuge tubes containing 3ml Sodium Polytungstate solution (SPT), calibrated to 2.35 specific gravity, that of the phytoliths. The samples were shaken well and centrifuged at 800rpm for 10 minutes. The suspense with the phytoliths was then decanted into clean 15ml tubes, and distilled water was added. The samples were shaken well and centrifuged at 2000rpm for 5 minutes, resulting in the phytoliths settling at the bottom of the tubes. The diluted SPT was poured off through a filter into a wash beaker for recovery and recalibration. The samples were then washed in distilled water a further 2 times. The phytoliths were then transferred to 5ml beakers, which had previously been weighed, and left to dry. Once dry, the weight of the beakers containing the phytoliths was recorded, and 2-3mg from each sample was mounted to glass microscope slides, with the exact weight mounted being recorded. The samples were mounted using a few drops of entellan in xylene as a mounting medium. The sample was added to the entellan and stirred to ensure an even distribution, then covered with a 24x24mm glass cover slip. The slides were left to air dry in a fume cupboard for 2 weeks to ensure that the xylene had completely evaporated before they were analysed using a microscope in a procedure that is described below.

6.3. Phytolith counting methodology

6.3.1. *Counting strategy*

The following method for counting was adopted following tuition from Arlene Rosen at the Institute of Archaeology, UCL. The primary aim of counting the different phytolith morphotypes present in the samples was to generate a statistically valid dataset that accurately represents the phytolith assemblages present in the sediments. In order to achieve this, both the overall number of phytoliths counted and the way in which they are recorded was taken into consideration. Research by Strömberg has indicated that recording 300 single-celled and 150 multi-celled phytoliths is sufficient to provide a statistically robust representation of the phytolith assemblage (Strömberg 2009), and these thresholds were adopted for this research. Single-celled and multi-celled phytoliths were recorded separately, since they both have the potential to provide different information (Piperno 2006, 26).

Phytoliths were identified as specific morphotypes, following the International Code for Phytolith Nomenclature developed by Madella *et al.* (2005) as far as possible, with some unusual morphotypes being given unique descriptive names where appropriate. This approach, which incorporates both terms based on the anatomical origin of the plant cell and more descriptive terms describing the physical attributes of the phytolith, is advocated for by Piperno (Piperno 1988; 2006, 26). The identification criteria for the major morphotypes are provided later in this chapter.

Each slide was first scanned at 100x and 250x magnification to check for any unusual morphotypes or diagnostic multi-celled silica skeletons which may fall outside the counted fields. If identified, their locations were recorded using either the microscope stage or an England Finder for future reference. The phytoliths were then counted at 400x magnification. The slide was counted as a series of consecutive microscope fields along a transect. Counting was begun at the midpoint of the cover slip near an outer edge, working towards the centre of the slide. Counting was not begun from the edge of the cover slip in order to avoid the distortion caused by the meniscus of the Entellan meeting the edge of the cover slip. The stage coordinates of the first field counted were recorded.

All the phytoliths in one field were recorded before moving on to the next field. Once a count of 300 single-celled phytoliths had been reached, the remainder of the field was counted and the total number of fields was recorded. If 150 multi-celled phytoliths had not been recorded at this point (and in most cases the number of multi-celled phytoliths was far lower than that of single-celled) then counting continued for multi-celled phytoliths only, again recording the number of fields that were counted.

In some cases, the mounting medium had either seeped beyond the area of the cover slip, or was not sufficient to cover the area, meaning that the total number of fields on the slide at 400x magnification was not the standard of 48^2. If this was seen to be the case then the number of additional or missing fields was counted and taken into account in the subsequent calculations of density. This was important since the phytolith count per field was then used to calculate an average for the whole slide.

The exact count of both single-celled and multi-celled phytoliths was then used to calculate the number of phytoliths per gram of sediment, using the following formula, where *n*=number of phytoliths:

(total *n* counted ÷ fields counted) × total fields on slide = *n*/slide

((*n*/slide ÷ mg mounted) × (total mg phytoliths ÷ mg sediment processed)) × 1000 = *n*/g sediment

The absolute counts and calculations for all samples are given as spreadsheets in the folder "01_Absolute_Counts" on the enclosed CD-ROM.

6.3.2. ***Recording method***

Initially, the phytolith counts were recorded using a tally on a recording sheet that listed the single-celled and multi-celled phytolith morphotypes. This method required observing the microscope field and then finding the morphotypes identified on the recording sheet and making a tally mark next to the appropriate name. It very quickly became apparent that there were several problems with this method in terms of both accuracy and comfort. Accuracy problems were that it was possible to lose track of which part of the field was being recorded and which phytoliths had already been counted when switching between microscope and recording sheet, or if the count was interrupted for any reason. It could also be difficult to find the correct row on the recording sheet quickly and accurately, a problem exacerbated by poor eyesight. Poor eyesight also contributed to the discomfort of using this recording method for any length of time, since it was necessary to either constantly remove and put on glasses or physically move close to the recording sheet every time.

It was decided that a new recording method was necessary in order to allow the slides to be counted in a timely manner, and hopefully with improved accuracy. Following advice from Arlene Rosen, who suggested using a voice recording method, it was decided to use voice recognition software in order to count the phytoliths. Direct voice-to-text software was chosen rather than a simple voice recorder in order to solve the problem of the slow speed of counting the slides, since a voice recorder would require the user to record the morphotypes on the slide and then re-listen to the whole recording while noting down the phytolith counts. The other problem with a direct voice recording is that it is more difficult to identify and erase mistakes while identifying the morphotypes without causing confusion.

After research into accuracy, reliability, affordability, and ease of use, Dragon Dictate v.7 was chosen as the most suitable voice recognition software. The programme allows an individual to 'train' the software in order to learn their voice and accent, and new words can be added to its dictionary. Such a capability was ideal for the purpose of recording phytolith morphotypes, increasing the accuracy of the terms recorded, and minimising the number of corrections that had to be made. The programme also has the capability of using voice commands to perform functions both within documents and on the desktop in general. Results were compared with one slide that had been counted using both the paper and computerised method, and found to have negligible differences, which in part could have been attributed to different identification decisions upon reappraisal of the slide.

The phytolith morphotypes were first recorded as a comma delimited list using the Notebook programme for Microsoft Windows XP, with one window for single celled morphotypes and one for multi-celled. The Notebook programme was used in order to minimise the possibility of any compatibility or performance conflicts between the voice recognition software and the recording environment, since Notebook is such a simple programme. Each field of the microscope was divided visually into four quadrants, then using the voice command function of the programme, the name of the phytolith morphotype was first said, followed by the ‘comma’ command. The single-celled phytoliths were counted by working through each quadrant, and then the multi-celled phytoliths were recorded. Counting continued until 300 single-celled and 150 multi-celled phytoliths had been recorded, with the number of fields required to reach these counts recorded.

Recording a comma delimited list served two functions. First, adding a comma forced a pause between two morphotypes, minimising the chance that the programme might confuse two terms as one unrelated word. The second reason was that it was then very straightforward to import the list into Microsoft Excel, placing each morphotype into an individual cell.

Once in Excel, a pivot table was then used to provide the counts of each instance of a particular morphotype. This also served to highlight any inconsistencies in the recording of the data, such as terms which the programme had ‘misheard’, or assigned a plural ending in error. Once these instances had been corrected, the summed counts were then pasted into a new sheet in the spreadsheet in order to calculate the number of phytoliths per gram of sediment (an almost instant process once the relevant mass of sediment and mass of phytoliths had been entered). With these counts calculated, the phytolith count for each single-celled and multi-celled phytolith was then entered into a standardised sheet with all morphotypes listed in order to make comparing and graphing the data straightforward. This process was carried out through using a VBA macro that copied and pasted the values to their appropriate location on the standardised sheet (the macro code is provided in the file “02_VBA” on the enclosed CD-ROM).

Although when written out in full this process appears laborious and time-consuming, in practice most of the steps described above were carried out almost instantly, and without the inaccuracy of human hand-eye coordination error. Recording directly to the computer also meant that the time-consuming step of tallying up and then inputting the phytolith counts from the paper recording sheet into a spreadsheet was eliminated.

In order to ensure that the programme was recording the phytoliths accurately, regular checks were made in the Notebook document while counting was in process. On occasions where a software error was encountered, it was fairly straightforward to find the point at which recording had ceased, since the phytoliths were counted in quadrants and therefore a particular pattern of phytolith morphotypes was easy to identify within the field. At the end of each field being counted a review was made of the list to ensure that there were no obvious errors or omissions.

An unexpected advantage to this method of recording is that unlike the tally method, recording each individual phytolith as part of a list allows a spatial element to be retained. This meant that, using the same microscope, it was possible to revisit a particular phytolith with relative ease should a question as to its identification arise later on and its precise location had not been recorded with an England Finder or stage coordinates at time of counting.

6.3.3. ***Numerical analysis of multi-celled phytoliths***

Numerical analysis of multi-celled phytolith types across contexts and sites using the absolute counts from samples is problematic since multi-celled phytoliths can vary widely in the number of cells in each silica skeleton. Owing to different pre- and post-depositional chemical and mechanical actions on the plant material within different contexts, a count of ten multi-cells found on one slide may represent the same original quantity of plant matter as a single large multi-cell of many hundreds of cells found on another slide.

One solution to this problem would be to count every cell in a silica skeleton individually, however there are two practical obstacles to this. Firstly, since the phytoliths are mounted in a fixed medium and counted using a light microscope the threedimensionality of the multi-cell is very difficult to determine, meaning that in cases where the skeleton has more than one layer of cells the lower layers would be obscured by the top layer, making this type of counting extremely difficult to carry out accurately. The second reason is that counting the individual cells in a multi-celled phytolith is a far more time consuming process than counting isolated single celled phytoliths. Counting and keeping track of each cell of a large silica skeleton of partially overlapping elongate psilate phytoliths, for example, slows down the amount of time it takes to record the phytoliths on a slide considerably. In my opinion, the cost of loss in accuracy due to the potential pitfalls of attempting to achieve an accurate count from a three-dimensional skeleton on what is effectively a two-dimensional plane, combined with the additional time required to carry out such a task, does not outweigh the benefit that could be gained from such a method of recording. These factors mean that such a process would unnecessarily add much time to the counting process for little benefit for the purposes of this study.

6.3.4. ***Phytolith identification criteria***

As detailed above, single-celled and multi-celled phytoliths were counted and recorded separately, and the criteria used to reach their identification varied slightly due to the different types of information which can be obtained from them and the differing degrees of confidence with which single- and multi-celled phytoliths can be identified in archaeological samples. Identifications of both single and multi-celled phytoliths were made using reference collections held at UCL, personal tuition from Arlene Rosen and Alison Weisskopf, reference photographs in books and papers (e.g. Piperno 2006; Lu 2009; Ball *et al.*1996 to name but a few), and a small number of reference plants gathered while in the field and processed for mounting to slides. In the absence of a locally specific phytolith reference collection, emphasis was placed on the accurate and extensive recording of single-celled morphotypes (‘splitting’ rather than ‘lumping’ being preferred for classification purposes), the identification of the major domesticated cereals along with Cyperaceae and *Phragmites australis*, and the recording of unidentified multi-celled phytoliths through descriptive means where possible to allow future identification. For example, a multi-celled silica skeleton from a grass husk that had a distinctive morphology but could not be firmly attributed to any known genus or species from references was given a descriptive name and recorded separately during counting, as opposed to simply recording it as an 'unidentified' husk (although this classification was also used in many cases where either preservation or morphology did not allow identification). A future project to create a comprehensive local phytolith reference collection is needed. Such a task was beyond the scope of this project, needing as it would extensive research into regional vegetation profiles in order to make appropriate decisions about which species to sample, collaboration with a locally-trained botanist to correctly identify species in the field, and the collection and processing of samples to produce reference slides.

6.3.4.1.Single-celled phytoliths

All the phytoliths recorded during counting were given identifying names, which were recorded during the counting process. The names reflect the degree of confidence in an identification. The naming of phytolith morphotypes follows the procedures outlined in the International Code for Phytolith Nomenclature (ICPN), provided by the ICPN Working group (Madella *et al.* 2005). The ICPN provides a methodology for the naming of phytolith morphotypes, and also gives a preliminary list of the most common phytolith types and their names following the rules set out by the ICPN. In this study, the most common phytolith types were named following those found in the ICPN document (Madella *et al.* 2005, 255). Phytolith types not found in this list were named following the stages set out by the ICPN where appropriate, which are described below. In some cases, however, a more colloquial, descriptive name was used to identify the phytolith type to allow for speed of identification while counting. In cases where a phytolith type could not be identified satisfactorily, but was recognised as being a phytolith through its behaviour under crossed polarised light, it was recorded as 'indeterminate'.

The procedure for the naming of phytolith types as set out in the ICPN follows a series of stages in order to reach a usefully descriptive identifier. The first stage in this process is the description of the shape of the phytolith, being a 2D or 3D descriptor of the phytolith in its main orientation (Madella *et al.* 2005). Secondly, the texture and/or ornamentation of the phytolith should be recorded, if this is characteristic or diagnostic and not the result of weathering or other post-depositional processes (Madella *et al.* 2005). Finally, the anatomical origin of the phytolith should be recorded, but only if this is observed *in situ* or has been clearly demonstrated beyond doubt in a previous publication that is referenced in the identification criteria.

In the case of this research, the ICPN protocol was followed as far as was possible, however as mentioned above, emphasis was placed on 'splitting' phytolith morphotypes during counting rather than 'lumping' them together, and therefore a descriptive name was often employed while counting. This allowed maximum flexibility when recording phytoliths, since different sub-categories of the same morphotype could easily be combined where appropriate in the analysis at a later stage. Since it is the single-celled phytolith counts that are suitable for statistical analysis, the aim was to have as full a record of different morphotypes as possible while still retaining meaningful categories within the data. To this end, a single-celled morphotype that differed significantly in size or form to others of its type was recorded separately, for example, a bilobe with a very angular appearance but still recognisable as a bilobe was recorded as a 'square bilobe', thus retaining its overall classification, but also recording its unusual form.

A list of all single-celled phytolith morphotypes recorded can be found on the CD-ROM in the file '05_Single_Cell'.

6.3.4.2.Multi-celled phytoliths

As detailed above, multi-celled phytoliths were recorded with the primary aim of identifying the major domesticated cereals and small-seeded wild grass husks, along with Cyperaceae and *Phragmites australis*, since these silica skeletons are well documented in the literature and UCL reference collections, and could therefore be identified with confidence in the absence of a region-specific reference collection. Other multi-celled phytoliths were identified from the available reference material where possible, or were recorded with anatomical origin (where this could be determined) and a description of key features to allow for future identification to genus or species level.

In the case of the economically significant plants, several morphological criteria were required in order to reach a firm identification of a multi-celled phytolith. These are listed in the file on the CD-ROM '06_Multi_Cell', which lists all the multi-celled phytolith morphotypes recorded. Those criteria marked in bold text were all required to be present before a firm identification was made. In cases where a key criterion could not be identified but other features pointed to a particular identification, the multi-celled phytolith was recorded with its anatomical origin and 'cf' then the most likely identification.

6.3.4.3.Other observations

In addition to the identification of single-celled and multi-celled phytoliths, other observations were made while counting the slide. Each slide was assigned an index card for notes at the time of counting, and this was used to record the nature of the phytolith material (whether well articulated silica skeletons, badly weathered and pitted etc.), the location and a brief sketch of any unusual or unidentifiable phytoliths, and the presence of any notable non-phytolith material such as large amounts of mineral inclusions or non-plant environmental indicators such as sponge spicules.

6.4. Faecal Spherulite extraction and identification

As an exploratory exercise, twenty of the sediment samples were sub-sampled for faecal spherulites. The sampling strategy in this case was context-driven, with the aim of sampling a range of different context types across the three sites. Although different contexts were sampled, emphasis was placed on samples which came from contexts with evidence of burning, such as hearths and ash deposits. The reason behind this emphasis was to determine whether the use of animal dung as fuel could be established from the spherulite evidence.

Following advice from Dr. Richard Macphail (pers. comm.; Macphail *et al.* 2004), it was decided to carry out no pre-treatment processes on the sediment samples beyond sieving through a 0.25mm sieve in order to prevent any chemical or physical degradation of the faecal spherulites. Around 1.5mg of sediment was mounted to a glass slide using a few drops of Entellan in xylene and covered by a 24 x 24mm glass cover slip. This mass of sediment was chosen since it gave good single-layer coverage of the area of the cover slip, allowing the maximum potential for faecal spherulites to be present and identified. The mass of sediment mounted to each slide was recorded in order to allow the density of faecal spherulites to be calculated, expressed as the number of faecal spherulites per gram of sediment.

Identification of the faecal spherulites was carried out under crossed polarised light. The identification of the faecal spherulites followed guidelines outlined by Canti, with an additional tutorial from Dr. Richard Macphail at UCL (Canti 1995; 1997; 1998). The primary identification criteria were the spherical shape of the faecal spherulites in combination with the presence of an 'extinction cross' radiating from the central point of the spherulite under crossed polarised light, caused by its crystalline structure (Canti 1998). Faecal spherulites were only positively identified if both these features were present.

Each slide was first examined at 100 x and 250 x magnification, and the entire slide was visually scanned for the presence of faecal spherulites. Those samples that were found to have faecal spherulites were then examined at 400 x magnification. Since it was not practical in terms of time and the exploratory nature of this exercise to count all the spherulites on the whole slide, it was decided that 5% of the total number of microscope fields at 400 x magnification would be counted, which amounted to 2.5 rows of the slide. The rows were counted as transects across the slide, starting from the centre of the top edge of the slide, since the centre of the slide was more likely to have an even distribution of sediment without the ‘edge’ effect of where the mounting medium meets the edge of the cover slip causing clumping of the sediment. This method yielded a minimum count of 1 for those slides that had been noted to be sparsely populated with faecal spherulites, and a maximum count of 192 for the slide most dense with spherulites. This demonstrated that the transect method chosen resulted in spherulites being counted for even the most sparsely populated slides, showing that 5% was a sufficient representative sample for the purposes of this study. Should a larger study be carried out in the future requiring statistical analysis, a larger number of fields would need to be counted in order to increase the sample size and the reliability of the results for statistical purposes. However, the primary aim of this study was to determine whether faecal spherulites were indeed present at the three sites, whether they were present in contexts with evidence of burning, and finally if possible to assess the density of spherulites at the three sites and in the different context types. The sample that was taken was sufficient to meet these aims.

6.5. Multivariate analysis methodology

In order to more fully explore the relationship between the samples, the phytolith assemblages and their contexts, multivariate statistical analysis was carried out using the CANOCO programme (v.4.5). In particular, this analysis was of use in identifying how the different altitudes of the three sites might affect the phytolith assemblages, and how the different contexts from which the samples were taken varied in their composition. Graphing the results of this analysis allows relationships between the data to be expressed visually.

In this analysis, counts of single-celled phytolith morphotypes were employed in the same way that species counts are employed in biological studies of animal or plant communities, with each individual single-celled morphotype being treated as a separate species. It was decided to use absolute counts rather than relative percentages for the analysis since the aim was to take into account both the composition of the phytolith assemblages as a whole and the abundance of individual phytolith morphotypes within a sample. The problems with using multi-celled phytolith counts for the purposes of numerical analysis have been outlined above, and are the same reasons why the single-celled phytolith counts were employed as the primary data set (response variables, identified as species data in CANOCO) for this statistical analysis. However, some of the multi-celled phytolith data were included in this analysis as explanatory variables in the form of presence/absence counts from the main economic plants that were identified. Explanatory variables are those variables which are suspected of influencing the composition of the sample (termed environmental variables in CANOCO) (Leps and Smilauer 2003, 4). It is hypothesised that changes in the explanatory variables will result in changes to the community composition of the phytolith samples.

For this study the explanatory variables which are available for analysis are: the date of the sample (expressed as a time period rather than an absolute date due to absolute dates not being available for all samples); the type of context (natural, floor, fill, burning, architecture); the altitude at which the sample was taken; and the presence/absence of selected economically significant plants in the sample, where these could be identified in the multi-celled phytoliths (wheat, barley, millet (either non-specified millet or *Setaria* or *Panicum* where such an identification was possible (Lu 2009)), sedges, and *Phragmites australis*). The variables that are of the most interest in answering archaeological questions about the data are the type of context, the period of the sample, and the presence of economically significant plants, since it is these variables that take into account human choices in the types of plant material that were used for different activities, and the changes in those activities over time. However, the altitude of each of the sites is also an important variable to take into consideration for explaining variability in the data, since the natural vegetation cover and potential for agricultural activity are both influenced by altitude, due to factors such as annual length of snow coverage and mean annual temperature.

The first step in carrying out this analysis is to transform the data into an appropriate format for the CANOCO programme. Since all the values included in the analysis are required to be numerical, several decisions had to be made about how best to translate the nominal variables into a meaningful numerical format. The period of the samples was coded as a semi-quantitative variable with values from 0 to 8, with 0 being samples of an uncertain date, and 8 being modern samples (

Table 6.1). Those samples for which no absolute dates were available, but which had been tentatively assigned a period through relative dating, were included with more firmly dated samples for the purposes of this analysis.

CANOCO value	Date
0	Uncertain Date
1	Middle Bronze Age
2	Late Bronze Age 1
3	Late Bronze Age 2
4	Late Bronze Age/Early Iron Age
5	Early Iron Age
6	Iron Age
7	Late Iron Age
8	Modern

Table 6.1: CANOCO Date coding table

The nominal variables describing context type were transformed into ‘dummy’ numerical variables. In this case, each different category became a dummy variable, and the values for the dummy variables were recorded either in binary (0 or 1), or, for contexts where the exact nature of the context was unclear, ‘fuzzy coding’ was employed (Leps and Smilauer 2003, 8). For example, in the case of contexts where there were spreads of ash and it was unclear whether the context was the direct result of an act of burning, or whether the ash had become mixed with other fill material as part of a rubbish dump, the variables ‘fill’ and ‘burning’ were each coded as 0.5 and 0.5. This allowed the potential influence of other, non-burnt material in contexts where the sample represented a mixed fill to be taken into account, in contrast to contexts which were clearly identifiable as the result of a deliberate act of burning, such as a hearth or fire pit. The presence/absence data from multi-celled phytoliths were also coded in the same way (1/0), with uncertain identifications given a value of 0.5 (Coding tables provided in the file “03_CANOCO_coding” on the CD-ROM).

The environmental variables were coded onto a spreadsheet, with each column being a variable and each row a sample. Likewise, the single-celled phytolith data were transposed onto a spreadsheet, with each column being a phytolith morphotype and each row a sample. The WCanoImp programme (part of the CANOCO package) was then used to import the data into CANOCO format.

Having imported the data into CANOCO, it was then necessary to decide whether a unimodal or linear method would be more appropriate for the analysis. It was decided to run the analysis both with and without the presence/absence data from the multi-celled phytoliths in order to determine whether it was meaningful to employ these data as explanatory variables. The results of both analyses are presented below. The decision on whether to use a linear or unimodal method was made by carrying out a detrended correspondence analysis (DCA) for indirect gradient analysis (unconstrained ordination, detrended by segments) and looking at the resulting lengths of gradient, shown here:

```
Lengths of gradient:        1.489  1.356  1.451  1.148
```

The resulting lengths of gradient were the same for both sets of environmental variables. The longest gradient here is 1.489, which indicates that the data do not deviate significantly enough from the assumed model of linear response to require a unimodal method (which would be a gradient length greater than 4). A linear method is therefore the more appropriate choice (Leps and Smilauer 2003, 51).

Having determined that a linear model was the most appropriate method to use, Principle Components Analysis (PCA), an indirect analysis of the data, was carried out in order to summarise the variation of phytolith morphotypes and their frequencies in the samples (Leps and Smilauer 2003, 171). It should be noted here that during this step several decisions had to be made about the transformation of the data, and these choices would be made for all the other analyses carried out in CANOCO. First, the choices for scaling for linear methods were kept at the default values (scaling focused on inter-sample distances, species scores divided by standard deviation). Next, a log transformation was selected for the transformation of species data (i.e. phytolith morphotypes), resulting in a multiplicative scale for the average abundance of the response variables with reference to an increase in the explanatory variables (Leps and Smilauer 2003, 14), meaning that the focus of the analysis is on relative change (*ibid*, 172). This mitigates for the differing densities of phytolith material at the three sites, and allows the focus to be on the relative abundance of the different morphotypes in the phytolith assemblage rather than their absolute counts (although these are also important to take into account, for example in considering the effects of factors such as moisture availability in the production and deposition of phytoliths). For centring and standardisation of the species data (counts of phytoliths), it was decided to standardise the data by error variance, the result of which is that those phytolith morphotypes that are better described by the environmental variables are given greater weight in the final analysis (Leps and Smilauer 2003, 52). This choice was made in order to better understand the relationship between the phytolith assemblages and the physical location of the sites and the contexts from which the samples were taken. No centring or standardisation was selected for the samples (Leps and Smilauer 2003, 172).

Chapter 7: Results

The following chapter presents the results of the phytolith and faecal spherulite analysis. Section 7.1 analyses the density of phytolith material in the sediment samples taken and discusses the implications of this for identifying anthropogenic sediments, and the processes of phytolith formation and subsequent taphonomy. Section 7.2 provides an overview of the phytolith assemblages for the three sites, discussing each site in turn and highlighting points of interest that are specific to the site. Section 7.3 presents the results of ubiquity calculations for the domesticated cereals identified, in addition to those for Cyperaceae (sedges), *Phragmites australis* (common reed), and wild grasses. In section 7.4 the proportion of single-celled dendritic to single-celled elongate psilate phytoliths is analysed as a measure of the relative presence of grass inflorescences in comparison to leaves or stems. Section 7.5 presents the results of multivariate analysis of the phytolith data, which takes into account the effect of variables such as altitude and date on the phytolith assemblages. In section 7.6 three climatic indices are calculated for the samples. The chapter finishes with section 7.8 which discusses the results of the faecal spherulite analysis.

7.1. Phytolith densities and the recognition of anthropogenic assemblages

One of the first questions to be asked of phytolith assemblages is whether they contain evidence deriving from human activities and differ from naturally-occurring phytolith assemblages. In the current study, sediments from archaeological sites were significantly enriched in phytoliths in comparison to representative natural soils of the region, suggesting that human activities resulted in the deposition of additional plant materials. Of course, this result must be considered as an indication only, since the natural soils sampled were modern and not natural deposits contemporary with the archaeological sediments.

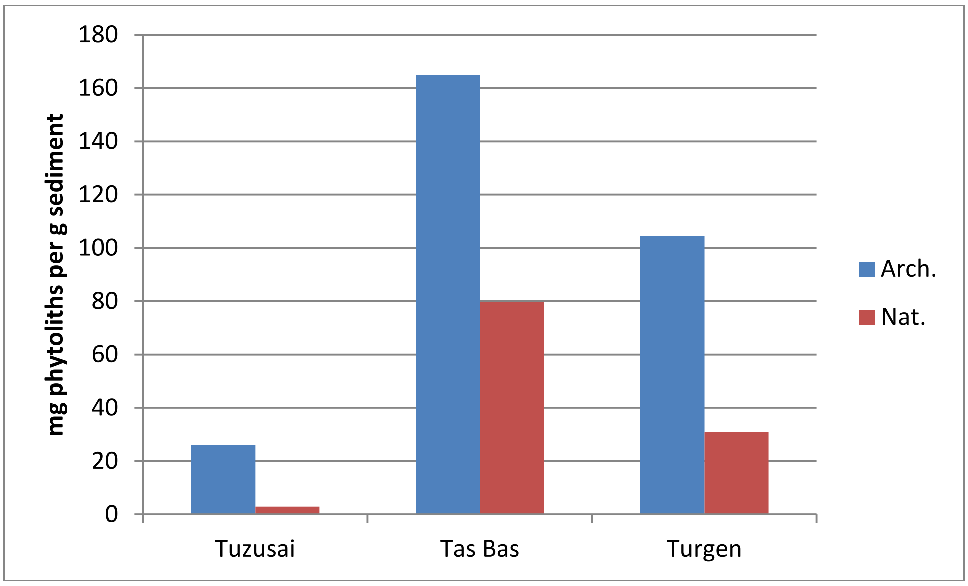


Figure 7.1. Mean density of phytolith material (mg phytoliths per g sediment)

Figure 7.1 shows the mean densities of phytolith material from the three sites (Dali is included in the Tasbas data), expressed as mg of phytoliths per g of sediment. These data are presented here for both the natural and archaeological contexts, expressed as milligrams of phytoliths per gram of sediment that was extracted from the samples. Phytolith density was calculated in the following way:

phytolith density per gram = mg sediment processed / mg phytoliths extracted x 1000

Those samples labelled as 'natural' in this study have been taken from onsite and offsite sections, and represent samples collected from modern-day topsoil. In the case of the offsite sections, both the soil 'A' and 'B' horizons were sampled. These modern topsoil samples represent a natural (non-anthropogenic) accumulation of phytoliths under current climatic conditions. By comparing the archaeological phytolith assemblages with those of natural origin it is possible to infer the anthropogenic influence of deposition of phytolith material, and demonstrate that archaeological phytolith assemblages are significantly different to those of natural origin, thus validating the interpretation of archaeological phytolith data. Of course, caution must be exercised when comparing these modern samples to those of archaeological origin, since changes in climate have the potential to affect the availability of silica in groundwater, and other factors may influence phytolith formation and post-depositional taphonomy, such as the evapo-transpiration rate, soil formation, variable preservation of different morphotypes according to different soil/sediment pH values (Cabanes *et al.* 2010; Jenkins 2011; Piperno 2006; Rosen and Weiner 1994), and the type of vegetation present, for example an increase in the presence of species that produce lower quantities of phytoliths such as dicotyledonous plants (Piperno 2006). It would be ideal to have contemporaneous natural deposits with which to compare the archaeological samples. This would require locating a suitable exposed geological section, perhaps a buried soil, confirming that the deposit was indeed of natural rather than anthropogenic origin, and dating the sample using absolute dating methods such as OSL or radiocarbon in order to confirm its age. Such a process was beyond the scope of this project, although it would certainly be a useful exercise in future in order to further understand the relationship between the archaeological site and the landscape of which it is part. Even with these caveats in mind, the samples from natural contexts still hold value as a general indicator of the types of phytolith assemblage that are to be expected from contexts with natural deposition as opposed to deposits of human origin. The comparison of phytolith density has the potential to give insight into the amount of plant matter that was brought into an occupied site, and may also be used to infer periods of abandonment.

As can be seen fromFigure 7.1, the samples from the three sites display phytolith densities that are very different from each other. These differences are apparent in both the archaeological and natural contexts, and in all three sites the archaeological contexts display a greater mean density of phytoliths per gram of sediment than the natural contexts. As discussed above, some of this variation might be attributable to changes in soil silica availability in the past compared to the present due to changes in moisture content, dissolved silica in groundwater, evapo-transpiration rates, and soil chemistry (Cabanes *et al.* 2011; Jenkins *et al.* 2011; Lancelotti and Madella 2012 Rosen and Weiner, 1994; Zurro *et al.* 2016). However, since all three of the sites are located at different altitudes, in different ecological zones, and with different date ranges, the fact that they all display a difference in the density of phytolith material between the natural and the archaeological contexts implies that there is a difference between natural and anthropogenic deposition of plant matter.

As was demonstrated in Chapter 3, changes in climate manifest differently in the varying ecological zones where the sites are located, meaning that all three sites have varying hydrological and temperature regimes. This is reflected in the differing densities of phytolith material found in the natural contexts at the three sites. Tuzusai has the lowest density of phytolith material deposited per gram of sediment, with the mean density of the natural deposits being 2.96mg of phytoliths per 1g of sediment. Turgen, located in the high mountain zone, has the highest density of phytoliths per gram of sediment, with 79.71mg of phytoliths present per 1g of sediment. Tasbas, geographically more similar to Turgen than Tuzusai, falls in the middle of the two other sites with mean phytolith density of natural deposits being 30.94mg per g of sediment. These densities for the natural deposits imply that there is a varying rate of phytolith formation and preservation at the three sites. Factors which could affect this rate are the availability of silica in groundwater, soil chemistry, and evapo-transpiration rates (Cabanes *et al.* 2011; Jenkins *et al.* 2011; Jones and Handreck 1965; Okamoto *et al.* 1957; Parry and Smithson 1958, 1964, 1966; Rosen and Weiner 1994). In addition to these phytolith formation factors, it is also important to note here one of the issues in phytolith extraction that was noted during the phytolith extraction process. This issue is the inclusion of a small amount of non-phytolith mineral material when carrying out the final phytolith fraction extraction using SPT calibrated to a specific gravity of 2.35. This inclusion was unavoidable, since the material had the same specific gravity of the phytoliths, and was therefore inseparable from the phytolith component of the sample. This was especially noticeable in the samples from Turgen and Tasbas, more so at Tasbas where a component of what appeared to be mica was noted as being included in the phytolith fraction during extraction. All three sites had some non-phytolith mineral inclusions in the samples following extraction, and this quantity varied from sample to sample and site to site. While only representing a small component of the final extracted fraction, these inclusions are nonetheless necessary to note as having the potential to introduce error into the interpretation of phytolith data.

Looking to the difference between the natural and archaeological contexts, at all three sites the archaeological contexts are denser in phytolith material than the natural contexts. This points to an anthropogenic factor beyond climatic pressures affecting the amount of plant material being deposited. While this may seem like common sense, testing this assumption will allow the archaeological contexts to be interpreted as such with confidence, as asserting the independence of the two different deposit types through phytolith density indicates that the samples being analysed are the product of human rather than natural processes. Such a comparison may also aid in identifying those archaeological contexts that are the result of a period of abandonment at a site, where phytolith accumulation is lower than when the site is occupied. In order to test this hypothesis, a statistical t-test was carried out on the samples. Since the samples being tested are assumed to be of different origin, an independent t-test is the most appropriate, where unequal variance is assumed in the two samples. The hypothesis in this case is that the samples of anthropogenic origin will have a greater density of phytoliths than those of natural origin, therefore a one-tailed test is used to test the validity of this hypothesis. The null hypothesis being tested is that there is no statistically significant difference in the phytolith density of samples of anthropogenic and samples of natural origin. The results of the t-test are as follows:

Tuzusai: $t(35)=4.34$, $p<0.05$ ($p=0.0000574$)

Turgen: $t(4)=2.32$, $p<0.05$ ($p=0.041$)

Tasbas: $t(3)=1.95$, $p>0.05$ ($p=0.073$)

As can be seen from the above p values, there is a statistically significant difference between the natural and the anthropogenic samples from Tuzusai and Turgen, since the p values are below the 0.05 threshold suggested by Fisher (1925) as being the level at which the null hypothesis can be satisfactorily rejected. In contrast, the p value for Tasbas is 0.073, which is above the threshold at which the null hypothesis can be rejected with confidence, indicating that the difference between phytolith density in the natural and anthropogenic deposits at Tasbas is not statistically significant. This result is a little concerning for the analysis of phytolith data from the site, since it cannot be said with confidence that the difference in phytolith density is due to anthropogenic influences. However, it is worth bearing in mind that the significance level of 0.05 is an arbitrary level, and that the p value of 0.073 is not much over this threshold. This result could indicate that a larger sample size from the site of Tasbas might yield a statistically significant difference between the samples, and that the p value of 0.073 can be treated as a borderline result, where difference between natural and anthropogenic samples can be neither firmly asserted nor rejected with statistical confidence. If we look at meta-analysis of the data, the t-test for all three sites combined, we see that $t(16)=2.91$, $p<0.05$ ($p=0.0051$), which shows that when the data is pooled and treated as a larger sample size the difference between natural and anthropogenic samples is statistically significant. The non-significant p value for Tasbas is therefore likely to be a reflection of the small sample size rather than evidence that there is no meaningful difference between the archaeological and natural deposits at Tasbas with regards to phytolith density at the site. It is also possible that this result for Tasbas reflects the large chronological gaps in occupation that have been revealed through absolute dating, and that some of the contexts sampled were the product of a long period of abandonment, and subject to the forces of bioturbation.

7.1.1. *The identification of archaeological sediments*

One of the outcomes of this research has been to show the contribution of phytolith analysis to the identification of archaeological sediments, highlighting questions of site formation processes which in turn aid in the interpretation of individual contexts, features, and sites as a whole. Analysis of the density of phytolith deposits has demonstrated the difference in the presence of plant matter between sediments of anthropogenic origin and those that are natural deposits. Multivariate analysis using single-celled phytoliths highlights samples that do not match those attributed to a similar period or context type, and can be used to infer whether a context may be intrusive or of non-human origin.

The differences in phytolith densities from both natural and anthropogenic deposits indicate that altitude, climate, aspect and soil chemistry are all factors in the formation, deposition and preservation of phytoliths, in addition to the influence of human activity. This demonstrates the importance of using relative counts if directly comparing the phytolith assemblages from the sites, since this will mitigate for these other formation filters to a certain extent.

7.1.1. ***Phytolith densities on individual sites***

7.1.1.1.Tuzusai density results

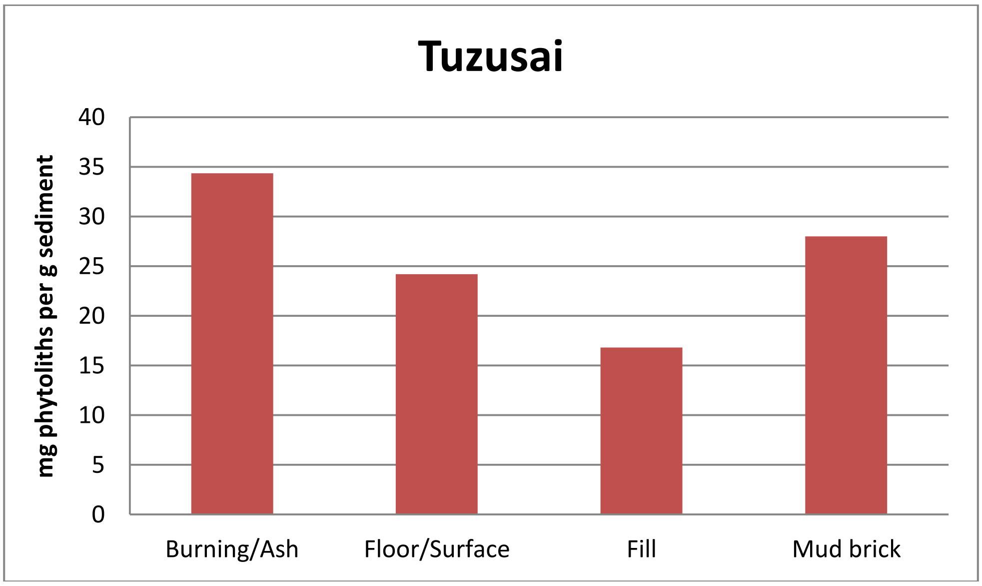


Figure 7.2. Mean density of phytolith material by feature type at Tuzusai

Figure 7.2 shows the mean density of phytolith material by feature type for Tuzusai. As can be seen from the graph, the greatest density of phytoliths were found in burning or ashy contexts, which includes hearths, firepits, and ash dumps and spreads of ashy material and charcoal. The context most dense in phytolith material at Tuzusai was an ash deposit (2011-214) found on the floor of pithouse 6. The lowest density of phytolith material was found in contexts that were identified as the fill of pits, pit houses, post-holes, and between occupation floors. Floors and other walking surfaces had a comparable mean density of phytolith material to the mud brick samples that were analysed. In the mud brick samples it is assumed that the inclusion of plant material was deliberate, having been added as temper to the mud. In the case of the floors and walking surfaces, the density of plant material may reflect deliberate deposition in the form of matting and bedding or temper added to prepared floors such as the plaster and clay surfaces, or it may reflect an accumulation of plant material from trampled waste. If we look more closely at the density of phytoliths from floor and walking surfaces (Figure 7.3) we can see that with the exception of one sample (2011-031) they display very similar densities to each other. This makes it difficult to draw any firm conclusions about the nature of the deposition of plant matter based on phytolith densities alone.

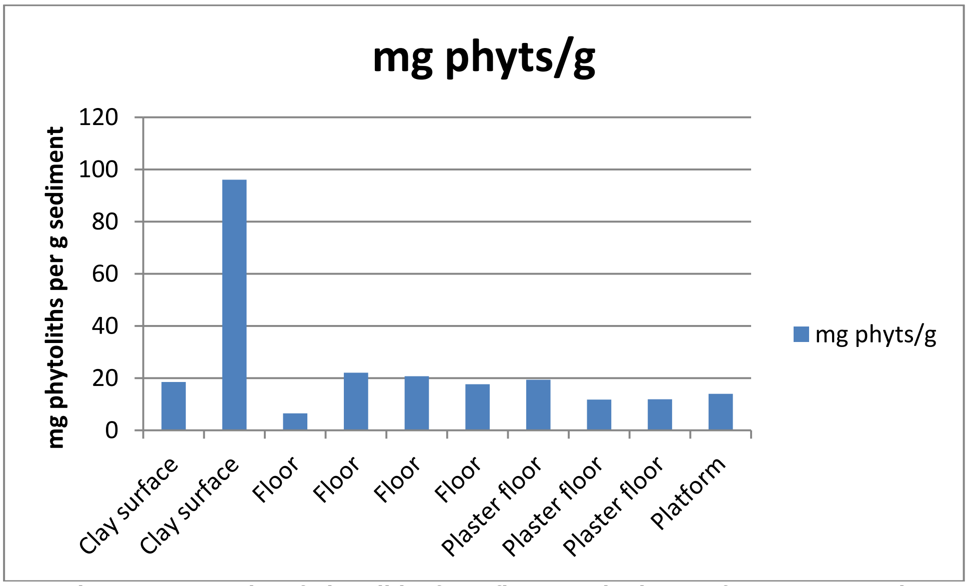


Figure 7.3. Density of phytoliths from floors and other surfaces at Tuzusai

7.1.1.2. Tasbas phytolith densities

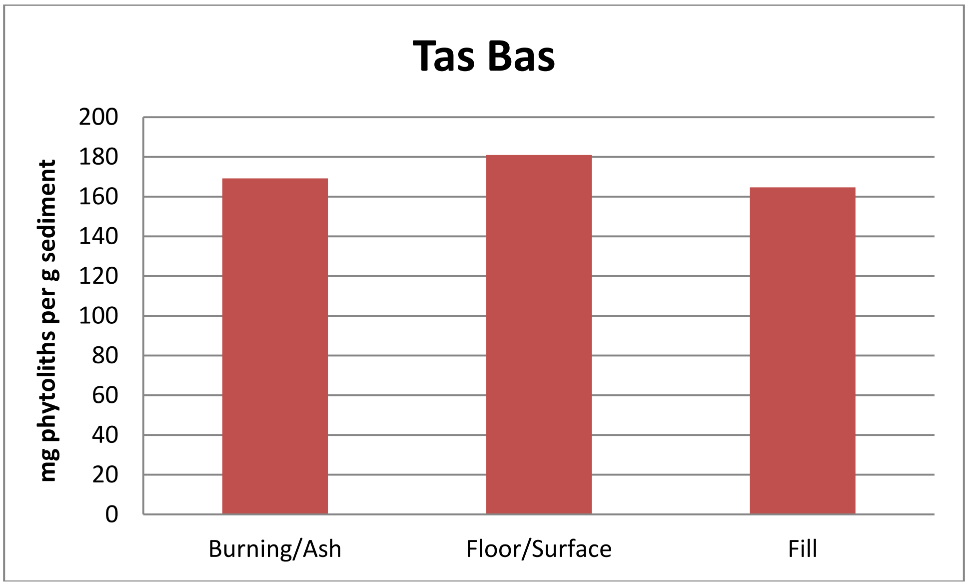


Figure 7.4. Tasbas phytolith densities (mg phytoliths per g sediment)

Figure 7.4 shows the mean phytolith densities from Tasbas for the three main context categories. In contrast to those from Tuzusai and Turgen, floors, fills and burning contexts at Tasbas do not show a marked difference between contexts with regards to phytolith density. This could in part be due to the mica inclusions that were noted in the samples while they were being processed, however if the mica accumulation was constant for all samples then it would not be expected to have a net effect on the densities overall. This lack of difference in phytolith densities is therefore either due to the amount of phytolith deposition being uniform across all contexts, or the accumulation of mica being uneven across all samples, thereby masking the differences in phytolith density between samples. One way to address this issue is to look to the count data for phytoliths, which will indicate any differences between the samples, although it will not necessarily accurately reflect the amount of plant matter that was present in a sample since the counts of multi-celled phytoliths can reflect either a very large or a very small amount of plant matter depending on the individual cell count of the silica skeleton.

7.1.1.3.Turgen phytolith densities

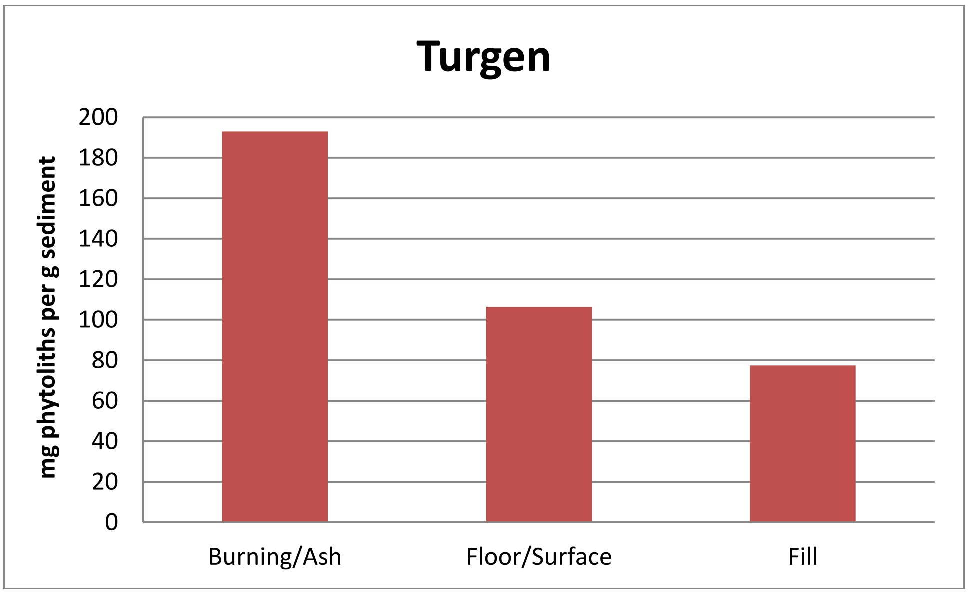


Figure 7.5. Turgen phytolith densities (mg phytoliths per g sediment)

The mean phytolith densities from Turgen, shown here in Figure 7.5 display a similar pattern to the densities of phytoliths from Tuzusai, with burning and ashy contexts having the highest densities, followed by floor and surface contexts, with fill contexts being the lowest in phytolith density. Floor contexts may have greater phytolith densities than fill contexts due to the packed nature of floors causing less water movement through the sediment, leading to a concentration of dissolved silica, resulting in higher phytolith preservation (Cabanes et al. 2011).

7.2. **Overview of phytolith assemblages at the three sites**

7.2.2. ***Tuzusai***

Table 7.1 below lists the presence or absence of the economically significant plants that have been identified from each sample in Tasbas and the neighbouring site of Dali, opened for test excavations and included here for comparison. In each case, a blank cell indicates the absence of a species, “X” indicates full confidence in an identification, while “?” indicates partial confidence where identification is difficult due to morphological or taphonomic factors. Millets are recorded here in such a way as to reflect the nature of their identification. Where species-level identification could not be achieved, but confidence is high that the multi-cell is millet, then these are recorded simply under 'millet'. When species-level identification is possible the two species are recorded separately.

Phase	***Context***	***Sample no.***	**Wheat**	**Barley**	**Millet**	***Setaria***	***Panicum***	***Phragmites australis***	**Cyperaceae**	**Wild grass husk**
Stratum 6 (Phase 1)	Hearth?	2009-044	X	X	X	X	X	X	X	X
	Ash	2010-018			X	X	X	X	X	X
	Pit fill	2009-062	X		X		X	X	X	X
	Fireplace	2009-065	X		X		X		X	
	Firepit/post-hole	2009-066	X		X		X	X		
	Floor	2011-129	X						X	
	Pit fill	2011-204	X		X		X		X	
	Fill	2011-209	X							
	Inside fireplace	2011-212	X					X		
	Outside fireplace	2011-213			X	X		X	X	
	Ash deposit	2011-214	X		X	X	X	X	X	X
	Pithouse fill	2011-239	X	X						
	Firepit	2011-240	X	?						
	Ash/charcoal	2010-015			X		X	X	X	X
Stratum 5 (Phase 2)	Fill	2010-012			X		X	X	X	
	Pit	2009-051	X		X		X		X	X
	Fill between floors	2010-060	X		X	?	X			
	Ashy fill above floor	2010-061	X	X	X		X		X	
	Ash dump	2009-063	X					X		X
	Storage pit fill	2010-069	X		X	X	X		X	
	Mud brick	2011-118	X					X		
	Firepit	2011-246		?				X		
Stratum 4 (Phase 3)	Mudbrick	2010-009	X		X		X	X	X	X
	Hearth	2009-064	X		X		X			X
	Ashy lens	2011-036	X	X	X	X	X		X	X
	Ash dump	2011-037	X							X
	Burning layer	2011-038	X						X	
	Burning layer	2011-039	X		X		X		X	
	Ash dump	2011-040			X		X		X	
	Mud brick	2011-116	X							
	Mudbrick	2011-117			X				X	
	Pithouse fill	2011-132			X		X			
	Pithouse fill	2011-133	X						X	

Phase	*Context*	*Sample no.*	Wheat	Barley	Millet	*Setaria*	*Panicum*	*Phragmites australis*	Cyperaceae	Wild grass husk
	Pithouse fill	2011-134	X						X	
	Mud brick	2011-119						X		
Stratum 3 (Phase 4)	Bottom of topsoil profile	2010-006	X		X		X	X	X	X
	Pit fill	2011-007	X		?					
	Burning layer	2011-012	X		X	X			X	X
	Top of burnt feature	2011-013							X	
	Top of burnt feature	2011-014			X	X	X		X	X
	Floor	2011-017	X					X	X	
	Floor	2011-027			X		X		X	
	Floor	2011-029							X	X
	Clay surface	2011-030	X					X	X	
	Clay surface	2011-031						X	X	
	Plaster floor	2011-032	?					X	X	X
	Plaster floor	2011-033	X					X	X	X
	Plaster floor	2011-034	X	?	X		X		X	
Stratum 2 (Phase 5)	Upper fill	2010-003	X	?	X	X			X	X
	Burning waste dump	2010-039							X	X
	Burned soil	2010-041							x	X
(Phase 6)	Platform	2012-013	X	X	X					
Offsite pithouse	Pithouse fill?	2010-027	X	X	X	X		X		X
	Pithouse fill?	2010-030	X		X					X
	Pithouse floor?	2010-033			X		X			X
Offsite topsoil	Offsite topsoil	2011-122								
	Offsite subsoil	2011-123								
Onsite topsoil	Topsoil	2010-024							X	

Table 7.1. Tuzusai presence/absence of economically significant plants

It should be noted here that although Rosen (2001) reported rice (*Oryza sativa*) phytoliths from the samples that she analysed from Tuzusai, a firm identification of rice could not be made in the phytolith samples processed as part of this research, nor was it identified in the macrobotanical samples from the site (Spengler *et al.* 2013). Multi-celled phytoliths from the husk of a grass/other monocotyledon were identified in the sample which bore a resemblance to those from rice (Pearsall *et al.* 1995), however in no samples were other phytoliths indicative of the rice plant present such as the distinctive double-peaked glume cell (Pearsall 2000, Fig. 5.24), or the scalloped keystone bulliform, or scooped bilobe (Weisskopf 2014) (scooped bilobes were identified, but were not analogous to those from *Oryza*). Due to these factors and the lack of a region-specific reference collection, it was not possible to make a confident identification of rice in the samples, since I could not rule out the possibility that another species was presenting similar characteristics.

A survey of the phytoliths from Tuzusai indicates that these data have the potential to inform not only on food production and procurement in the Iron Age, but also on the non-food use of plants at the site. The contexts from which the samples have been taken can be broadly grouped into four types: floors; hearths and ash dumps; mud brick and plaster; and the fill of pit houses. In addition, it should be noted that off-site topsoil and sediment samples were taken to enable a comparison of naturally-occurring and anthropogenic phytolith assemblages.

The phytolith assemblage from Tuzusai is rich, indicating that a wide variety of plant matter was brought to the site, utilized and discarded. Multi-celled phytoliths from cereal husks that could be identified include wheat (*Triticum* spp.), broomcorn millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*) and barley (*Hordeum vulgare*). Initial indications are that the most abundant phytoliths from cereal husks present on the site are those of wheat and broomcorn millet. This is not a direct indication of their relative abundance in the diet of the people of Tuzusai, but rather reflects the depositional fate of crop processing waste in the area of habitation. Phytoliths from other economically significant plants included those from the common reed (*Phragmites australis*) and sedges

As Harvey and Fuller have pointed out (2005, 741), the possibility of crop processing waste being used as animal fodder or bedding should also be considered, and cereal husks and other processing waste may end up on site through the burning of dung for fuel, or the use of dung and straw for construction. One sample that may support this case at Tuzusai is 2011-036, an ashy lens with darkish burnt soil and clay smears, located to the East of the plaster floor in quadrant H-2 (level 211). This sample was found to contain multi-celled phytoliths from the husks of wheat, barley, both broomcorn and foxtail millet, and wild grasses. This sample was also processed for faecal spherulites, most abundantly produced by ruminant herbivores (Canti 1999), which were found in this sample in relatively large quantities.

7.2.2.1.Dung fuel

Further addressing the question of fuel types used at Tuzusai, of the samples processed for faecal spherulites those from ashy contexts were found to contain a relatively higher abundance, which lends weight to the argument that dung was being used as a fuel. If dung was being burned in the hearths of Tuzusai, it was probably not the only fuel being used, as samples from ashy contexts also contained phytoliths that are indicative of trees or shrubs. These phytoliths are not diagnostic beyond their general classification as coming from 'woody' plants, however they do imply that perhaps a mixture of dung and trees/shrubs were burned for fuel.

Another aspect of plant use demonstrated at Tuzusai is in the presence of phytoliths from reeds (*Phragmites australis*) and sedges (Cyperaceae), which are commonly used in construction, such as for roofing or floor coverings. An interesting context here is sample 2011-246, context 53. This deposit of ashy material was found to contain a large number of big multi-celled phytoliths from *Phragmites australis*, as well as large multi-celled phytoliths from the leaf or stem of monocotyledonous plants. The context was also found to contain faecal spherulites. This context measures 1m x 0.6m, has a depth of 8cm, and lies on the upper floor of Pit House 1. Given the well-articulated nature and abundance of the *Phragmites australis* multi-celled silica skeletons, it is unlikely that it is present as a component of animal dung. Two alternative explanations are that it was being used as fuel for a rather large fire pit, or this sample represents the destruction by fire of a structure that included reeds and dung in its construction (Hurcombe 2014, 136). The presence of phytoliths from *Phragmites australis* and Cyperaceae in the samples at Tuzusai, in addition to the presence of sponge spicules and diatoms, indicates that wetland resources were readily exploited by the people of Tuzusai.

7.2.2.2. Mud brick

The mud brick fragments at the Iron Age site of Tuzusai are as follows: (1) lumps of mud brick that appear to be irregular or like 'mud balls;' (2) hand-molded plano-convex mud brick (elongated loaf shaped); (3) large rectangular mud brick blocks (either hand-formed or mold-formed) (Chang and Beardmore 2015; Van Beck and Van Beck 2008, 143-158). For the purposes of this study the phytolith composition of the latter two types of mud brick were analysed: (1) the yellow-coloured, hand-molded plano-convex mud brick (elongated loaf shaped), (usually 15 cm X 10 cm X 8 cm in size) and (2) the red-brown coloured, large rectangular mud brick blocks (either hand-formed or mold-formed), (usually 30 cm x 20 cm x 15 cm in size). Samples from four different bricks, two of each type, were taken. The assumption underlying the analysis was that the phytoliths present in the mud bricks were derived from plant material added as temper to the mud to help bind it, and therefore any differences in plant matter might indicate differing types or quantities of temper (Chang and Beardmore 2015).

The samples were analyzed for both the density of phytoliths within the sample (expressed as mg of phytoliths extracted per g of sediment) and also the percentage composition of the phytolith assemblage, observed through counts of single-celled morphotypes (Twiss *et al.* 1969). In addition to these quantitative values, multi-celled silica 'skeletons', which allow more precise identification to genus and occasionally species level (Piperno 2006: 23), were recorded as a qualitative presence/absence observation. Variation in the percentage composition of total single-celled morphotype counts might indicate different plant assemblages were used to bind the mud. This is not the case, however. Figure 7.6 shows the percentage composition of single-celled phytolith morphotypes, demonstrating that both types of brick had broadly similar compositions in terms of plant assemblages present.

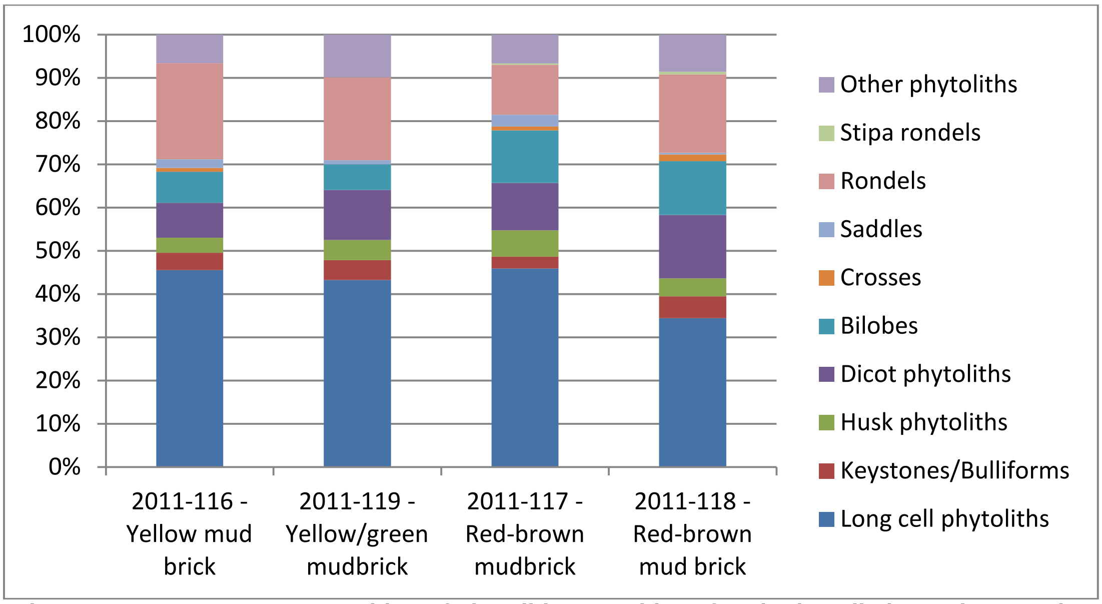


Figure 7.6. Percentage composition of phytolith assemblage for single-celled morphotypes in mud brick samples.

However, when the density of phytoliths in each sample is compared, it becomes apparent that the red-brown coloured mud brick has far higher densities of phytolith material per gram of sediment compared to the yellow coloured mud brick (Figure 7.7). If the reasonable assumption is made that all the sampled bricks have undergone the same post-depositional taphonomic processes on the site, given that they come from a small excavation area and narrow time period (ca. 400 BC to 1 AD), the higher density of phytoliths in the red-brown coloured bricks represents a higher concentration of plant matter present. It appears, therefore, that a similar assemblage of plant matter was added to the two types of mud brick, however the red-brown coloured mud brick contained far greater quantities of this temper than the yellow coloured mud brick. This suggests deliberate differences in plant tempering practices in brick production which is also evidenced in the different colours of the resulting bricks.

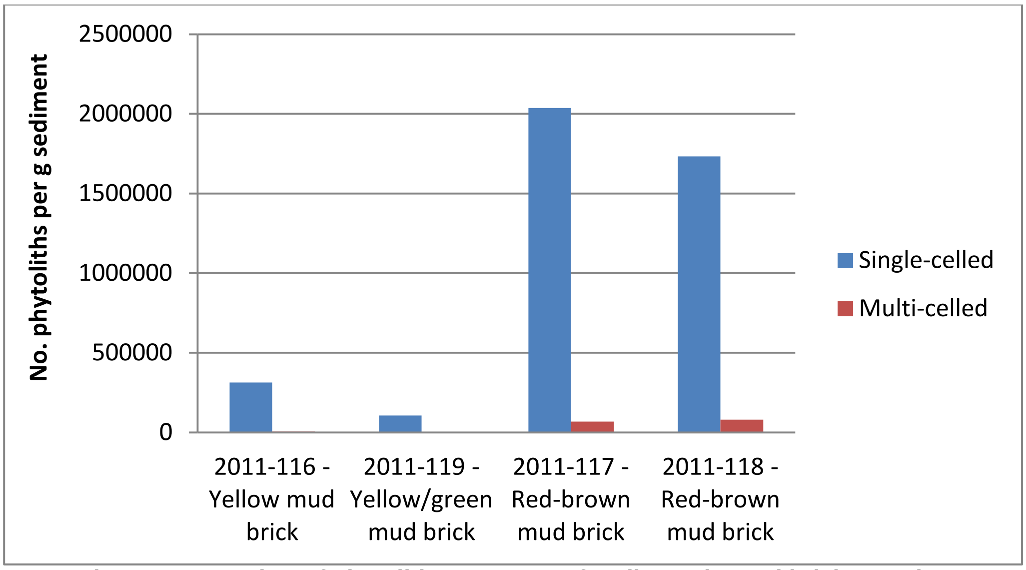


Figure 7.7. Number of phytoliths per gram of sediment in mud brick samples

At the site, the larger red-brown mud bricks are usually associated with house foundations and are therefore more durable. The yellow bricks are associated with floor construction, internal wall constructions or the top layers of a mud brick platform, and therefore could be les durable. These contained a lower density of plant materials (Chang and Beardmore 2015).

7.2.3. ***Tasbas***

Table 7.2 below lists the presence or absence of the economically significant plants that have been identified from each sample in Tasbas and the neighbouring site of Dali, opened for test excavations and included here for comparison.

Phase	Context	*Sample No.*	Wheat	Barley	Millet	*Setaria*	*Panicum*	*Phragmites australis*	Cyperaceae	Wild grass husk
Phase 1	Ash scatter	2011 - 219								
	Ash scatter	2011 - 220						X	X	
Phase 2a	Post-hole fill	2011 - 216						X	X	
	Post-hole fill	2011 - 217						X	X	
	Post-hole fill	2011 - 218	?					X		
	Cxt 105	2011 - 221			X		X	X	X	
	Oven	2011 - 229						X	X	

Phase	Context	*Sample No.*	Wheat	Barley	Millet	*Setaria*	*Panicum*	*Phragmites australis*	Cyperaceae	Wild grass husk
	Oven	2011 - 230						X		
	Oven	2011 - 231								
	Ash deposit	2011 - 235		X	X		X	X	X	
	Fill	2011 - 237		?	X					
	Ash spread	2011 - 238		X/?				X		
Phase 2b	Ash spread	2011 - 95			X				X	X
	Floor	2011 - 100	X		X					X
	Floor	2011 - 101			X					X
	Floor	2011 - 102			X				X	
	Floor	2011 - 103			X			X	X	X
	Floor	2011 - 104				?				
	Floor	2011 - 105					?		X	
	Fill	2011 - 88			?	X	X	X	X	
	Fill	2011 - 89			?			X	X	
	Fill	2011 - 90	?				?			
	Cultural fill	2011 - 223					X	X	X	
	Cultural fill	2 011 - 224			X		X	X	X	
	Organic w/charcoal	2011 - 226	X		X		X	X	X	
	Context 19	2011 - 228			X		X			
	Cultural fill	2011 - 234		?	X		X	X	X	
Phase 3	Burnt material	2011 - 93	X		X				X	
	Burnt material	2011 - 94			X			X	X	X
	Pit fill	2011 - 106						X	X	X
	Burnt layer	2011 - 83			X				X	
	Ash spread	2011 - 091					?	X	X	
	Organic layer	2011 - 099						X		
offsite	Offsite topsoil	2011 - 107								
	Offsite subsoil	2011 - 109								
Onsite topsoil	Onsite topsoil	2011-OSTS								
Dali	Burning context	2011-096			X				X	
	Fill	2011-097							X	
	Fill of pithouse	2011-098							X	

Table 7.2. Tasbas presence/absence of economically significant plants

Of the domesticated cereals, wheat (*Triticum* sp.), barley (*Hordeum vulgare*) and both millets (*Panicum miliaceum* and *Setaria italica*) have been identified from the Tasbas samples, and millet identified from Dali. Where species identification of millet was possible, *Panicum miliaceum* proved to be the dominant species, with *Setaria italica* identified positively in only one sample (2011-088) and tentatively in one other (2011-104). Wheat was identified positively in 3 samples (2011-93, 2011-100, 2011-226), and tentatively in 2 other samples (2011-90 and 2011-218). Barley was identified positively in 2 samples (2011-235 and 238), with a further 2 samples containing tentative identifications (2011-234 and 237). Further identifications of barley and the other cereals may be made once reference material is re-consulted in light of these firm identifications, since a conservative approach to identifications has been adopted.

The presence of Cyperaceae (sedge) phytoliths in the majority of samples, in combination with their absence from the offsite topsoil and subsoil samples indicates that sedges were brought into the site for some of their many uses such as in weaving and basketry, floor covering, thatching, fencing and rope making. Sedges are generally associated with poor soils or marshy lands. Phytoliths of *Phragmites australis* lend weight to the interpretation that nearby marsh lands were exploited for their plant species. *Phragmites australis* has many economic uses, which include thatching, matting and basketry. The presence of *Phragmites australis* at Tasbas is not at all surprising, given that in the present day at least reed beds are found a very short distance from the site on the lowest terrace, making it a very convenient and abundant resource. Although present within the immediate vicinity of the site, it is unlikely that *Phragmites australis* was growing on and around the settlement itself, since its elevation and position on well-drained moraine makes it highly unsuitable for reed beds. It is therefore reasonable to assume that the presence of *Phragmites australis* at the Tasbas settlement is due to anthropogenic deposition.

7.2.3.1.Spatial patterning in phytoliths

First, the samples taken as a transect across a floor indicate differing activity areas across the floor itself (2011-100 to -105). There appears to be a concentration of millet and wheat husk phytoliths in sample 2011-100, a concentration which reduces on a gradient away from the sample as the samples move across the floor. This is also supported by comparing the ratio of psilate : dendritic single celled phytoliths as shown in Figure 7.18. Psilate (smooth) single cell phytoliths are found in the leaf or stem part of a plant, while dendritic phytoliths are found on the husk. Looking at samples 2011-100 to 105 on the graph, it would appear that the proportion of dendritic single cells compared to psilate single cells decreases from a high in sample 2011-100 as one moves through the transect. A pattern of decreasing concentration of phytoliths (measured in number per gram of sediment) is also seen when comparing the count of all single celled phytoliths in each sample. This apparent concentration of wheat and millet phytoliths could represent an area where crop processing was taking place, or be the result of floor sweepings being concentrated in one area. A small number of faecal spherulites (most commonly produced by sheep) were noted in sample 2011-100, with a slightly smaller number noted in sample 2011-103, which could be consistent with the sweeping of debris to one side of an occupation floor.

It is interesting to note that the three samples representing the contents of an oven (2011-229, 2011-230, 2011-231) contained no multi-celled phytoliths of domesticated cereals, although macrobotanical remains of barley have been identified from this context (Doumani *et al.* 2015). This is most likely due to the fact that only clean grain was came into contact with the oven, since it is the outer protective husk of the seed which yields diagnostic phytoliths, while the seed itself does not. Further analysis is required before a satisfactory explanation can be reached. Sample 2011-229 has the highest ratio of dendritic to psilate single cells amongst the samples. This was noted as being the contents of an oven and that the sample included mud brick. It is possible that the large proportion of dendritic phytoliths represents the use of chaff as temper in making mud bricks, or its use as fuel in the oven. It is also possible that livestock were fed the chaff and other crop processing waste, and then the dung was used as temper and fuel. This may explain why no articulated multi-cells of domesticated cereals were identified.

7.2.3.2. Oven 109b

Three samples taken from oven feature 109b (2011-229, 2011-230 and 2011-231) were compared. Sample 2011-229 included mud brick from the structure of the oven, whereas 2011-230 and -231 were both taken from the oven contents itself. Barley grains were identified in the macrobotanical samples from 2011-229 (FS22) and 2011-230 (FS17). The phytolith samples were very different in character, and a firm identification of multi-celled barley phytoliths was only obtained from sample 2011-229. The phytoliths from samples 2011-230 and -231 proved to be far more disarticulated than those in 2011-229, making a firm identification of any multi-celled husk phytoliths extremely difficult. Both 2011-230 and -231 had a high number of mineral inclusions compared to -229, in addition to far fewer multi-celled phytoliths per gram. 2011-229 displayed a large and varied number of multi-celled phytoliths from both the husk and the culm/leaf part of grasses, indicating that the whole plant was used in the production of the mud brick. The degraded and disarticulated nature of the phytoliths in samples 2011-230 and -231 could be due to the use of dung as fuel, meaning that phytoliths suffered both mechanical and chemical degradation before being burnt in the oven. The phytoliths from the mud brick are far less degraded, and the sample presented silica skeletons consisting of a large number of articulated plant cells. This might be an indication that fresh plant matter rather than dung was used in the production of the mud brick. The phytolith assemblage for this sample is consistent with the use of crop processing waste as temper in the mud brick, where the discarded chaff and straw is used. The presence of a large number of barley grains identified from the macrobotanical sample and visible embedded within the mud brick is perplexing, since one would expect that the grains themselves would be conserved for either human or animal consumption. The presence of barley grains in the oven contents but the lack of barley husk phytoliths will be discussed later in this thesis, however the disarticulated nature of the phytoliths from samples of the oven contexts, perhaps contributed to the fact that barley husk phytoliths could not be firmly identified in the sample.

7.2.4. *Turgen*

Phytolith samples analysed from Turgen come from two different locations on the site: the floor of a temporary dwelling, dated through ceramics to the Early Iron Age, and a section in the excavation wall that was cleaned back to provide a full stratigraphic sequence for the site. The section in the excavation wall included a large ash and charcoal dump/fire pit and an associated spread of burnt earth mixed with ash that appears to lie just below the upper floor surface of the dwelling.

below lists the presence or absence of the economically significant plants that have been identified from each sample in Turgen.

Phase	***Context***	***Sample no.***	**Wheat**	**Barley**	**Millet**	***Setaria***	***Panicum***	***Phragmites australis***	**Cyperaceae**	**Wild grass husk**
Matrix	*Matrix*	*2011-165*								
Phase 1	*Fill of pit/post-hole*	2011-166							X	X
	Post-hole fill	2011-167							X	
	Post-hole fill	2011-168							X	X
Phase 2	Floor/Fill	2011-169								
	Floor/Fill	2011-171							X	
	Floor/Fill	*2011-172*							X	X
	Fill/matrix layers	*2011-191*							X	
	Fill/matrix layers	*2011-192*							X	X
Phase 3a	Ash	2011-174			X				X	
	Ash	2011-175							X	
	Ash/Clay	*2011-176*								X
	Ash	2011-183			X	X			X	
	Ash	2011-184			X				X	
	Ash spread	*2011-187*								
	Ash spread	*2011-189*					?		X	
Phase 3b	Floor	2011-148							X	X
	Floor	2011-149							X	X

Phase	***Context***	***Sample no.***	**Wheat**	**Barley**	**Millet**	***Setaria***	***Panicum***	***Phragmites australis***	**Cyperaceae**	**Wild grass husk**
	Floor	2011-150							X	X
	Floor	2011-151							X	X
	Floor	2011-152								
	Floor	2011-153							X	
	Floor	*2011-154*								
	Floor	*2011-155*							X	
	Floor	*2011-156*	?						X	
	Floor	*2011-157*							X	
	Floor	*2011-158*							X	
	Floor	*2011-159*								
	Floor	*2011-160*								
	Floor	*2011-161*								
	Floor	*2011-162*			?				X	
	Floor	*2011-163*							X	
	Floor	*2011-164*	?							
	North of 'corridor'	*2011-193*								
	South of 'corridor'	*2011-194*								X
Phase 4	*Fill*	*2011-177*							X	
	Fill	2011-178							X	
	Fill	2011-186							X	X
Phase 5	Fill	2011-179							X	
Phase 6	*Fill below kurgan*	*2011-185*								
Onsite topsoil	Topsoil	2011-182								
Offsite	*Offsite topsoil*	*2011-195*								
	Offsite subsoil	*2011-196*								

Table 7.3. Turgen presence/absence of economically significant plants

The phytolith assemblage from Turgen is dominated by the leaf/stem and husk parts of grasses, and indicates that the site was occupied during the summer months, due to the presence of husk parts from grass inflorescences in all archaeological samples. The grass short cell phytoliths mostly consist of rondel and trapezoid forms associated with Pooid grasses (Twiss 1992), which are adapted to cool, moist environments, although it is interesting to note that in two of the floor contexts bilobe short cells were identified, albeit in very small numbers. Bilobe forms are only found in the Panicoid subfamily, and their presence may indicate the transportation of plant material from outside the area to the site, or provide evidence for the presence of the Panicoid grass *Setaria italica*. However, due to the very small number of bilobes and their isolated presence, caution must be exercised in any interpretation, and these data alone are not enough to support a firm interpretation.

In addition to grass phytoliths, evidence for woody plants is present in the form platey and polygonal forms. While some single cell platey forms are found in the floor contexts, no multi-celled phytoliths indicative of woody plants were identified in these contexts. This is in contrast to the ash/charcoal contexts, where both single and multi-cell phytoliths of woody plants were identified. All burning contexts also contained phytoliths from sedges. This assemblage indicates the use of a mixed fuel of woody plants, grasses and sedges, with the grasses and sedges either being burned as gathered plants, crop processing waste, or animal dung. Two contexts in the ash/charcoal deposit of Phase 3a contained phytolith multi-cells that appear to come from the glume of millet, and in one sample the silica skeleton of a *Setaria italic* glume fragment was identified. *Setaria* has a very short growing season of 60 – 120 days, low water requirements, and can be cultivated to an altitude of 3300m asl (Brink 2006). Landraces from the north-west and Inner Mongolian plateau have been found to be adapted to cold weather and a short growth period at high altitude (Wang *et al.* 2012). It is therefore possible that *Setaria* was cultivated here as part of a strategy of seasonal occupation, an interpretation reinforced by the presence of grinding stones and pestles, although this does not preclude the additional exploitation of wild cereal resources in the vicinity.

7.3. **Ubiquity**

The calculation of taxon ubiquity across archaeological contexts is a useful way to assess the relative abundance of a particular taxon at the sites in this study. It measures recurrence, i.e. how often a plant type is present in different contexts (Hubbard 1975). It allows a quantitative comparison of taxa between sites that is less influenced by the effect of pre-depositional phytolith formation and post-depositional taphonomic processes on total phytolith count. In addition it is a useful method by which to gain an overview of the abundance of taxa on sites as a whole and by phase (Pearsall 2000, 212). Of course, the absence of multi-celled phytoliths within a sample could simply be a product of poor silica skeleton production, weak bonds between cells or strong mechanical and chemical disturbance following deposition resulting in few to no multi-cells being preserved. As with any archaeological dataset these issues in preservation must be borne in mind during any analysis of the samples. In the same way that it is applied to macrobotanical remains, ubiquity analysis can be most meaningfully applied to those multi-celled phytoliths that have been firmly identified as belonging to a particular species, genus or family, in particular phytoliths from plants of economic significance such as those cultivated for food or used in craft and construction.

Ubiquity is an expression of the presence or absence of a taxon in different contexts on a site, and can be calculated for the site as a whole or for different phases within a site. It is calculated using the following formula:

$$\text{Ubiquity} = (np/nc) \times 100$$

Where np is the number of contexts in which a given taxon is identified, and nc is the total number of contexts examined (after Johannessen 1984). By calculating ubiquity rather than using absolute counts of multi-celled phytoliths, problems pertaining to the pre- and post-depositional fragmentation of plant silica skeletons can be mitigated for. Of course, the number of contexts sampled impacts upon the usefulness of ubiquity as an expression of the distribution of plant species at a site, with very small samples having the potential to offer misleading results. However with this caveat in mind, ubiquity is a useful method of analysis and adds another dimension to interpretations of plant and landscape use at archaeological sites.

The ubiquity of economically significant plants was calculated for those species or families whose presence in each archaeological sample could be identified from multi-celled phytoliths. Only multi-celled phytoliths that could be identified with confidence were included in the calculation of ubiquity, although some possible identifications are also discussed here where significant. In total seven different economically significant types were identified from the multi-celled phytoliths across the three sites in this study. Of the domesticated cereals, wheat, barley, foxtail millet and broomcorn millet were positively identified in the samples. In addition to these more specific identifications, a further category of 'millet' was also recorded where the morphological characteristics of the multi-celled phytolith were sufficient to identify the presence of either broomcorn (*Panicum miliaceum*) or foxtail (*Setaria italica*) millet, but not sufficient to differentiate between the two species (following the identification criteria of Lu *et al.* 2009; Weisskopf and Lee 2014). In the case of millets, ubiquity is therefore recorded here at two levels. If a sample contained either *Setaria*, *Panicum* or an indeterminate millet, it was first recorded as containing 'millet' as a general category. Those samples that contained identifiable taxa were then also recorded separately in order to allow comparison of the presence of the two species where possible. This is a good example of why ubiquity is a useful tool for the analysis of these types of data. The inability to identify every multi-celled phytolith in a sample as belonging to a particular taxon due to its localised morphology (as demonstrated by Lu *et al.* 2009) does not impact upon meaningful numerical analysis of the data. This point is particularly pertinent to phytolith analysis, where in many cases the cell count or morphology of a particular multi-cell may not be sufficient to assign it a firm identification, which would then lead to an inaccurate representation of the number of multi-celled phytoliths from a particular taxon present in a sample. Calculating ubiquity rather than using absolute counts of multi-celled phytoliths is one way to mitigate for this potential inaccuracy.

As well as food crops, phytoliths from two plants associated with craft and construction were also identified in the samples: those from the common reed (*Phragmites australis*) and multi-celled phytoliths from the sedge family (Cyperaceae). Details about the identification criteria employed to reach these positive identifications can be found in the methodology chapter. Only the archaeological contexts are included in the ubiquity calculations since the modern samples are not relevant to this method of analysis. Unsurprisingly, the taxa included in this analysis were not found in any of the onsite or offsite modern natural contexts, with the exception of phytoliths from Cyperaceae, species of which were noted to be growing in the immediate environs of the sites and the offsite sections when the samples were collected.

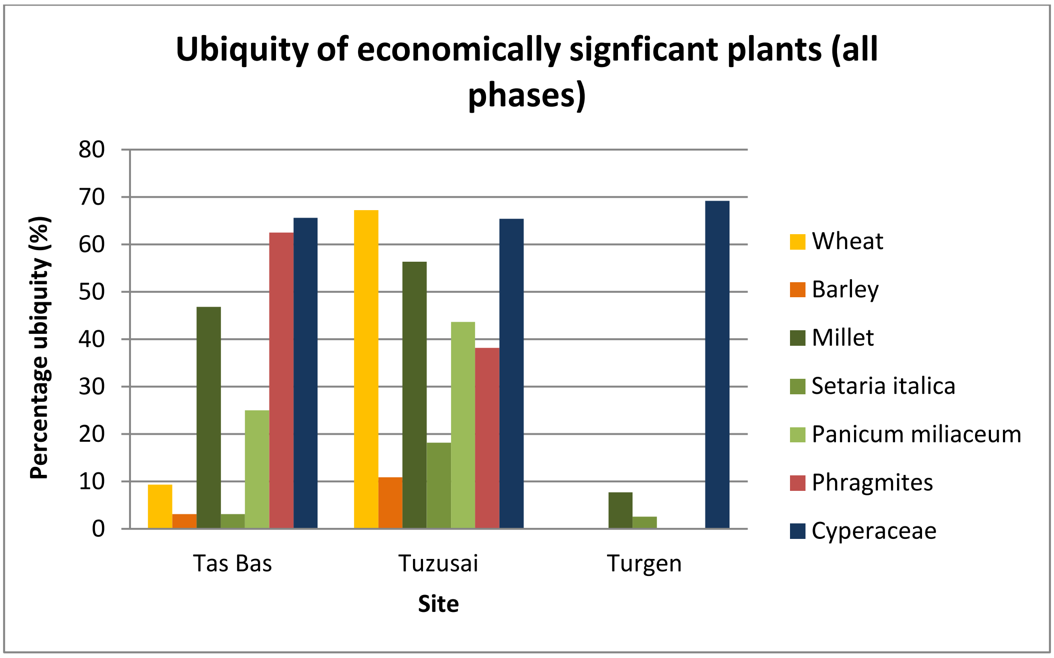


Figure 7.8: Ubiquity of economically significant plants for all sites

7.3.1. *Cultivated cereals*

As can be seen in Figure 7.8, which shows the ubiquity of economically significant plants for all archaeological contexts at the three sites, there is a marked difference between the ubiquity of cereal crops at Tasbas and Tuzusai and those at Turgen. The only cereal to have been identified at Turgen is *Setaria italica*, and that was present in only one sample (2.6% ubiquity), with non-specified millet having 7.6% ubiquity, being present in 3 samples. When compared to the 46.9% ubiquity of millets at Tasbas and 56.3% ubiquity at Tuzusai, it is evident that domesticated cereals of any kind were not at all common at Turgen, with millet, most likely only *Setaria* italica, being brought into the site rarely and present in only a very small number of contexts. In contrast, both Tasbas and Tuzusai indicate a heavier exploitation of cultivated cereals, with *Panicum miliaceum* being the dominant taxon at Tasbas (25% ubiquity), and wheat being most prevalent at Tuzusai (67.2%).

It is interesting to note that the same 'package' of cereals is present at both Tuzusai and the earlier site of Tasbas, with wheat, barley, *Panicum* and *Setaria* all having been recorded at the two sites. However, overall ubiquity of these cereals is much lower at Tasbas. In a phytolith assemblage, the presence but low ubiquity of a particular cereal taxon reflects the lack of husk parts (lemma and palea), which produce the diagnostic multi-celled phytoliths for these taxa, as opposed to the unhusked grain analysed in macrobotanical analysis. Possible explanations for low ubiquities of certain taxa at Tasbas are that: a) these cereals could have been cultivated in the environs of the site but processed away from the domestic contexts from which the samples in this study were collected and crop processing waste was not re-used or burnt on site; b) these cereals were cultivated elsewhere and only clean grain was brought to the site; or c) these cereals formed a very small component of the diet of the people of Tasbas and therefore only small quantities were brought into the site. It is likely that the real reason behind these lower ubiquities is a combination of these factors, and that these cereals played a less important role in diet than at the later site of Tuzusai. As well as lower overall ubiquities, Tasbas and Tuzusai show differing emphasis on the four taxa. At Tasbas the dominant crop is *Panicum* (25% ubiquity) with wheat, barley and *Setaria* forming a far smaller component of the assemblage (9.4%, 3.1% and 3.1% respectively). At Tuzusai a different assemblage composition is found, with wheat being the dominant cereal (67.2% ubiquity), followed by *Panicum miliaceum* (43.6%), then *Setaria italica* (18.2%) and finally barley (10.9%). These ubiquities data do not show changing quantities of each cereal taxon, but rather reflect the overall distribution of these different cultigens at a site. Using wheat as an example, it cannot be said from these data that 'more' wheat was being processed and consumed at Tuzusai than at

Tasbas, but rather that wheat, or the processing waste from wheat, was more widely distributed at Tuzusai, appearing in a majority of contexts and demonstrating that it was more commonly brought to the site and deposited in a variety of contexts than at Tasbas. These differences in distribution could reflect either changing practices in the use, distribution and disposal of crop processing waste, and/or they could show the increasing abundance and availability of wheat into the Iron Age. The presence of wheat in only 9.4% of the contexts examined at Tasbas implies that when brought to the site, either as grain or crop processing waste, wheat was more carefully controlled than at Tuzusai, and its deposition took place in a small number of contexts.

7.3.2. ***Phragmites australis* and Cyperaceae**

The two other economically significant plants to have been identified in the samples were multi-celled phytoliths from the common reed (*Phragmites australis*) and from the sedge family (Cyperaceae). Both these taxa have uses in craft and construction ranging from matting and basketry to roofing, fuel and temper (Hurcombe 2014: 41, 113, 136). The presence of multi-celled phytoliths from Cyperaceae were not too surprising since they are found in the environs of all three of the sites in this study, and since the phytolith identification can be made only as far as the family level (with a couple of exceptions such as *Scirpus* sp.) a firm link between their presence on a site and anthropogenic factors is not immediately certain. It is perhaps telling that the ubiquities of Cyperaceae at the three sites is similar, with 65.6% ubiquity at Tasbas, 65.4% at Tuzusai, and 69.2% at Turgen. However, in archaeological contexts the most likely pathways of deposition are either their use by humans for activities such as basketry (Hurcombe 2014: 41) or their deposition on the site through animal dung, reflecting grazing practices.

7.3.3. ***Ubiquities on individual sites***

7.3.3.1.Tuzusai

Tuzusai displays the highest presence of domesticated cereals across all phases, with wheat found in 67.2% of the samples analysed, *Panicum miliaceum* in 43.6% of samples, *Setaria italica* in 18.2% (unspecified millet was found in 53.6% of samples) and barley in 10.9% of samples. Since it is the inflorescence of the grass that produces the diagnostic multi-celled phytoliths this implies that the majority of households had access to either wheat grain or crop processing waste. The presence of crop processing waste implies that these cereals were being cultivated in the environs of the site, and the chaff could have found its way into the household either in association with grain to be consumed, or through secondary usage such as the use of chaff as animal fodder and the subsequent burning of dung as fuel, or direct burning of chaff as fire kindling. Another use for crop processing waste is as temper in construction materials. Evidence for the use of processing waste from wheat at Tuzusai can be found in the presence of wheat phytoliths in mud brick samples (2011-216, 2011-218) and a plaster floor (2011-032–2011-034), lending support to the interpretation that wheat was being cultivated at the site, since it would appear that crop processing waste was present in large enough quantities to warrant its use in mud brick, a building material usually made within the immediate vicinity of the building to be constructed. Wheat firmly identified in domestic contexts (as opposed to fill layers, indeterminate contexts such as ash spreads or construction materials) at Tuzusai is found in floors (2011-017, 2011-027, 2011-029, 2012-013), hearths (2009-044, 2009-065, 2009-065, 2011-212, 2011-240) and pit fills (2011-007, 2009-051).

When the ubiquity calculation is presented by phase (Figure 7.9), it would appear that overall ubiquity of the main cereal crops falls across the site from Phase 1 to Phase 5. In the case of Phase 6 the effects of the sample size on the calculation can be seen, as only one sample was taken from this phase (2012-013), meaning that ubiquity for this phase can only be expressed as 0 or 100%. This fall in ubiquity over time does not necessarily indicate a fall in the abundance of the cereal crops at the site in absolute terms, but rather reflects their presence in fewer contexts over time. It is possible that this fall is an artefact of the samples taken, since samples from the later phases (Phases 4–6) include more samples from floors and areas of burning as opposed to firmly identified hearths and the fill of pit houses. However, it is also possible that the presence of crop processing waste in fewer contexts represents a change in the way in which such waste was brought into and used at the site. For example, it may represent a shift from crop processing in and around the home to processing in a specialised central area away from the settlement, with only clean grain being brought into domestic contexts.

In contrast to the cereals, the presence of *Phragmites australis* in contexts at Tuzusai does not show such a strong decline in ubiquity over time, with ubiquity hovering at around 50% at the main site for Phases 1, 2, and 4, while reaching a low of 15.4% in Phase 3. This is in contrast to the presence of phytoliths from Cyperaceae on the site, which shows an increase in ubiquity in later phases, and a steady presence in c.50–60% of contexts in Phases 1–3. The increasing prevalence of phytoliths from this family could well be an indicator that conditions around the site became cooler and damper in later phases, with sedges becoming more abundantly available for exploitation in the vicinity of Tuzusai, as well as occurring naturally on the site.

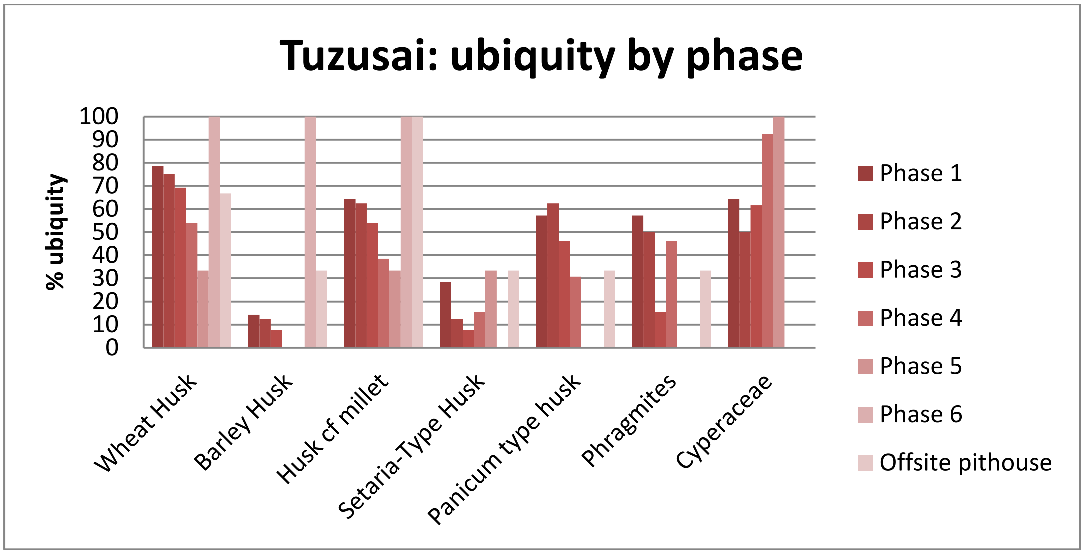


Figure 7.9: Tuzusai ubiquity by phase

7.3.3.2.Tasbas

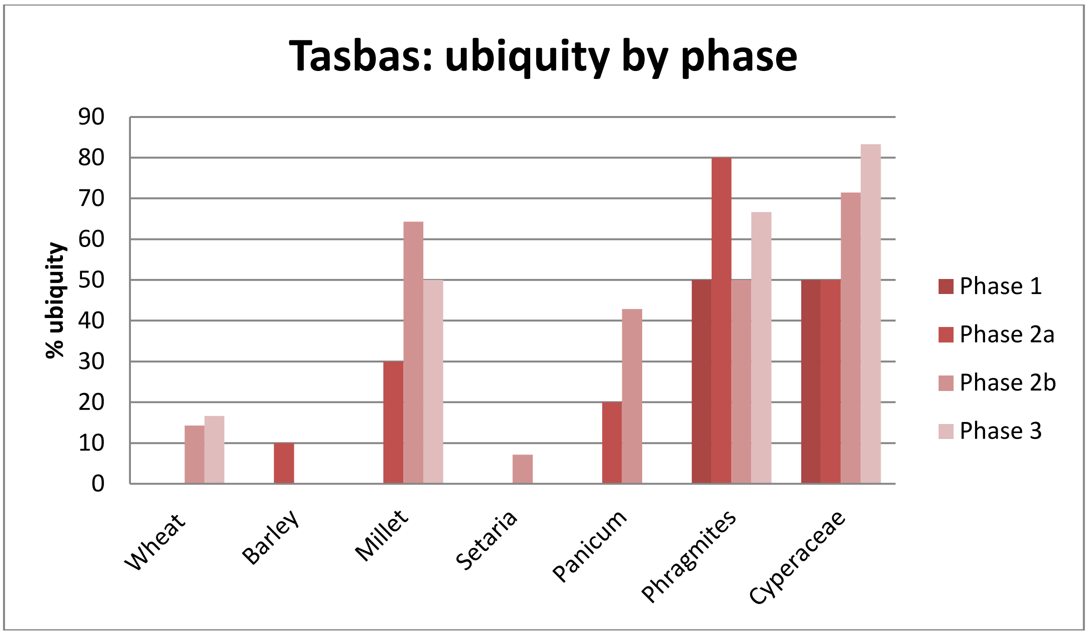


Figure 7.10: Tasbas ubiquity by phase

As can be seen from Figure 7.10, domesticated cereals were not identified in all phases in the contexts examined at Tasbas, however they were all identified at the site at some point in its occupation history. Multi-celled phytoliths from both *Phragmites australis* and Cyperaceae were identified in all phases. Wheat (*Triticum aestivium/turgidum*) was identified in contexts in phases 2b and 3, showing a very slight rise in ubiquity between Phase 2b to Phase 3 (14% to 17%). It was not identified in phases 1 or 2a, although very low numbers of wheat grains were identified in the macrobotanical assemblage for these phases (Doumani *et al.* 2015). Multi-celled phytoliths from barley (known to be *Hordeum vulgare var. nudum* from the macrobotanical remains) were only identified in Phase 2a, with 10% ubiquity. This is in contrast to the findings from the macrobotanical analysis for this phase, where the ubiquity of barley grains from floated samples was 80% (*ibid.*). This discrepancy between the phytolith and macrobotanical data demonstrates a difference in distribution and deposition between clean, de-husked grain and barley husks at the site (the multi-celled phytoliths of which may represent either whole panicles brought to the site for storage or crop processing waste), since it is the husk of the cereal that produces diagnostic phytoliths. This highlights that phytoliths and macro-remains, while they both indicate the presence of the same crops, actually record the evidence for different crop-related activities and residues, with phytoliths perhaps providing a clearer picture of some crop-processing stages by virtue of not requiring charring for preservation (see Harvey and Fuller 2005).

Multi-celled phytoliths from millet (either *Setaria italica* or *Panicum miliaceum*) were identified in phases 2a, 2b and 3, with 30% ubiquity in Phase 2a, 64% ubiquity in Phase 2b, and 50% ubiquity in Phase 3. For instances where it was possible to identify the multi-celled millet phytoliths to species level, the pattern of the rise in ubiquity for *Panicum miliaceum* reflects that of the unidentified millet in phases 2a and 2b, with ubiquity rising from 20% in Phase 2a to 43% in Phase 2b. Phytoliths from *Setaria italica* were firmly identified only in Phase 2b, and ubiquity is low, being present in only 7% of samples. A comparable picture is also seen in the macrobotanical remains from Phase 2a, where very small numbers of grains from *Setaria* were identified in three contexts (counts of 5, 5, and 1), representing 27% ubiquity in the flotation samples, with no grains being identified in Phase 1. This low ubiquity in the phytolith data indicates that *Setaria italica* husks were only present in very few contexts at the site, and combined with the macrobotanical remains the evidence points to limited exploitation of *Setaria italica* at Tasbas. The similarity between changes in the pattern of ubiquity for the category of 'millet' (which includes firmly identified multi-celled phytoliths of both millet species and phytoliths where a distinction could not be made between *Panicum miliaceum* and *Setaria italica* using the criteria outlined in Lu *et al.* 2009) and the changes in the ubiquity of *Panicum miliaceum* in phases 2a and 2b indicates that it is reasonable to assume that the majority of the unclassified multi-celled millet phytoliths from Tasbas are of *Panicum* rather than *Setaria*. This is further reinforced by the low ubiquity of *Setaria italica* in both the phytolith and macrobotanical data. The rise in the ubiquity of millet from Phase 2a to 2b indicates that the husk parts of millet became more widespread throughout the various contexts at the site in the latter part of Phase 2, being identified from floors as well as in scatters and dumps of ash, which could be the result of both deliberate and accidental burning events. This indicates that during the latter part of Phase 2 millet husks, either in the form of whole panicles or the waste chaff from processing the cereal, became more widely deposited across the site. This could be the result of millet becoming more extensively exploited in the latter part of the Phase, with a greater quantity being brought to the site for processing, resulting in a wider distribution of millet husks across a variety of contexts. On the other hand, since the phytolith data reflects only the presence of husks rather than whole grains, this increase in ubiquity could also be evidence of a change in the location of where the millet crop was processed, with more processing happening on the site, resulting in the deposition of crop processing waste in a wider variety of contexts. It is also possible that in addition to human consumption, millet was also increasingly used in the latter part of Phase 2 as animal fodder, with the dung then being used as fuel on the site, therefore becoming a pathway for the deposition of millet husk phytoliths in the ash contexts that were examined. This additional pathway for the deposition of millet phytoliths may explain the increase in ubiquity of millet at the site in Phase 2b. In Phase 3 the ubiquity of millet decreases from 64% to 50%, however far fewer phytolith samples were analysed from Phase 3 than phases 1 and 2, and caution must be exercised in interpreting this result. With this caution in mind, it is possible to say that millet was certainly still being exploited at Tasbas during this period, and that there was not a dramatic fall in its ubiquity across the site from Phase 2b to Phase 3. The three samples that were found to contain millet were all from a large layer of burnt organic matter with carbonate inclusions. This layer represents discarded domestic ash and the deposition of other household rubbish associated with the ephemeral nature of the occupation of Tasbas during this phase (Doumani *et al.* 2015).

The lower presence of crop processing waste as opposed to clean grain on the site is also reflected in the macrobotanical data, where cereal rachises were present in 45% of macrobotanical samples from Phase 2a, while cereal grains had over 90% ubiquity for the phase (Spengler, reported in Doumani *et al.* 2015). Unfortunately, similar comparison between the macrobotanical and phytolith data for phases 2b and 3 is not possible, since flotation samples were only processed for phases 1 and 2a.

Multi-celled phytoliths from *Phragmites australis* and Cyperaceae were found in all phases. In Phase 1, *Phragmites australis* is present with 50% ubiquity, rising to 80% ubiquity in Phase 2a, 50% in Phase 2b and climbing again to 67% in Phase 3. As discussed above, due to the nature of the location of and subsoil beneath the settlement it is more likely that the presence of *Phragmites australis* reflects human-induced deposition (either through the direct collection and use of *Phragmites australis* for craft and construction, or as a result of foddering practices and subsequent importation of dung to the site) rather than natural vegetation growth. Although showing variation between phases, the consistent presence of multi-celled phytoliths from *Phragmites australis* at 50% ubiquity or above indicates that reeds were commonly exploited at the site in all phases. The ubiquity of phytoliths from Cyperaceae (sedges) at the Tasbas settlement is slightly more difficult to interpret, since their presence could reflect either natural or anthropogenic deposition. During the collection of samples in the field, sedges were observed growing around the settlement, and are known to be part of the vegetation profile of the sub-alpine cereal steppe meadow zone in which Tasbas is located (Kotov 1960, 232). There are therefore three pathways by which sedges could make their way into archaeological contexts at Tasbas: natural growth, particularly during periods of site abandonment; human collection for domestic use, such as floor matting; and animal dung, where animals have been grazed in the environs of the site and dung collected for use as fuel and in construction. Although it is difficult to disentangle these three pathways with regards to ubiquity, it is interesting to note that in the later phases 2b and 3 there is a rise in the ubiquity of phytoliths from Cyperaceae (from 50% in phases 1 and 2a to 83% in Phase 3). This corresponds to a fall in the ratio of phytolith morphotypes from 'woody' dicotyledons to those from grasses found at the site (discussed below in the section 'Climatic Indices'). These two factors together may indicate an increasing reliance on the use of dung as fuel, together perhaps with a change in foddering and grazing practices, resulting in the more widespread deposition of Cyperaceae in the settlement.

7.3.3.3. Turgen

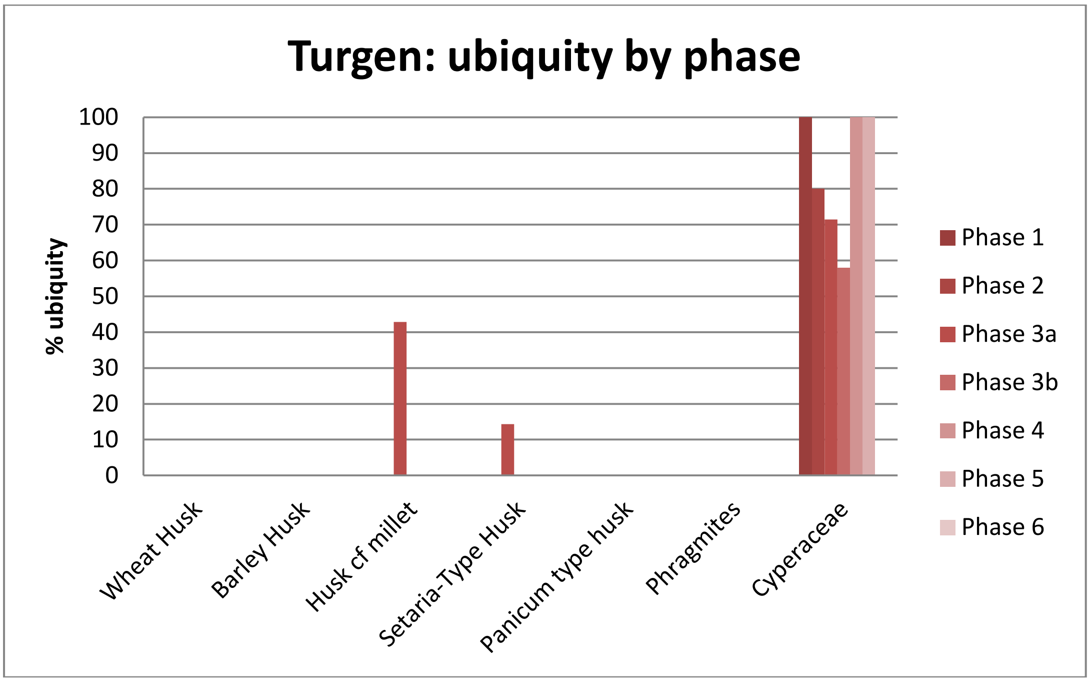


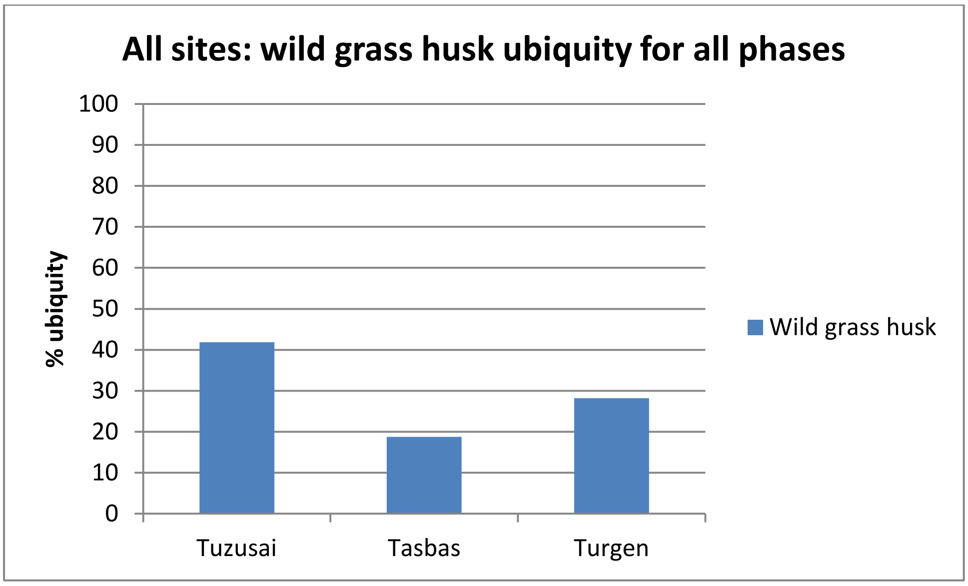
Figure 7.11: Turgen ubiquity by phase

As can be seen from Figure 7.11, the only cereal phytoliths to have been firmly identified at Turgen appear to belong to *Setaria italica*, with other multi-celled phytoliths identified as belonging to millet, with more precise identification not possible. Figure 7.11 shows that if both those phytoliths identified as unspecified millet and those identified as *Setaria* are combined for the ubiquity calculation, the ubiquity for this cereal is 43% in Phase 3a, with no other phases identified as having any domesticated cereals present. This overall low presence of millet, and indeed any other domesticated cereal at Turgen, indicates that the exploitation of *Setaria italica* by the occupants of the settlement was short-lived, only occurring during one phase of occupation. Unfortunately, due to the nature of the site, Phase 3a is represented only by a large ashy deposit, which was sampled in several places. It appears to lie at a level immediately below the living surface of Phase 3b, and may therefore be a pit that was contemporaneous with Phase 3b. The 43% ubiquity of what appears to be *Setaria italica* is therefore an indication that the overall presence of phytoliths from *Setaria italica* was very low. It is possible that this presence may represent the small-scale exploitation of this fast-growing crop as a supplement to a summer diet in the high mountain pastures which consisted of mainly wild resources and meat from herd animals.

As can be seen from Figure 7.11, multi-celled phytoliths from Cyperaceae were present at the site in all phases at over 50% ubiquity, with 100% ubiquity in phases 1, 4, and 5. Since sedges are part of the alpine steppe vegetation profile in the environs of Turgen (Kotov 1960, 232), there are many pathways by which these plants could be deposited at the site. Since it appears that Turgen is a seasonal 'camp site' settlement, natural growth of sedges at the site once abandoned is entirely possible, together with the deposition of dung from animals grazed in the surrounding meadows, and the domestic use of sedges such as for matting. It is interesting to note that the lowest ubiquity of sedges is represented in Phase 3b, which represents the living surface of the settlement. It may be, therefore, that phases 1, 4 and 5 represent periods of more ephemeral occupation of the site, where the natural vegetation was incorporated into the archaeological deposits.

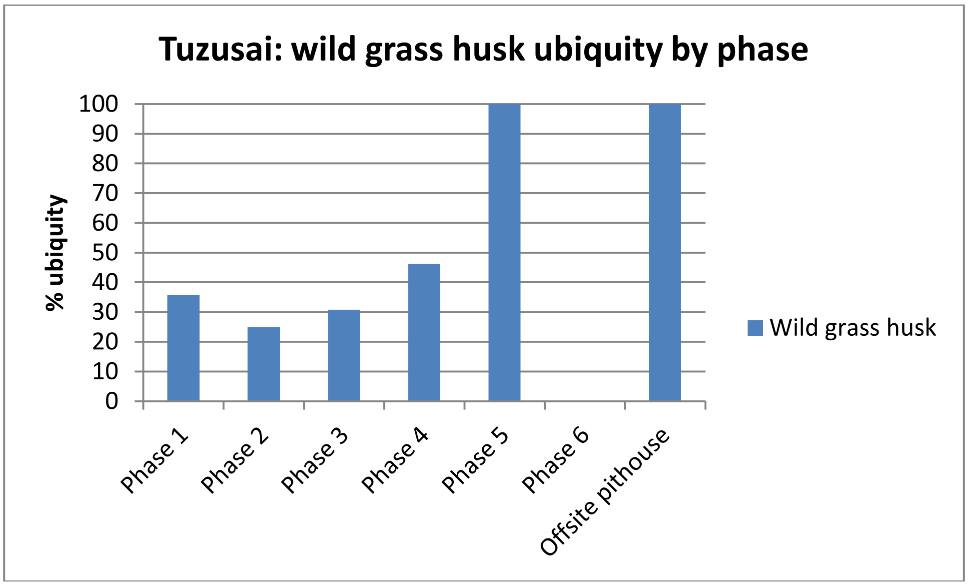
7.3.4. ***Wild grasses***

The following graphs demonstrate the ubiquity of those phytoliths identified as coming from the husks of wild (small seeded) grasses (for identification criteria see Methodology). These have been included for comparison with the ubiquities of domesticated cereals, however it must be stated that much more research is needed in the future to build a phytolith reference collection for this region of Central Asia in order to provide more confident identifications phytoliths from both wild and domesticated plants (a case in point is the identification of rice (*Oryza sativa*)). These data also exclude those multi-celled phytoliths that were left unidentified during counting, and given descriptive names to aid their future identification. Those phytoliths may come from either wild or domesticated plants, but it was not possible to make a positive identification within the scope of this project.



7.12. Ubiquity of wild grass husks for all phases

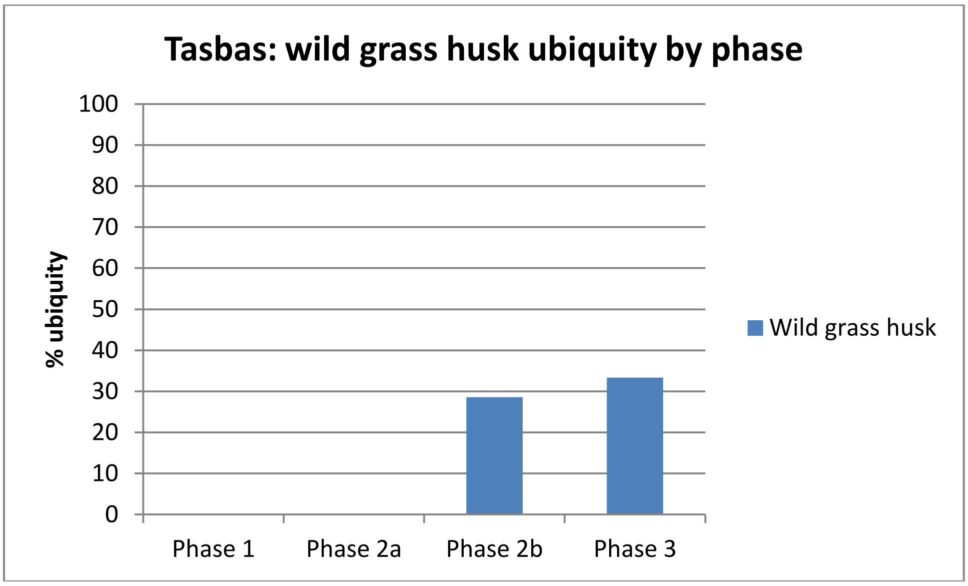
7.3.4.1.Tuzusai



7.13. Tuzusai: ubiquity of wild grass husks by phase

The ubiquity of wild grass husks at Tuzusai ranges from 0 – 100 %, with the highest ubiquity being in Phase 5 (100%) and at the offsite pithouse (also 100%). Two of the contexts from Phase 5 were a dump of burning waste and burned soil. The presence of wild grass husks in these contexts likely represents dung being burned as fuel. There is a trend for the increasing presence of wild grass husks from phases 2 – 5, ranging from 25 – 100% ubiquity. The absence of wild grass husks from Phase 6 is an artefact of a very small sample number representing this phase (only one context), however the lack of evidence for wild grasses in this context is noteworthy, since this was a mud brick platform possibly used for the preparation of food, as indicated by the large numbers of animal bones and broken ceramics deposited on its surface (Chang pers. comm.).

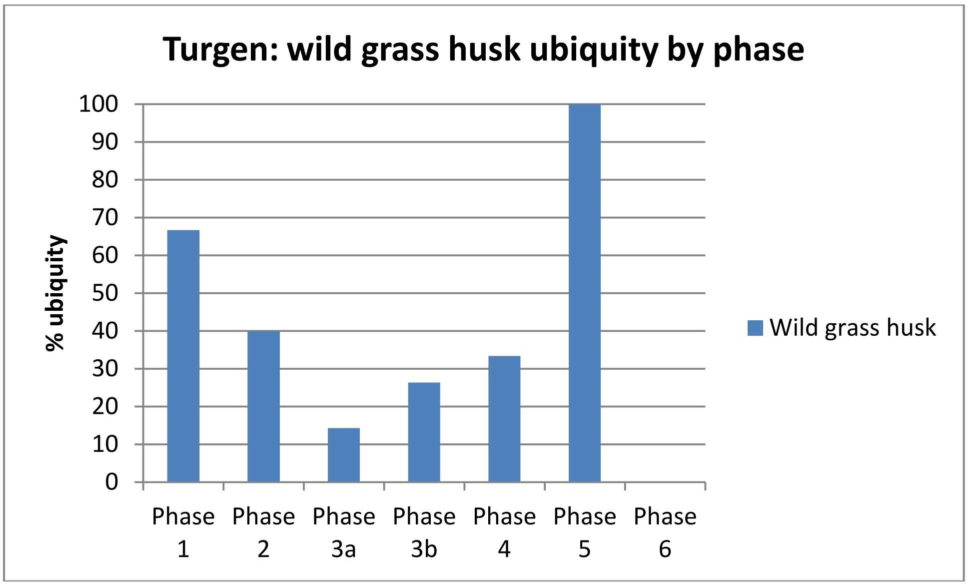
7.3.4.2.Tasbas



7.14. Tasbas: Ubiquity of wild grass husks by phase

No wild grass husks were identified in phases 1 and 2a at Tasbas, with their ubiquity in phases 2b and 3 being 28.6% and 33.3% respectively.

7.3.4.3.Turgen



7.15. Turgen: ubiquity of wild grass husks by phase

Wild grass husks were identified in nearly all phases at Turgen, with the exception of Phase 6. It is interesting to note a steady fall in the ubiquity of wild grasses from phases 1 to 3a (from 66.7% to 14.3%). All samples from Phase 5 were found to contain wild grass husks.

7.4. **Proportion of elongate psilate to dendritic phytolith morphotypes**

The proportion of elongate psilate to dendritic phytolith morphotypes can be used as an indicator of the relative deposition of the culm/leaf and seed bracts of grasses in archaeological contexts. This is because these morphotypes are found only in these respective anatomical positions (Ball *et al.* 1996; Piperno 2006; Rosen 1999). The graphs below (Figures

Figure 7.16,

Figure 7.17 and Figure 7.18) represent a summary by phase of the proportion of elongate psilate to dendritic phytoliths at each of the sites in this study, expressed as a percentage. Note the scale of the graphs, ranging from 50 – 100%, since elongate psilate phytoliths were far more abundant in all samples.

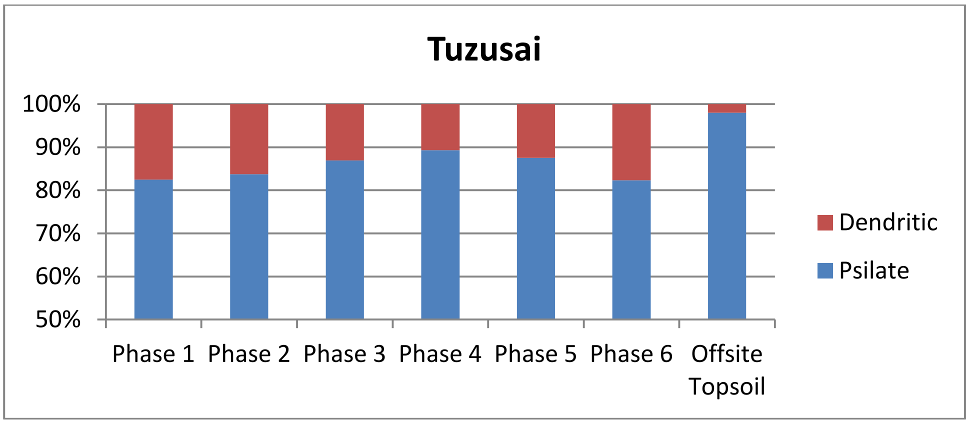


Figure 7.16. Tuzusai. Proportion of psilate to dendritic phytolith morphotypes by phase.

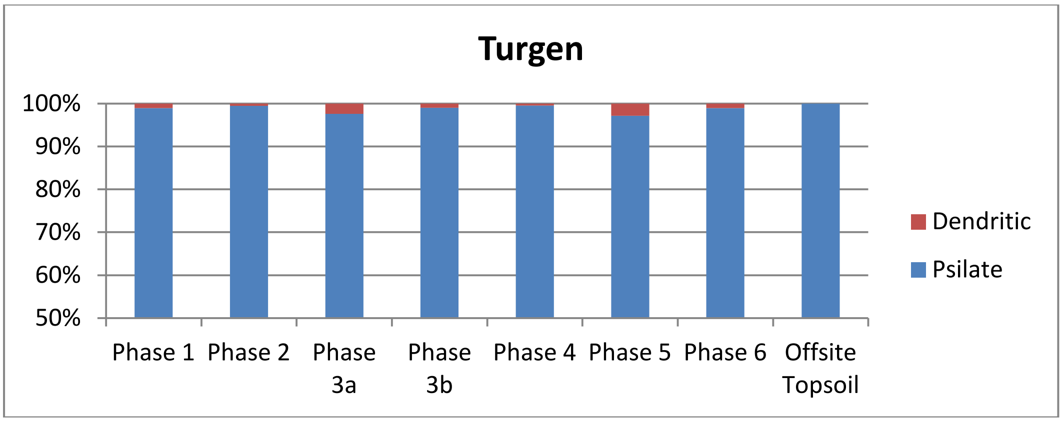


Figure 7.17. Turgen. Proportion of psilate to dendritic phytolith morphotypes by phase.

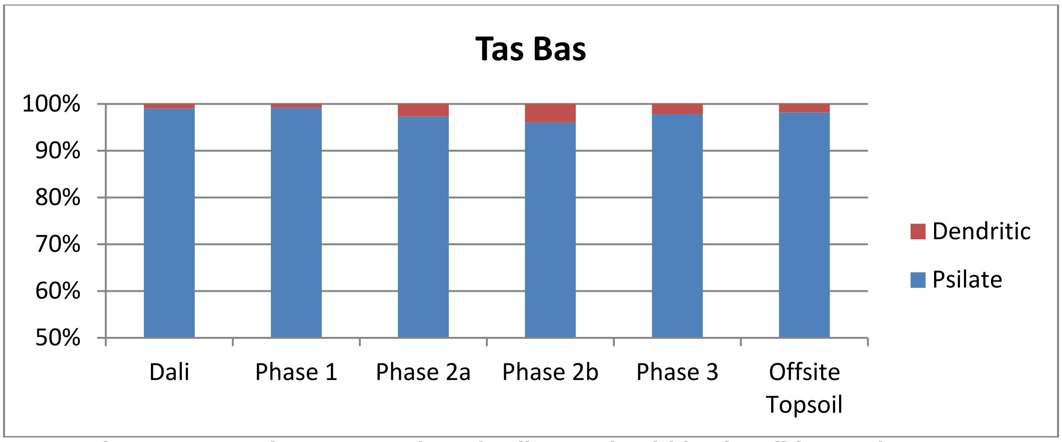


Figure 7.18. Tasbas. Proportion of psilate to dendritic phytolith morphotypes.

As can be seen from

Figure 7.16,

Figure 7.17, and Figure 7.18, the largest proportions of dendritic phytoliths were found at Tuzusai (between 11 – 18%), and this is true for all phases across the three sites. Phases 1 and 2 had higher proportions of dendritic phytoliths than phases 3 – 5. Phase 6 is represented by a single sample (2012-013), and therefore its value may not be indicative of the whole phase, however the context for this phase was a mud brick platform located between pit houses where a number of broken pots and animal bones were deposited (Chang 2012 Field report). Given the presence of these other food-related deposits, the relatively higher proportion of dendritic phytoliths (18%) in this sample is most likely to represent waste from crops, and indeed multi-celled phytoliths from wheat, barley, and millet were all identified within this sample. Compared to the offsite topsoil samples, which are assumed to represent natural, non-anthropogenic deposition, the proportion of dendritic phytoliths in the archaeological samples is much higher and therefore indicative of larger quantities of seed bracts being deposited at the site. This is most likely in the form of crop processing waste in various forms, such as the storage, cleaning and disposal of husked grains on site, or chaff being burnt or fed to animals at fodder and their dung being burned, or added to mud brick as temper (Chang and Beardmore 2015; Newton 2004). The data indicate that phases 1 and 2 saw proportionately more deposition of dendritic phytoliths, and by inference therefore higher deposition rates of grass husks at the site. Phase 4 has the lowest proportion of dendritic phytoliths, and may represent either a period of less intense occupation with fewer crops and other grasses being brought to and processed at the site, or a change in the way that crop processing waste was deposited at the site.

Figure 7.17 shows the proportion of dendritic to elongate psilate phytoliths from Turgen. Overall, the proportions are much lower than at Tuzusai, but are comparable to those at Tasbas. It is interesting to note that although small in number, dendritic phytoliths were found in all the archaeological samples for all phases. This indicates that the site was occupied during the summer and early autumn months when grasses were flowering and fruiting. There were no dendritic phytoliths identified in the offsite topsoil samples, which implies that there are very low natural rates of deposition of these phytoliths around the site. Of the archaeological samples, phases 3a and 5 have the highest proportions of dendritic phytoliths. Phase 3a consisted of a large amount of ash and burnt material, and the multi-celled phytoliths identified within the sample included millet, of which one example appeared to be *Setaria italica*, in addition to possible multi-celled phytoliths from *Panicum miliaceum*, although the identification of *Panicum* was less certain than that for *Setaria*. In this phase there were also multi-celled phytoliths from grass husks which could not be identified, but their presence in the sample indicates that this deposit consisted of the results of a gathering of grass seeds, in greater numbers than in the other phases, be they wild or domesticated. The higher proportion of dendritic phytoliths from Phase 5 is also of interest, since this also consisted of a deposit of burnt material. This higher incidence of dendritic phytoliths in burning contexts could reflect activity such as the burning of crop processing waste, or the use of animal dung as fuel (Lancelotti and Madella 2012).

Figure 7.18 shows the proportion of elongate psilate to dendritic phytoliths from Tasbas by phase. As can be seen from the graph, the proportions are similar to those from Turgen, and the proportions of dendritic phytoliths are much lower than those at Tuzusai. Phase 2b has the highest proportion of dendritic phytoliths, with Phase 2a also having a higher proportion than the other phases. Samples from Phase 1 and the samples from Dali have a lower proportion of dendritic phytoliths than the offsite topsoil samples.

7.5. Multivariate analysis

The results of the Principal Component Analysis (PCA) are presented here in the first instance as species-environment biplots, with the focus being on the first two principal components (Figure 7.19). Since this is an indirect analysis, the environmental variables were not included in the analysis itself, and are therefore projected passively onto the ordination diagram (Leps and Smilauer 2003, 176). A graph displaying all the phytolith morphotypes would be extremely difficult to read to the point of giving very little useful information, and therefore the Species Fit Range was adjusted to between 15 and 100% to eliminate those morphotypes that are less well characterised by the first two principal components. This resulted in 19 morphotypes, out of a total of 44, being displayed.

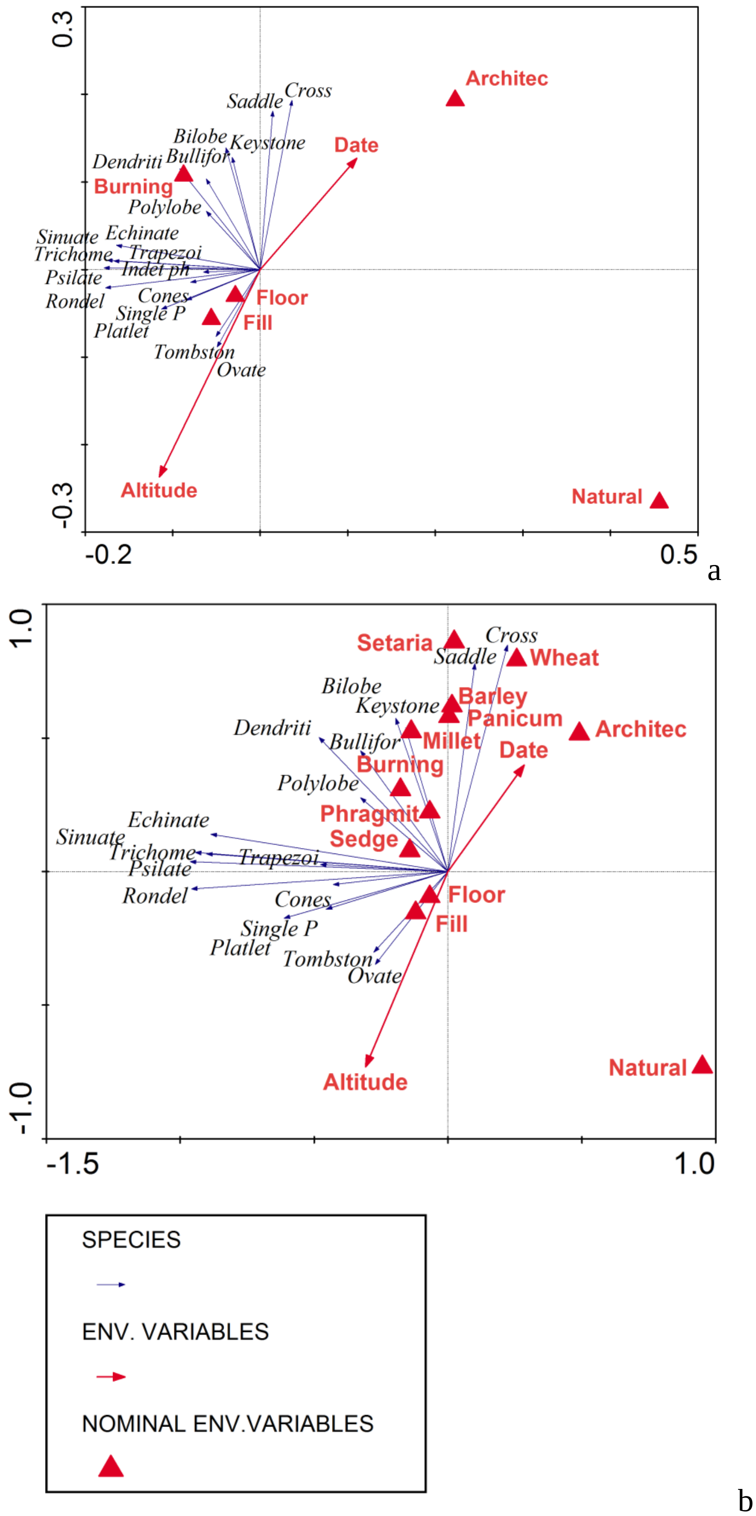


Figure 7.19. Biplots of the results of Principal Components Analysis (a) without presence/absence data as environmental variables included in the analysis (the first two axes explain 26.9% of variability in the species data); (b) with these data included (the first two axes explain 27.1% of the variability in the species data).

The biplots illustrated here show a negative correlation between the values for altitude and date. The first principal component is slightly more closely correlated with the date, and the second with altitude. In terms of phytolith morphotype abundance, saddles and crosses are least abundant at higher altitudes, and more prevalent in later dated samples. Ovate and ‘tombstone’-shaped phytoliths are closely correlated with altitude, and more abundant at higher altitudes. The dummy variables (nominal variables) represented by triangles on the diagram are distributed according to their frequency in the data, with those having lower frequency lying further from the origin (Leps and Smilauer 2003, 177). As can be seen from the diagram, floor and fill were the most frequent context types that were sampled. The fact that the majority of the samples taken were of archaeological origin is reflected in the fact that the label of ‘natural’ samples (on- and offsite topsoil samples) lies the furthest from the origin. Of the economic plants that were identified through multi-celled phytolith data, sedge and *Phragmites australis* were the most frequently present in the samples, with wheat and *Setaria italica* being identified the least frequently. It is interesting to note that while the morphotypes ‘platelet’ and ‘single plate’ were recorded as two different morphotypes due to size difference, it is apparent from the extremely close proximity of their species arrows in these diagrams that their presence in the assemblage is very closely correlated. The morphotypes psilate, echinate, sinuate, trichome and rondel are closely correlated, and this may reflect their anatomical origins on the grass. They occupy a separate ordination space to dendritic and polylobe morphotypes, which may be a reflection of their deposition in different contexts and in different abundances. This could indicate differing treatment of the florescence and leaf/culm of grasses brought to the sites due to activities such as crop processing.

The biplot diagrams from the PCA indicate that including the presence/absence data from the multi-celled phytoliths appears to be of use in exploring the data, and therefore the other analyses will include them as environmental variables. The added value of their inclusion can also be seen in the summary of the analysis, given below.

Analysis without multi-celled presence/absence data:

```
Axes                                         1      2      3      4 Total
variance

Eigenvalues                      :       0.163  0.102  0.067  0.055
1.000
Species-environment correlations  :       0.472  0.805  0.581  0.220
Cumulative percentage variance
of species data               :         16.3    26.5   33.2   38.7
of species-environment relation:         22.9    64.5   78.7   80.4

Sum of all              eigenvalues
1.000
Sum of all canonical     eigenvalues
0.159
```

Analysis with multi-celled presence/absence data:

```
Axes                                         1      2      3      4 Total
variance

 Eigenvalues                      :       0.163  0.108  0.067  0.055
1.000
 Species-environment correlations  :       0.553  0.843  0.626  0.424
 Cumulative percentage variance
    of species data               :        16.3   27.1   33.8   39.3
    of species-environment relation:        22.0   55.7   67.2   71.5

 Sum of all              eigenvalues
1.000
 Sum of all canonical     eigenvalues
0.227
```

As can be seen from the results of the analysis, the potential amount of variance that could be explained by the environmental variables without the multi-celled data is 15.9% (sum of all canonical eigenvalues), whereas with the multi-celled presence/absence data included, this value rises to 22.7%. This shows that including these data as part of the analysis does result in a significant increase in the amount of variation that can be explained by the environmental variables. It therefore makes sense to include these values in the remainder of the analysis.

Figure 7.20 shows a biplot of species and samples from the results of the PCA. The samples have been classified according to their date in order to identify any patterns in the data regarding samples of similar date. The same data is presented in Figure 7.21, but this diagram plots the samples with the environmental variables passively projected onto the ordination space. The centroids for the dummy nominal environmental variables are shown here as triangles but their labels have been removed in order to make the diagram easier to read. The species and samples biplot shows that saddle and cross morphotypes are more likely to be abundant in samples of a later date (for archaeological samples), while the tombstone and ovate morphotype is more likely to be found samples classified as Late Bronze/Early Iron Age.

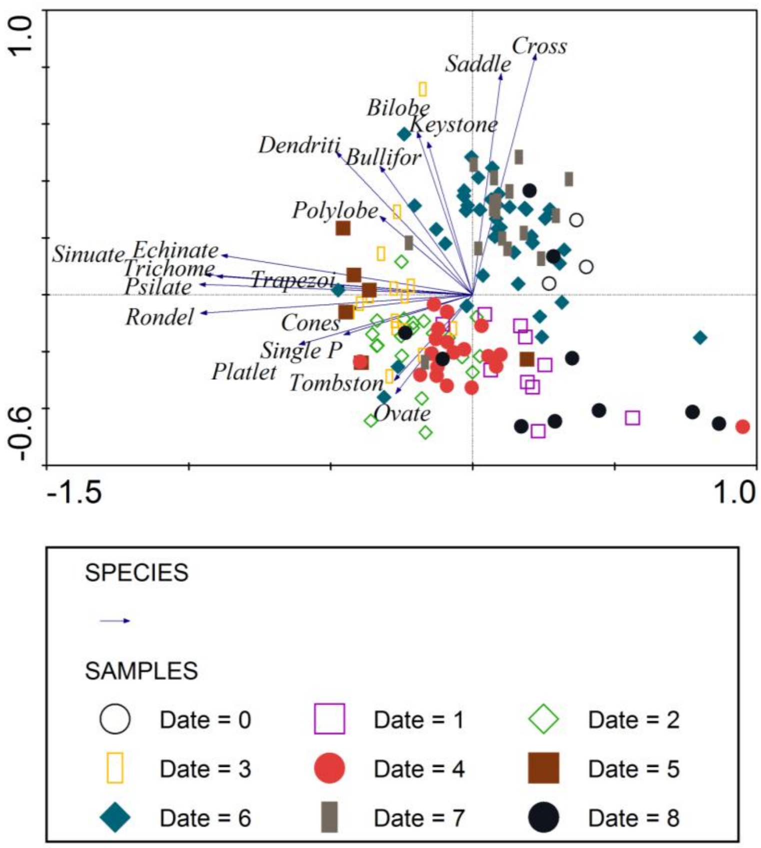


Figure 7.20. Species and samples biplot of PCA (the first two axes explain 27.1% of the variability in the species data). Samples are classified by date.

As can be seen from the two diagrams, there is a clustering of samples with the same date classification. Samples classified as being of Iron Age and Late Iron Age date (numbered as 6 and 7 on the diagram) do not show any distinct variation from each other, but are distinct from samples of earlier dates. This effect may in part be due to the fact that most of the samples of this date come from the site of Tuzusai which lies at a much lower elevation to the sites of Turgen and Tasbas. This is reflected in Figure 7.21, which shows that the samples from Tuzusai are least likely to have their variability explained by the altitude explanatory variable, demonstrated through their location with respect to the arrow depicting this variable. The effect of altitude on the variation found within the samples is explored through performing further ordinations on the data, and the results of this are discussed below. However, even for samples that come from a similar elevation, i.e. those from Turgen and Tasbas, there is still a grouping within the data in which samples of similar date are more likely to have a similar variation within their phytolith assemblage. This can be seen by comparing Figure 7.21 with Figure 7.22. Figure 7.22 again presents the results of the same analysis, but in this instance the samples are classified by their altitude. This diagram shows that for those samples from the sites at higher altitude (Turgen and Tasbas), the samples are not so clearly distinguished when identified by their altitude, and it is the classification by date which highlights clustering within the data.

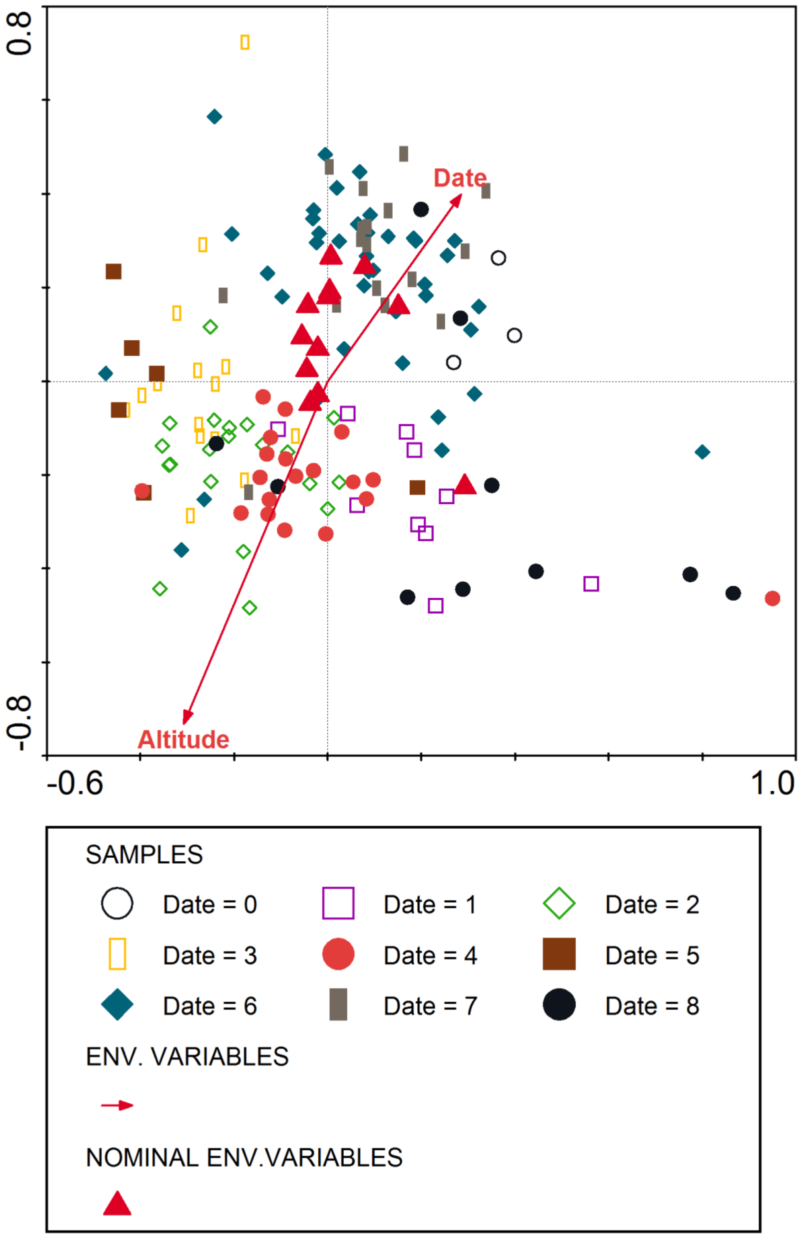


Figure 7.21. Samples and environmental variables biplot of the PCA (the first two axes explain 27.1% of the variability in the species data), with the environmental variables passively projected onto the ordination space. Nominal environmental variables are unlabelled here in order to made the plot easier to read. The samples are classified by date.

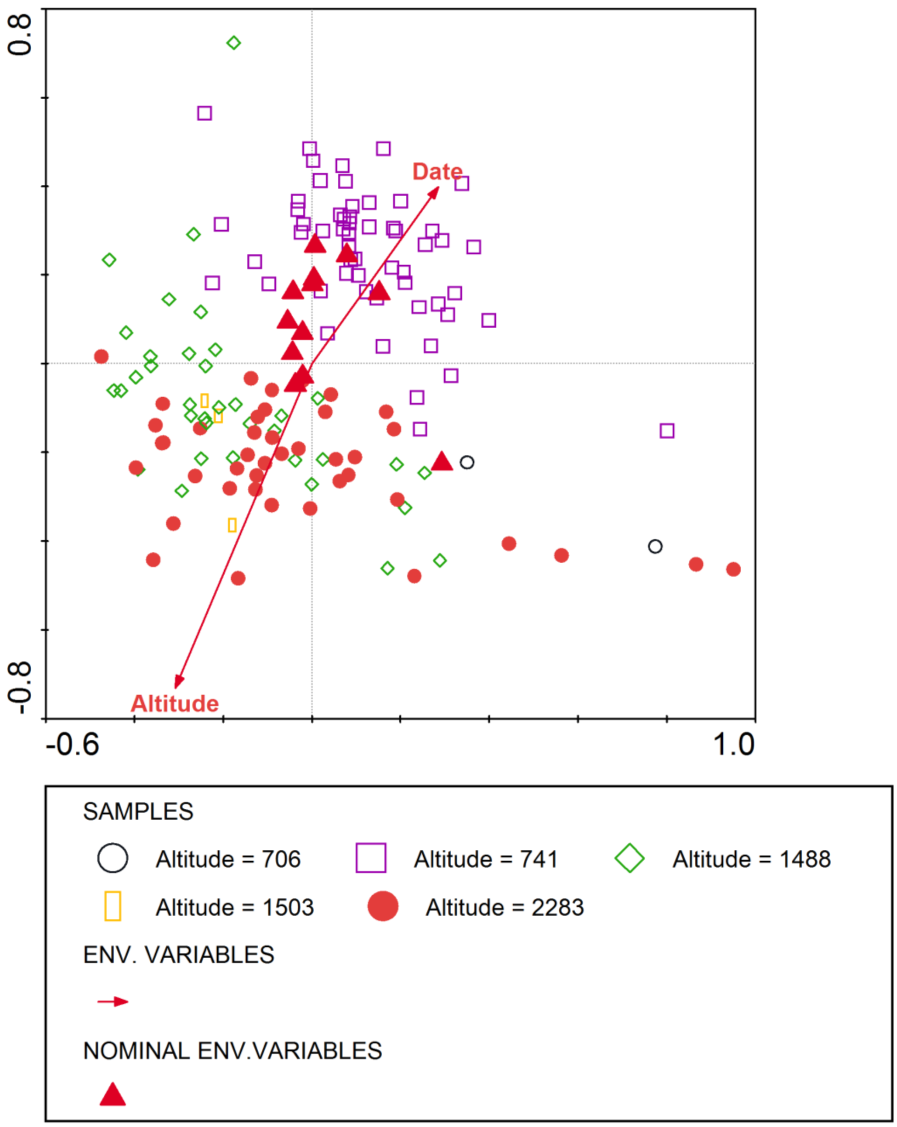


Figure 7.22. Samples and environmental variables biplot of the PCA (the first two axes explain 27.1% of the variability in the species data). Samples are classified by altitude, and the environmental variables are passively projected onto the ordination space.

Since the principal components analysis is an unconstrained ordination (indirect gradient analysis), the environmental variables that are present in the ordination diagrams are projected passively onto the ordination space after the analysis has taken place (Leps and Smilauer 2003, 176), and therefore the resulting diagrams show the variation between samples in relation to each other without direct reference to the effect of the environmental variables. In order to explore the direct effect of the environmental variables it was necessary to carry out a constrained ordination, in this case a redundancy analysis (RDA). Since there appears to be a clear distinction in the PCA diagram between the samples from Tuzusai at lower altitude and those from Tasbas and Turgen at higher altitude, it was decided to look at the effect of altitude on the composition of the samples, and to see what effect the other variables might have on the data once this effect has been accounted for. The aim was to investigate whether the effects of those variables that are of archaeological interest, such as the date and context of the samples, might be visible in the data once the natural effect of the altitude on the phytolith assemblages had been accounted for. In order to identify the effect of altitude the RDA was performed with altitude as the only environmental variable and the other variables assigned as covariables for the analysis. A Monte Carlo permutation test with 499 permutations was carried out as part of the analysis in order to determine the statistical significance of the canonical axis (i.e. the effect of altitude).

The results of the RDA are as follows:

```
Axes                                        1      2      3      4 Total
variance

Eigenvalues                        :      0.075  0.152  0.069  0.056
1.000
Species-environment correlations  :      0.835  0.000  0.000  0.000
Cumulative percentage variance
of species data                  :       7.5     22.7   29.7   35.3
of species-environment relation:         100.0    0.0    0.0    0.0

Sum of all               eigenvalues
1.000
Sum of all canonical     eigenvalues
0.075
```

The summary table above shows that the total variability that is explained by the canonical axis (first axis) is 7.5%. Although this value is low, the results of the Monte Carlo permutation test (shown below) indicate that this result is significant (P = 0.0020) (*ibid*, 179).

```
Test of significance of all canonical axes  : Trace      =    0.075
                                               F-ratio    =   11.120
                                               P-value    =    0.0020
```

It is interesting to note that the variability explained by the first unconstrained axes is greater than that of the canonical axis (15.2% for axis 2), however the significance test demonstrates that altitude does have a statistically significant effect on the composition of the phytolith assemblages.

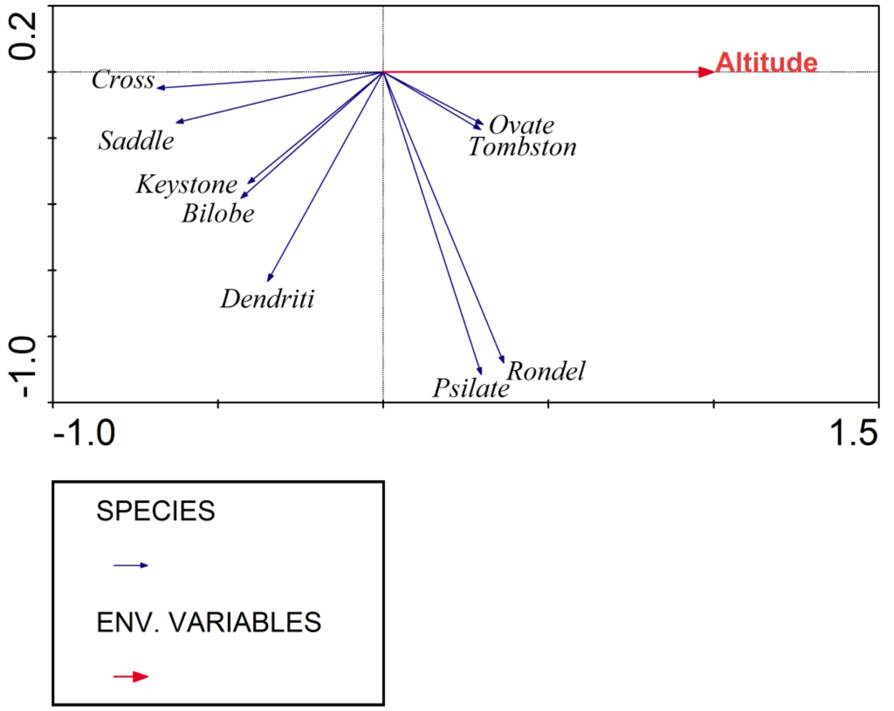


Figure 7.23. RDA. Species and environmental variable biplot. The total variability that is explained by the constrained (canonical) axis (first axis) is 7.5%, total variability explained by the unconstrained axis is 15.2%.

Figure 7.23 depicts the constrained ordination axis (the horizontal axis) and the second unconstrained axis. The constrained axis represents the variation in abundances of phytolith morphotypes that can be explained by altitude (Leps and Smilauer 2003, 179). Only nine morphotypes are displayed since the threshold for inclusion in the ordination diagram was set to those morphotypes with at least 7% of the variability of their values explained by the first ordination axis, since this axis explains 7.5% of the variability in the data (Leps and Smilauer 2003, 180). As can be seen from the diagram the ‘cross’ and ‘saddle’ morphotypes are negatively correlated with altitude, having greater abundance at lower altitudes. It is likely therefore that should these morphotypes be present at sites at higher altitude this is more likely to be as a result of some other factor than the natural ‘background noise’ of the phytolith assemblage, and may therefore point to an anthropogenic explanation for their presence. Conversely, ‘ovate’ and ‘tombstone’ phytoliths are most likely to be found in abundance at high altitude.

‘Dendritic’ phytolith morphotypes have a weakly negative correlation with altitude, and the species plot arrow extends well into the unconstrained ordination space. This may imply that there are other factors affecting the deposition of grass inflorescences at the sites beyond the altitude. The case is similar for ‘rondel’ and ‘psilate’ phytoliths, although with a very weak positive correlation with altitude, again implying that variables other than altitude are also having an effect on their variability.

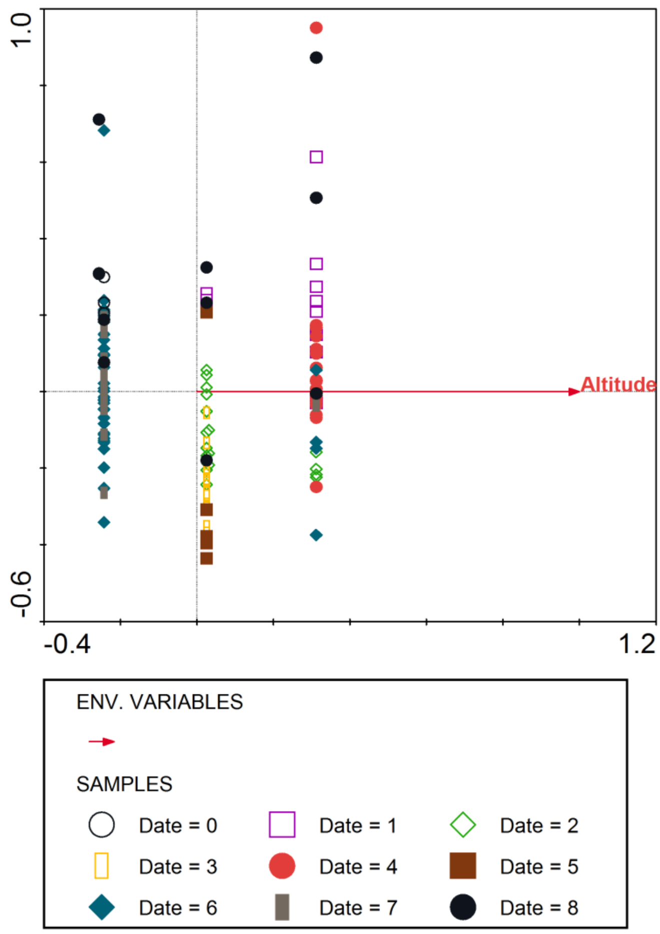


Figure 7.24. RDA. Samples and environmental variable biplot. The total variability that is explained by the constrained (canonical) axis (first axis) is 7.5%, total variability explained by the unconstrained axis is 15.2%. Samples are classified by date.

Figure 7.24 illustrates the location of the samples within the ordination space with the constrained horizontal axis. The samples have been classified according to their date. Since the altitude of the samples was recorded as a site-wide value, the samples from the three distinct sites can be seen in the ordination diagram arranged along the constrained axis. However, looking at the vertical (unconstrained) axis, it is possible to see that samples of similar date do cluster together in the ordination space, indicating the influence of other variables.

Having accounted for the effect of altitude, it is now possible to carry out a second redundancy analysis in which this effect is removed from the ordination, allowing the effect of the other environmental variables to be highlighted. In this second RDA, altitude is assigned as a covariable in CANOCO, removing its effect from the analysis and instead focusing on the effect of the other variables. The results of the second RDA are as follows:

```
Axes                                         1      2      3      4 Total
variance

 Eigenvalues                       :     0.050  0.032  0.018  0.012
1.000
 Species-environment correlations  :     0.619  0.642  0.641  0.536
 Cumulative percentage variance
    of species data                :       5.4    8.9   10.8   12.2
    of species-environment relation:      33.7   55.3   67.5   76.0

 Sum of all              eigenvalues
0.920
 Sum of all canonical     eigenvalues
0.147
```

The sum of all canonical eigenvalues shows that the amount of variability which is explained by the other environmental variables, in addition to the 7.5% of variability explained by the altitude, is 14.7% (Leps and Smilauer 2003, 181). While this figure is not especially high, the results of the Monte Carlo permutation test show that the additional variation explained by the other environmental variables is statistically significant (P = 0.0020):

```
Test of significance of all canonical axes  : Trace      =    0.147
                                               F-ratio    =    1.985
                                               P-value    =    0.0020
```

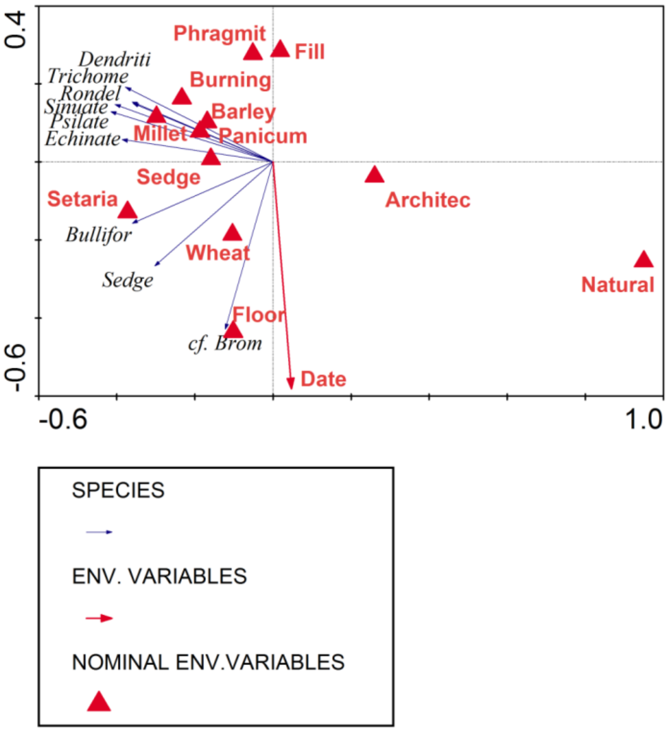


Figure 7.25. Second RDA. Species and environmental variables biplot. The amount of variability which is explained by the other environmental variables, in addition to the 7.5% of variability explained by the altitude, is 14.7%.

Figure 7.25 is a biplot of species and environmental variables of the results of the RDA, which shows those morphotypes whose variability is best explained by the environmental variables. As can be seen from the diagram dendritic, sinuate, psilate, echinate, rondel and trichome phytoliths all share similar ordination space and do not show a strong positive or negative correlation with the date. They are also closer to the centroids for the 'fill' and 'burning' context classifications implying that they are likely to be found with greater frequency in contexts of this type. These morphotypes are also close to the centroids for millet (the presence/absence data for *Setaria italica* and *Panicum miliaceum* were included in addition to a general identification of 'millet' to allow this extra information to be included where such an identification was possible), barley, sedge, and to a lesser degree wheat and *Phragmites australis*. These single-celled morphotypes are associated with both the leaf/culm and inflorescence of grasses, and the prediction of their increased abundance in burning and fill contexts and in the presence of economically significant plants implies that they are present in the samples as a result of human activity such as crop processing and dung burning. The phytolith morphotype cf. *Bromus* is closely associated with the centroid for the 'floor' context classification. It also shows a positive correlation with the date variable.

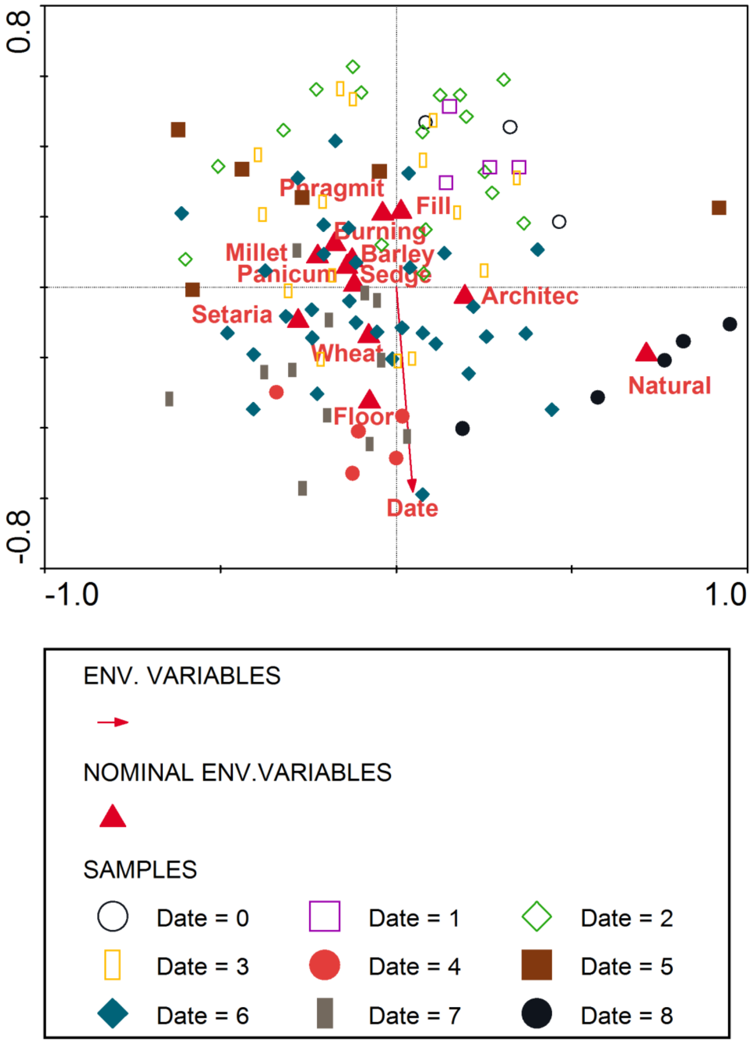


Figure 7.26. Second RDA. Species, samples and environmental variables triplot. Samples classified by date. The amount of variability which is explained by the other environmental variables, in addition to the 7.5% of variability explained by the altitude, is 14.7%.

Figure 7.26 is a biplot showing the relationship between the samples and the environmental variables. The labels for all variables have been left on the diagram since these data are important in its interpretation, however it is acknowledged that this does make the diagram more difficult to read. The samples have been classified by date. As can be seen from the diagram the samples labelled as having a date classification of 8, which are the modern onsite and offsite topsoil samples, are located most closely to the centroid for contexts identified as 'natural', and they also lie some distance from the majority of the other samples in the ordination space. If this is compared to Figure 7.21, in which the axes are unconstrained, it is possible to see the effect of the environmental variables in explaining the variability in the natural samples, and the ordination diagram highlights that these are distinct from the samples from archaeological contexts. Figure 7.26 also shows that even with the effect of altitude removed from the ordination, the samples continue to demonstrate a separation and grouping according to their date classification, although this is not quite as clear as it was in the principal components analysis, where no environmental variables were included in the analysis (see Figure 7.21). This shows that even once the effect of altitude has been accounted for in explaining the variability within the samples, there is still a significant difference in the composition of the phytolith assemblages in samples of different dates. In particular, there is a distinction between samples classified as dating from the Middle to the Late Bronze Age (date classification of 1-3 on the diagram), and those belonging to the Late Bronze/Early Iron Age, Iron Age, and Late Iron Age (4, 6 and 7 on the diagram). The samples classified as belonging to the Early Iron Age (5 on the diagram) fall in an ordination space which contains a mixture of samples of different dates. These samples of this date are from Tasbas, and include sample 2011-099, which can be seen as the solid square to the far right of the diagram. It was unclear at the time of sampling whether this sample represented an archaeological or natural deposit, and included what appeared to be a matted carpet of fibres. It is clear from the results of the ordination that this is a natural deposit, since it lies far from the mean of the other archaeological deposits, and closer to the modern topsoil deposits. It therefore most likely represents an intrusive natural feature, such as a rodent hole or tree bole.

7.6. Climatic indices

Two climatic indices were calculated for each phase of each site using single cell morphotypes that are particular to the Pooid, Panicoid and Chloridoid subfamilies of grasses (Twiss *et al.* 1969) (climatic index Ic, and aridity index Iph). In addition, the ratio of phytoliths from woody dicotyledonous plants versus those from grasses was also calculated (D/P°). Pooidaeae grasses have a C3 photosynthetic pathway, and generally are adapted to cool season growth in wet or dry environments (Twiss *et al.* 1987). Wheat, barley, oats and rye all belong to the Pooidiae subfamily. Panicoid grasses mostly have a C4 photosynthetic pathway, and are adapted to warm or hot seasonal conditions in moist or dry environments (Twiss *et al.* 1987). Both *Panicum miliaceum* and *Setaria italica* belong to the Panicoidiae subfamily. Chloridoid grasses also have a C4 photosynthetic pathway, and like Panicoid grasses are adapted to warm or hot seasonal conditions, but they often tolerate lower soil moisture availability than Panicoid grasses (Twiss *et al.* 1987). They are therefore useful in indicating relative aridity. (Piperno 2006, 32–34; Rosen, 2001, 187; Strömberg 2009). Single cell phytolith morphotypes particular to Pooid grasses are rondels, trapezoids and rectangles, while saddles are found in Chloridoid grasses, and crosses and bilobes in Panicoid grasses (Twiss *et al.*, 1969).

For the archaeological samples, the climatic indices calculated are viewed through a filter of anthropogenic selection. It is not possible to say that these indices are a direct reflection of the climate, but rather the values from the archaeological samples reflect the types of microenvironment that were exploited by humans, be that for grazing, foraging or cultivation. For this reason, each value was calculated by combining the phytolith counts for all samples in a phase in order to give as wide a picture as possible of wider landscape use and climate through time. The calculations were made in the following way (after Bremond *et al.* 2008):

Climatic Index:

Ic (%) = (Pooid morphotypes / Pooid + Panicoid + Chloridoid morphotypes) x 100

Aridity Index:

Iph (%) = (Chloridoid morphotypes / Chloridoid + Panicoid morphotypes) x 100

Woody dicotyledon/Grass ratio:

D/P° = Woody dicotyledonous morphotypes / grass morphotypes

The results of these three calculations are presented here in graph form for each site. In addition to the archaeological samples, samples from the modern topsoil were also processed for each site, and the three ratios calculated. One of these samples was taken from the topsoil at the excavation site itself, and the other was taken from offsite. The results from the modern onsite and offsite topsoil samples are also included in the graphs for comparison in order to give an indication of the differences between the modern natural phytolith profile and the archaeological samples.

It should be noted here that during the identification of saddle short-cell phytoliths, Chloridoid saddle forms (see, for example Piperno 2006; Twiss *et al.* 1969) and 'plateau' saddle forms produced by *Phragmites australis* (Lu and Liu 2003) were recorded together. This was an oversight by the author, and one which may result in a false representation of the number of Chloridoid saddles in a sample. However, as can be seen from Figure 7.37 i) to k), both Chloridoid and *Phragmites australis* saddles appear to have been present in the samples, and therefore the aridity index indicator is not entirely unfounded. However, it can only be understood to represent a possible pattern, and revisiting the samples and separating the Chloridoid and *Phragmites australis* saddles would be the only way to generate a reliable index of this nature. It has been left in this analysis to demonstrate the potential of such an index for these samples, since Chloridoid saddles were indeed present.

7.6.5. ***Tasbas***

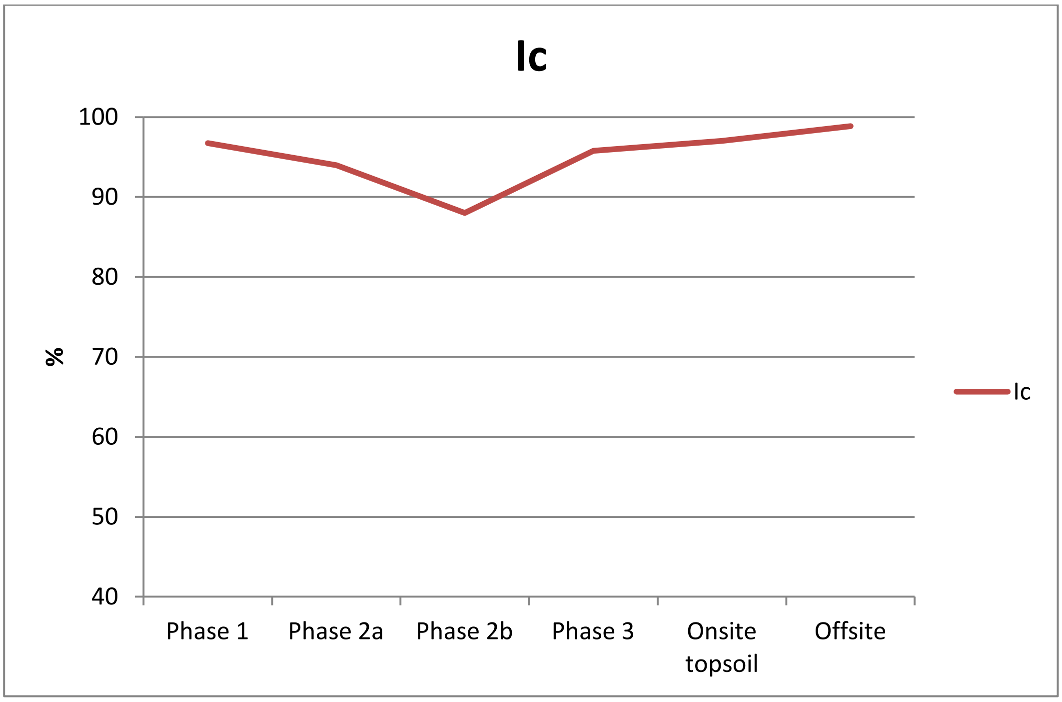


Figure 7.27. Tasbas Climatic Index (Ic)

The Climatic Index (Ic) for Tasbas (Figure 7.27) indicates a slight trend towards increasing exploitation of warm-adapted grasses from phases 1 to 2b, with the index value decreasing from 96.7% in Phase 1 to 88% in Phase 2b, demonstrating that a larger percentage of Panicoid and Chloridoid morphotypes were present in the samples from Phase 2. In Phase 3 this value increased to 95.8%, indicating that more grasses from cooler environments were deposited at the site during this phase. The values for phases 1 and 3 are more similar to those obtained from the modern onsite and offsite topsoil samples, which were 97% and 98.9% respectively. As stated above, this index is not a direct reflection of the climate during each phase, but instead indicates what sort of environment the grasses being brought into the site were adapted to. In particular, this index represents human choices in which cereals were brought to the site, as well as patterns in animal grazing and foddering. The increase in phytolith morphotypes from warmer-adapted grasses may be a reflection of both the increasing exploitation of Panicoid cereals such as *Panicum miliaceum* and *Setaria italica* in these phases, as well as the grazing of animals in lower-altitude, warmer steppe meadows. Of course it is possible that this trend towards more warm-adapted grasses being brought into the site from phases 1 to 2b is a reflection of the types of vegetation that were available for exploitation in the immediate environs of the site, and this in turn may be a reflection of a favourable climate for their growth during these periods. Conversely, the trend towards grasses more adapted to cooler climates having greater representation in Phase 3 may also reflect a shift in the climate towards cooler temperatures. However, this shift in Phase 3 could also be the result of the lower presence of Panicoid cereals in the archaeological deposits, which could represent a change in the type and nature of subsistence strategies in this later phase as opposed to a change in the climate. When compared to the modern onsite and offsite topsoil samples, it would appear that the types of grasses being exploited at Tasbas were in general those adapted to warmer temperatures than are found in the natural topsoil phytolith profile of the present day, even after an apparent trend towards the exploitation of cooler-adapted grasses in Phase 3. It is not possible to attribute these differences directly to differences in the climate between antiquity and the present day, but rather the modern topsoil samples allow us to compare the phytolith profiles of natural versus anthropogenic accumulations of vegetation, and how these differ in the types of environment represented.

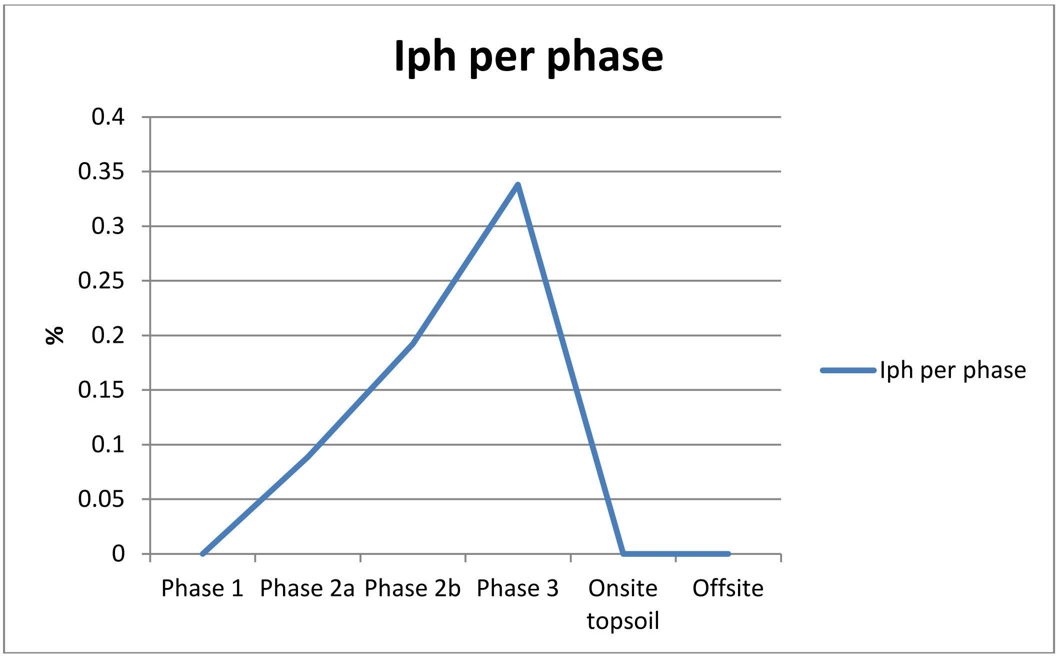


Figure 7.28. Tasbas Aridity Index (Iph)

The Aridity Index (Iph) data (Figure 7.28) indicate a trend towards the increasing presence of Chloridoid grasses in the archaeological record from phases 1 to 3. This is in sharp contrast to the modern topsoil samples, in which no Chloridoid 'saddle' morphotype phytoliths were identified. It must be noted here that the percentage increase in Chloridoid phytoliths is extremely small, rising from zero in Phase 1 to 0.34% in Phase 3. However, the increase is steady and consistent, and does seem to indicate a trend of grasses from drier environments being utilised more in the later phases of the site.

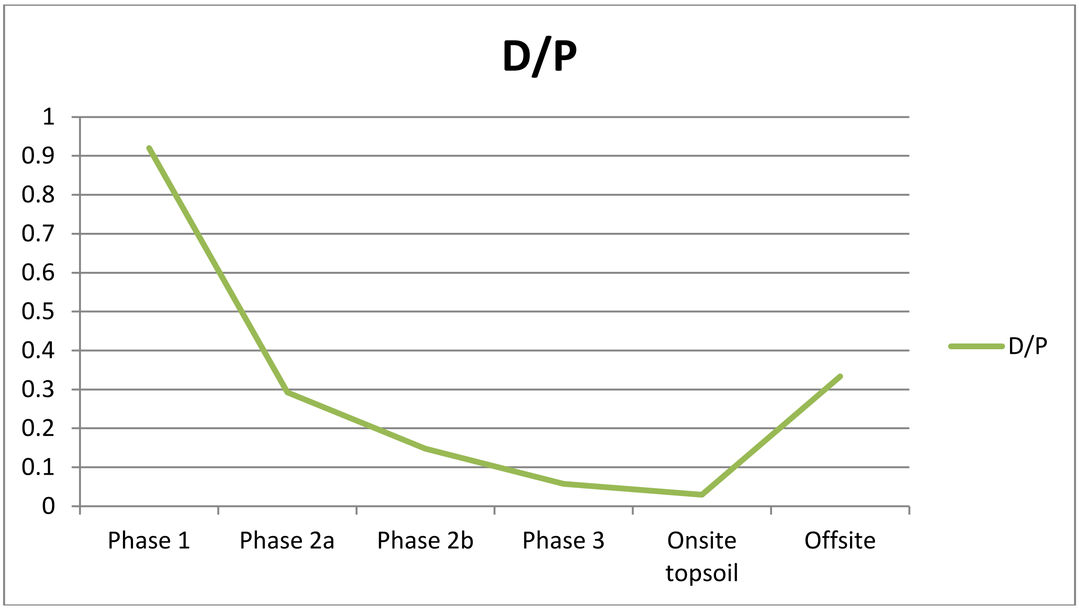


Figure 7.29. Tasbas D/P ratio

The ratio of woody dicotyledonous to grass phytoliths is perhaps the most contentious calculation, since the production of the 'platey' form of phytolith indicative of woody dicotyledonous plants is known to be highly variable and inconsistent from species to species (Strömberg 2004). This ratio is therefore presented here rather tentatively. The graphed data (Figure 7.29) indicate that the ratio of phytoliths from woody dicotyledonous plants to those from grasses fell from Phase 1 to Phase 3. This could reflect environmental and anthropogenic changes. If the Aridity Index does indeed reflect a climatic increase in aridity, then this may have led to a reduction in tree cover, meaning that less wood was available for use as fuel and in construction. Conversely, human-induced deforestation may have led to less water being retained in the soil, increasing soil aridity meaning more drought-tolerant species were present. If, however, the changes indicated in the Aridity Index are the result of changing patterns of land use in a stable climate, then the lower presence of woody plants may reflect changes in grazing practices and the increase of the burning of dung as fuel in the later phases, as well as changes in the types of plant exploited for construction and craft.

7.6.6. ***Tuzusai***

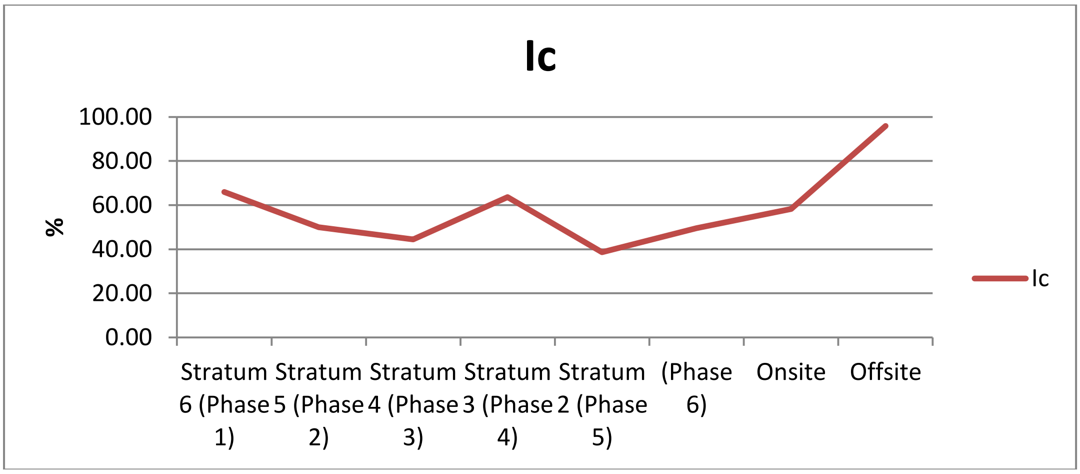


Figure 7.30. Tuzusai Climatic Index (Ic)

The Climatic Index values calculated for Tuzusai (Figure 7.30) show that phytoliths from Pooid grasses were present in much smaller proportions than at Turgen and Tasbas. Phases 2, 3 and 5 had the lowest values (49.9%, 44.4%, and 38.6% respectively). The values for phases 1 and 4 are similar (65.9% and 63.6%). The value from the onsite topsoil sample falls within the range of the archaeological samples (58.3%), whereas the offsite sample has a much higher proportion of Pooid grass phytoliths (95.9%). In the archaeological samples, the general trend appears to be one of falling proportions of Pooid grass phytoliths from phases 1 to 5, with Phase 4 as an exception to this trend.

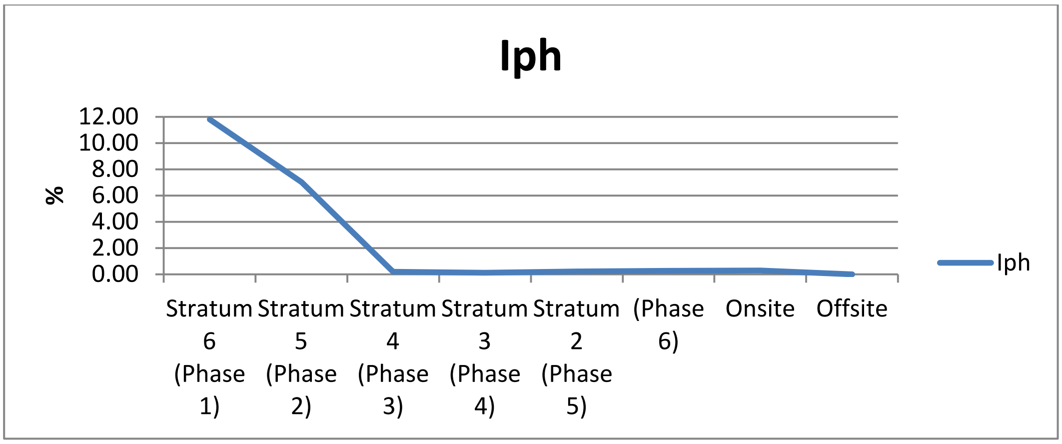


Figure 7.31. Tuzusai Aridity Index (Iph)

The Aridity Index for Tuzusai (Figure 7.31) shows a sharp fall in the percentage of phytoliths from Chloridoid grasses in relation to those from Panicoid grasses from 7.01% in Phase 1 to 0.19% in phase 3. This value remains low in all subsequent phases, and is 0 for the offsite topsoil sample. When considered with the Climatic Index data, it would appear that during phases 1 and 2 grasses adapted to warmer, drier environments were deposited at the site in greater proportions than in the later phases. It is interesting to note that although the Climatic Index value for Phase 4 is higher than its preceding and proceeding phases, the Aridity Index value is low (0.12), unlike the values for phases 1 and 2.

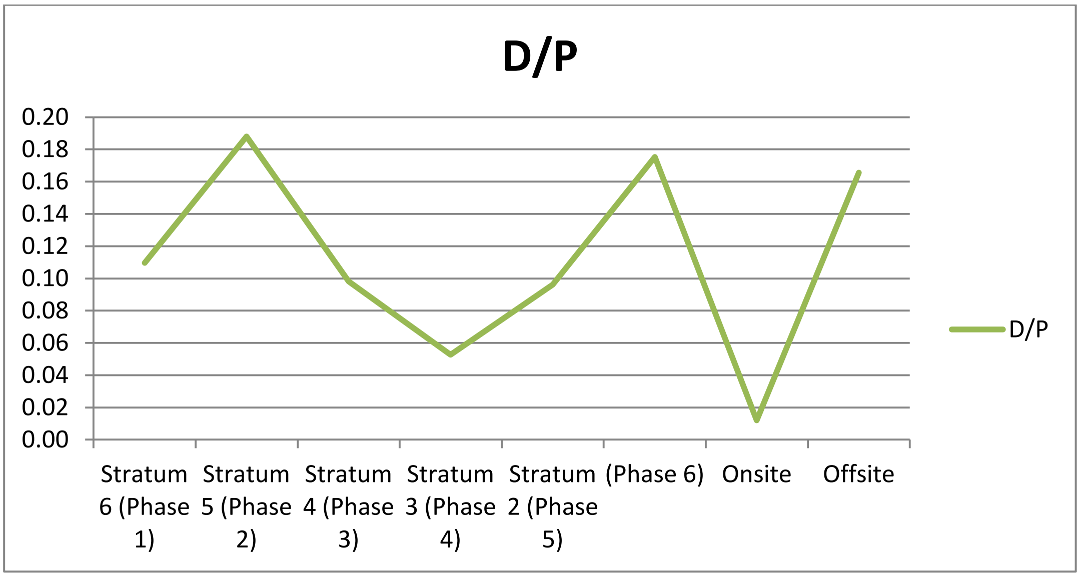


Figure 7.32. Tuzusai D/P ratio

The ratio of phytoliths from woody dicotyledonous plants to those from grasses (Figure 7.32) does not indicate a single trend over time, however it is interesting to note that Phase 4 has the lowest value of the archaeological samples (0.05), again indicating that this phase perhaps saw a period of different activity to the other phases.

7.6.7. ***Turgen***

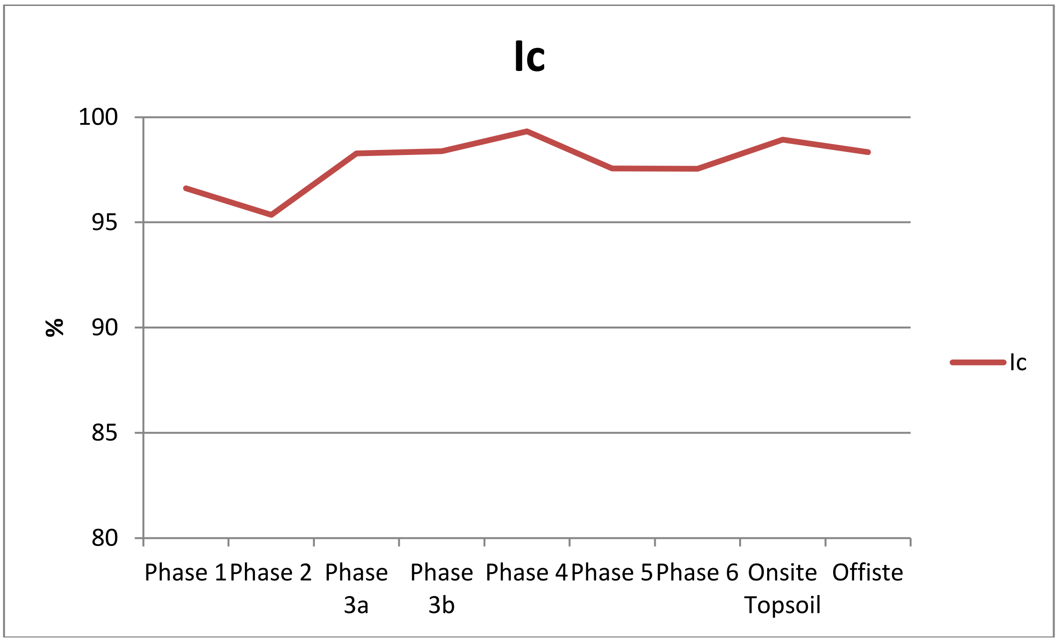


Figure 7.33. Turgen Climatic Index (Ic)

The Climatic Index data for Turgen show that any change in the percentage of Pooid morphotypes per phase was very slight, with less than 5% variation between the phases. The percentage of Pooid morphotypes in samples from phases 1 and 2 (96.6% and 95.4% respectively) is lower than in all the other phases, and also compared to the modern onsite and offsite topsoil samples, which range between 97.5% and 99.3%. It must be emphasised that this difference is very slight, however this difference does indicate that during these phases grasses adapted to warmer and/or drier conditions were deposited at the site more frequently than in later periods. This could be due to a warmer and/or drier climate during this phase, reflect differing human choices in which ecological zones were utilised, or be an indication that Panicoid cereals were being exploited during this period and deposited in these contexts. Phases 3a to 6 do not seem to show any strong difference in the Ic values for the samples, and indeed are comparable to the modern topsoil samples that were processed from both on- and off-site, with variation between these samples being only 1.8%. This very low variation, and in particular the similarity to the modern topsoil samples could indicate a stable climate with very little variation in the vegetation profile over time, together with localised land use around the site. Phases 5 and 6 are part of the later burial mound which overlies the occupation layers, and therefore most likely reflect the vegetation profile at the site itself rather than the deposition of plant matter from the surrounding area.

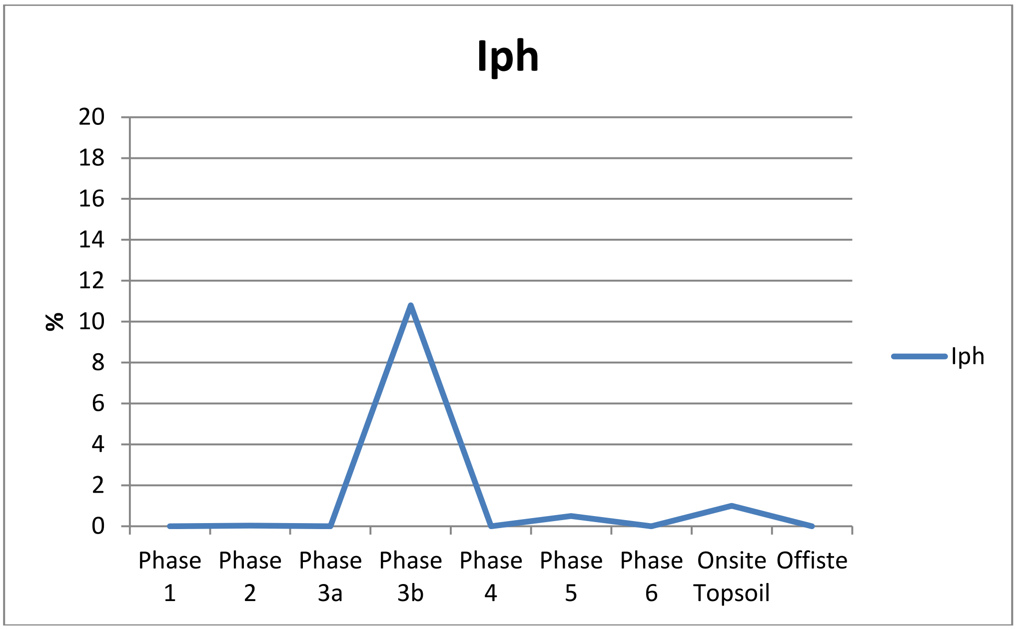


Figure 7.34. Turgen Aridity Index (Iph)

The Aridity Index data presented here show that during Phase 3b phytoliths from Chloridoid grasses were present in higher proportion to phytoliths from Panicoid grasses than in the other phases (Iph value of 10.8%). No Chloridoid morphotypes were identified in the samples from phases 1, 3a, 4, or 6, and the Iph values for phases 2 and 5 were just 0.03% and 0.5% respectively. The modern topsoil samples indicate that in the present day the natural occurrence of Chloridoid phytolith morphotypes is also low, with none having been identified in the offsite sample, and their proportion to Panicoid morphotypes being only 1% in the onsite sample. This, in combination with the Ic value for Phase 3b remaining similar to the value from other phases, suggests that the higher proportion of Chloridoid phytoliths in the samples from Phase 3b is the result of an increase in the exploitation of Chloridoid grasses or the drier environments to which Chloridoid grasses are adapted during that phase.

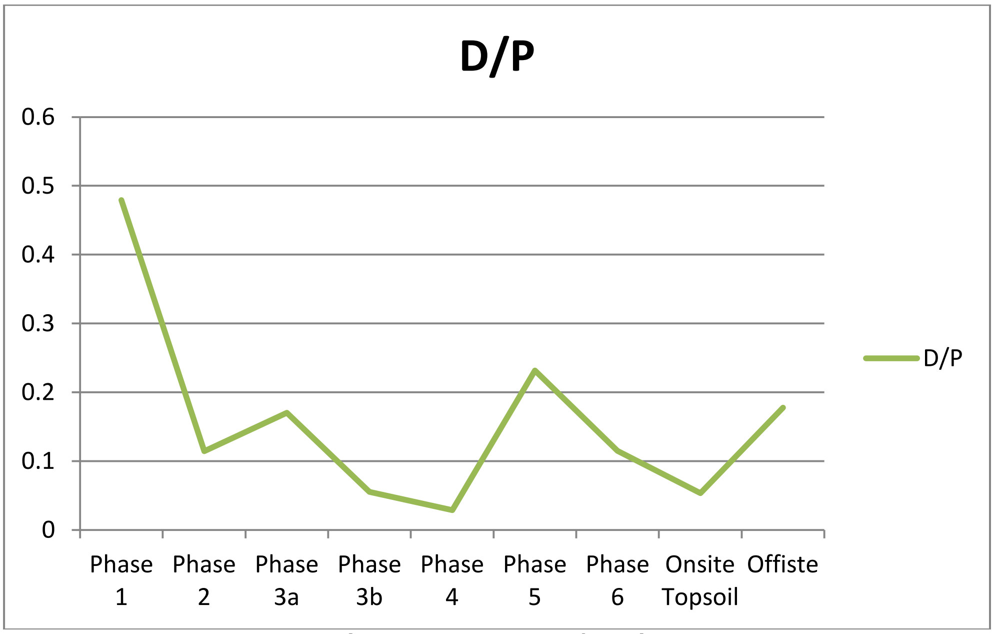


Figure 7.35. Turgen D/P ratio

The ratio of phytoliths from woody dicotyledons to those from grasses, shown here in Figure 7.35, demonstrates that phytoliths from grasses dominate in all archaeological phases, and also in the modern topsoil samples from both onsite and offsite. Phase 1 had the highest ratio of woody dicotyledon phytoliths to those from grasses, with a value of 0.48. The lowest values were from phases 3b (0.06) and 4 (0.03), which were comparable with the value from the modern onsite sample (0.05). The higher ratio of woody dicotyledons in Phase 1 might be explained by the fact that one of the contexts in this phase appeared to be the base of a post-hole, and it could be that this is indicative of the use of wood in construction during this phase. Likewise, the higher ratio seen in Phase 5 (0.23) may also reflect materials used in the construction of the burial mound that this phase represents.

7.7. **Phytolith morphotypes**

The following photographs show the main single-cell phytolith morphotypes that were identified and used in this analysis, together with those multi-celled silica skeletons that were identified to genus level. The photographs are presented here in groups according to anatomical origin (where this is possible to discern), and the any additional desctiption used in the analysis for the recording of distinctive morphotypes is given in the caption. The scale bar for all photographs is 10µm.

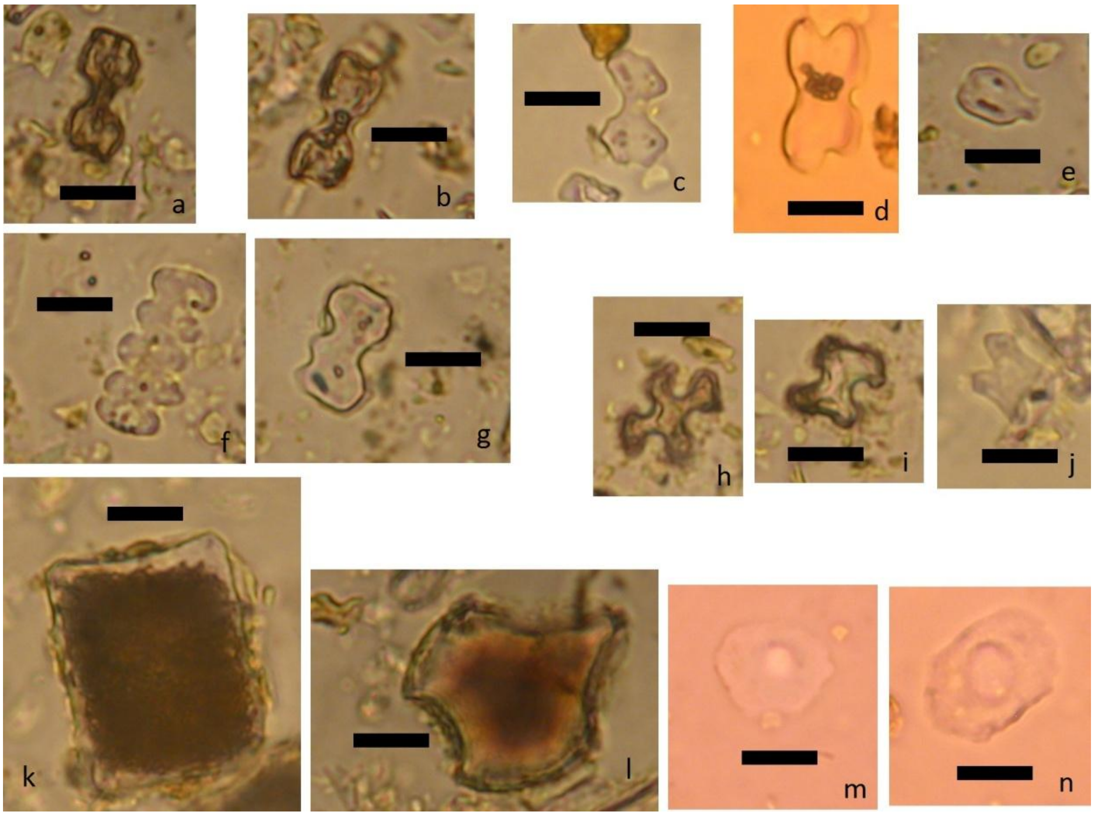


Figure 7.36. Short cell phytoliths (see Piperno 2006; Twiss *et al.*, 1969): grass phytoliths a) & b) bilobes; c) square bilobe; d) scooped bilobe; e) half bilobe (broken); f) & g) polylobe; h), i) & j) quadralobes (crosses); k) bulliform; l) keystone; Cyperaceae phytolith m) sedge cone; n) 'fried egg' – possible sedge cone but firm identification not possible from variants of this form seen. Scale bar in each photograph is 10µm (author's own photographs).

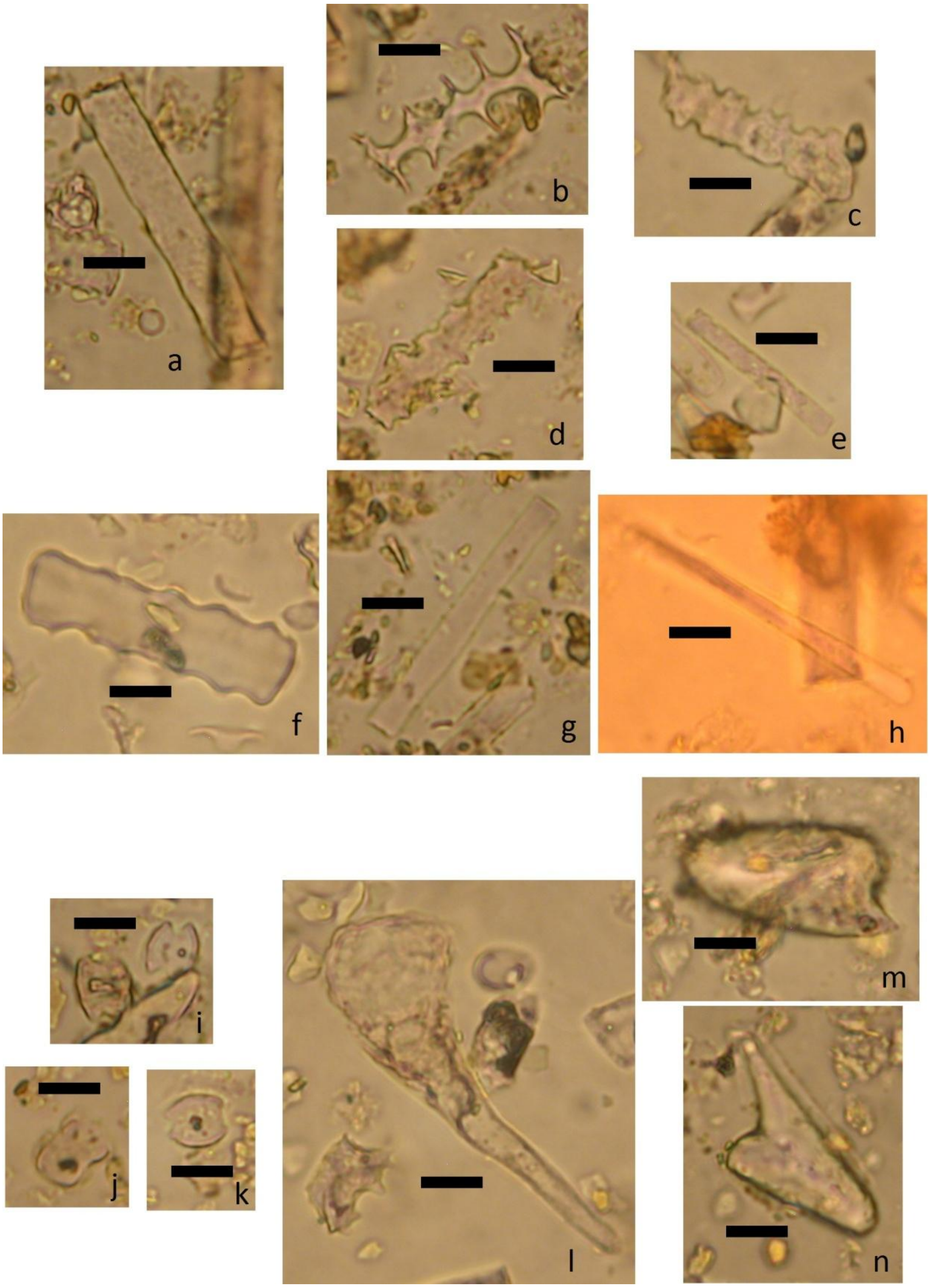


Figure 7.37. Long cell grass phytoliths at the top, short cell saddle grass phytoliths and hair phytoliths underneath (see Piperno 2006): long cell - a) elongate psilate; b) elongate dendritic; c) elongate crenate; d) elongate echinate; e) & g) elongate psilate, cf. Cyperaceae; f) elongate sinuate; h) elongate psilate tapering one end; short cell - i)-k) saddles, j) appears to be of the 'plateau' morphotype originating in *Phragmites australis* (Lu and Liu 2003); l) hair; m) & n) trichomes. Scale bar in each photograph is 10μm (author's own photographs)

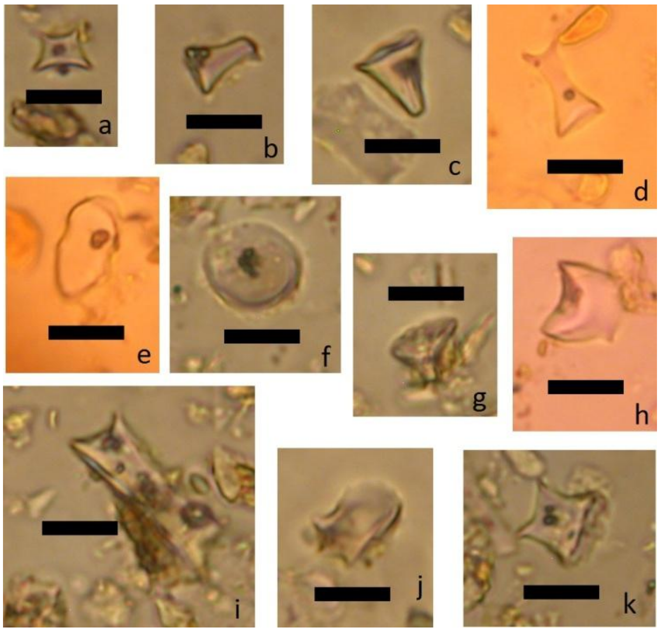


Figure 7.38. Short cell rondel grass phytoliths (Piperno 2006; Twiss *et al.*, 1969): a) rondel; b) tower rondel; c) conical rondel; d) tower rondel with processes; e) hide rondel (named for resemblance to animal hide); f) *Stipa*-type rondel; g) hat rondel; h) chunky rondel; i) long rondel; j) scutiform; k) horned rondel. Scale bar in each photograph is 10µm (author's own photographs).

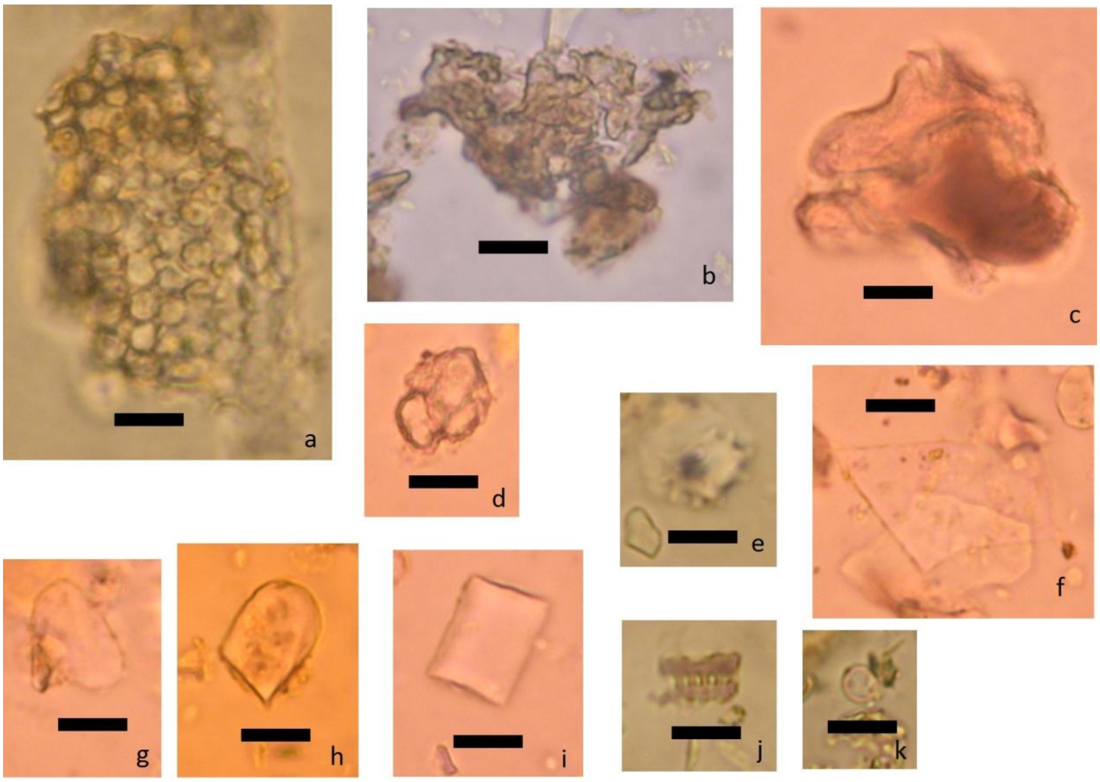


Figure 7.39. Phytoliths from dicotyledons or of uncertain origin (Bozarth 1992; Piperno 2006): a) honeycomb structure from dicotyledon (Bozarth 1992); b) amorphous silica plates/sheets with mineral inclusions typical of woody dicotyledons; c) jigsaw-puzzle phytoliths from a dicotyledon; d) small plates from dicotyledon; e) plate with processes, possibly from dicotyledon; f) lightly silicified silica 'sheet' from woody dicotyledon; g) oval phytolith, possibly from dicotyledon; h) 'tombstone' phytolith, possibly from dicotyledon; i) blocky polyhedron phytolith, found in *Pinus* sp. (also observed in modern *Picea schrenkiana* reference); j) tracheid from dicotyledon; k) spheroid from dicotyledon. Scale bar in each photograph is 10µm (author's own photographs).

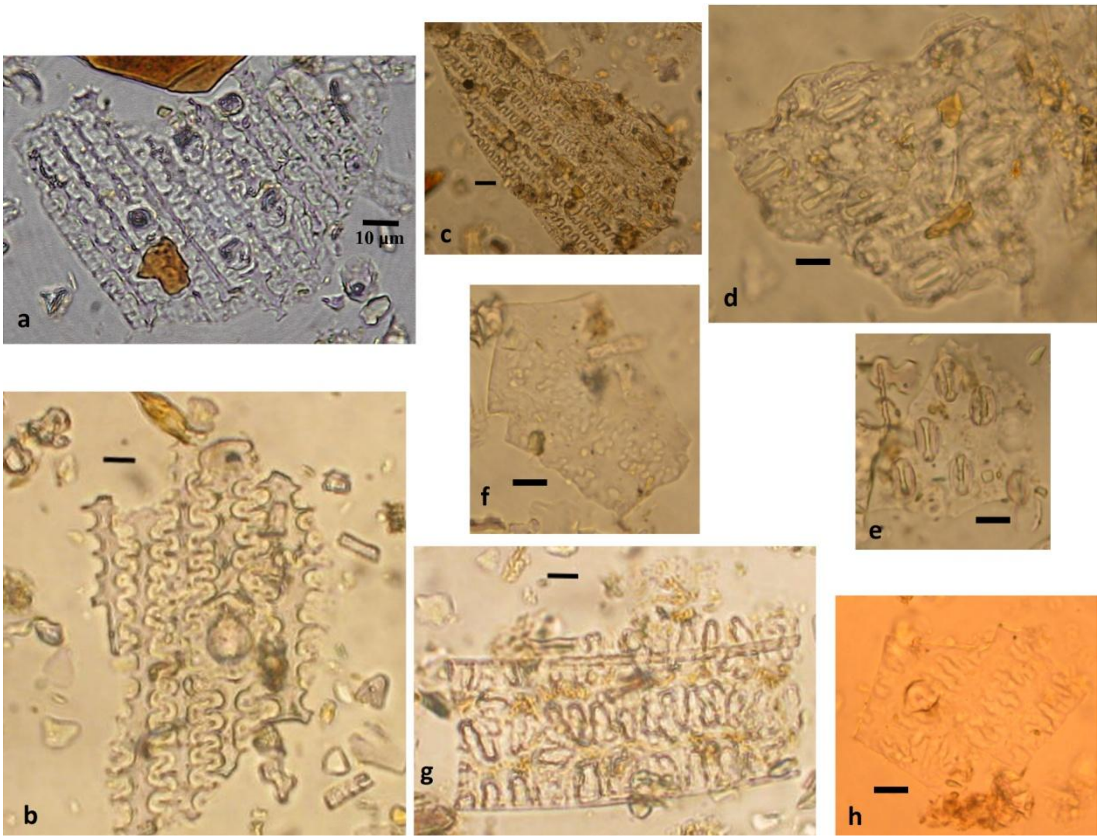


Figure 7.40. Multi-celled grass phytoliths that have been identified to genus level or beyond: a) barley husk (*Hordeum* sp.) (identified using references: Rosen 1992; Arlene Rosen pers. comm.; UCL reference collection); b) wheat husk (*Triticum* sp.), having large sometimes irregular dendritic wave pattern, papillae having 10-12 pits (Rosen 1992; Arlene Rosen pers. comm.; UCL reference collection); c), d) and e) silica skeletons characteristic of *Phragmites australis,* c) stem and d) & e) epidermal layer with many stomata (UCL reference collection, Arlene Rosen pers. comm.); f) *Setar`ia italica* husk, having symmetrical rounded dendritic forms (Lu *et al.* 2009b); g) & h) *Panicum miliaceum* husk, having asymmertrical 'finger-like' dendritic forms (Lu *et al.* 2009b). Scale bar in each photograph is 10µm (author's own photographs).

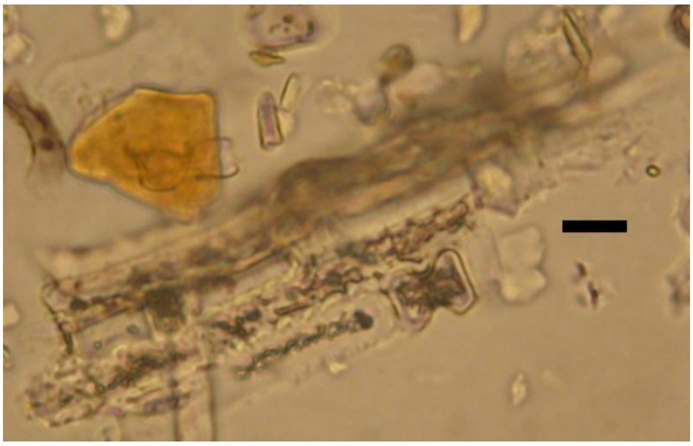


Figure 7.41. Multi-celled phytolith from grass leaf or stem, showing long and short cells *in situ* (elongate psilate, elongate echinate, elongate sinuate, and bilobe). Scale bar is 10µm (author's own photograph)

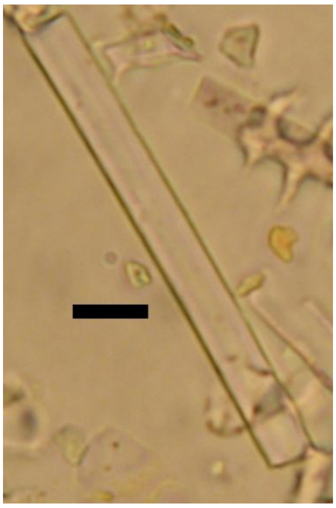


Figure 7.42. An example of biogenic opaline silica of non-plant origin: a sponge spicule, identified through its long narrow psilate form, and presence of central core (axial filament) running through its length (Uriz *et al.* 2003). Scale bar is 10μm (author's own photograph).

7.8. Faecal spherulites

Of those samples which were sub-sampled, with sediment mounted directly to a slide as an exploratory exercise, thirteen were found to contain faecal spherulites (see Figure 7.43, Figure 7.44). Faecal spherulites were identified in samples from all three sites, indicating that a more comprehensive study in the future could be carried out, since the soil chemistry at the three sites appears to be favourable for their preservation. Figure 7.44 shows the count of faecal spherulites in the samples analysed, calculated as the number of faecal spherulites per gram of sediment. As can be seen from the graph, Tuzusai had the highest concentrations of faecal spherulites per gram of sediment of the three sites. These higher concentrations at Tuzusai could be due to greater formation and preservation of spherulites due to soil chemistry (maximum abundance is reached at a soil pH higher than 7, Canti 1999), and/or a higher use and deposition of animal dung at the site. Unfortunately, precise pH data is not available, however Rosen (1997) reported the presence of snail shells and nodules of $CaCO_3$ in the sediments she observed in and around the site during geoarchaeological investigations, indicating an alkaline pH for the surrounding soils and sediments.

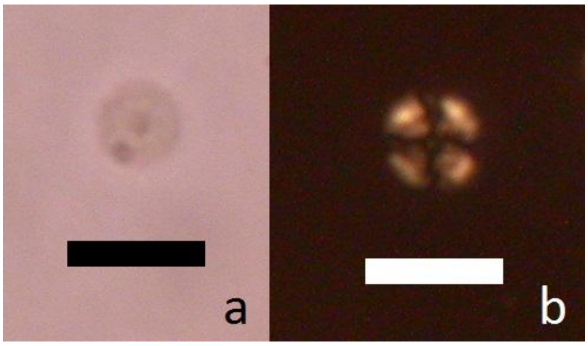


Figure 7.43. Faecal spherulite under a) plane polarised light and b) crossed polarised light, showing extinction cross. Scale bar in each photograph is 10µm (author's own photographs).

In the samples from all three sites there are far more faecal spherulites in contexts that are the result of burning activity than in floor contexts. Due to the small sample size it was not possible to test the statistical significance of this difference on a site-by-site basis, and therefore a t-test was performed on all the samples together. This resulted in a p-value of 0.01114, indicating that the difference in concentrations found in these two context types is statistically significant as it is below the p-value threshold of 0.05 (Fisher 1925). This indicates that there is a difference in either the rate of deposition or the rate of preservation of faecal spherulites across the site which is dependent on the type of context.

To address the issue of preservation first, Canti (1999) asserts that pH is one of the most important factors in the production and preservation of spherulites in archaeological contexts, with spherulite numbers being extremely low to absent in sediments with a pH below 6 (*ibid.*). One possibility is that those contexts which are the result of burning have a more favourable pH for the preservation of spherulites than the pH of the sediment found in floor contexts. The pH of cow dung ash is high (around 10 – 11, Genin *et al.* 2002; Waziri and Suleiman 2012), likewise reported values for raw sheep dung are alkaline (around 8.5, Adhami *et al.* 2014), and the burning process would make it even more so. Wood ash is also known to be strongly alkaline (a pH of around 10.4, Risse 2002). Therefore, whether dung, wood or a mix of fuel types were burned, the ashy contexts are most likely to be strongly alkaline depositional environments, and it is not surprising that the preservation of spherulites is good for these contexts. Although the ashy contexts may have a vastly higher pH than the floor sediments, it seems unlikely that differing taphonomic processes alone account for the significant difference in the concentration of spherulites. If we were to assume that preservation and degradation due to soil chemistry alone were responsible for the varying spherulite concentrations (with a model of even deposition of spherulites in all contexts), then we should also expect that there should be little variation within the group of samples from ashy contexts, since a favourable pH is assumed for all samples from this context type. As the samples from Tuzusai demonstrate, this is not the case, with sample 2011-036 containing over twice the number of spherulites than in the other ashy samples from Tuzusai.

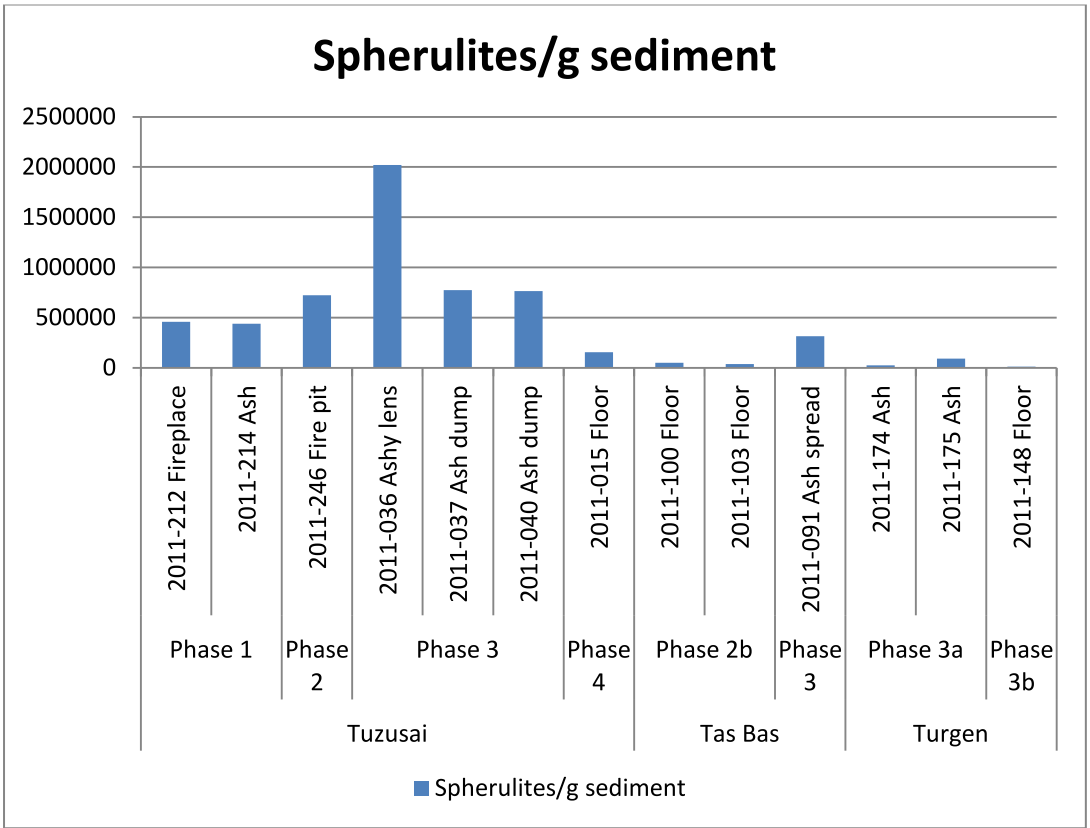


Figure 7.44. Presence of faecal spherulites in selected samples, presented as number of spherulites per gram of sediment

This difference in concentration between contexts of similar origin with assumed similar preservation potential suggests that factors other than preservation are affecting the spherulite concentrations. It is possible, therefore, that these differences between similar contexts with assumed similar pH values are due to varying quantities of dung that were deposited within a particular context. Additionally, although the pH (and therefore preservation potential) of the floor contexts is unknown, the fact that the difference between ashy and floor contexts is statistically significant for the three sites combined indicates that it is likely that there were simply fewer spherulites deposited in the floor contexts. It is therefore reasonable to interpret the higher concentrations of spherulites in ashy contexts as an indication that dung was being systematically burned for fuel at least at Tuzusai and Tasbas (where the concentrations are higher), and perhaps as a supplementary fuel at Turgen, which in the present day is located near to abundant wood resources in the form of pine forests.

The presence of spherulites in the samples from floor contexts might indicate the use of dung for architectural purposes, such as temper in mud brick or wattle and daub construction. Although not quantified, samples 2011-030 and 2011-032 were also observed to have spherulites present. These samples come from Tuzusai and were taken from a plaster floor and surrounding deposits, and may be analogous to the plaster floors identified at the site of Jani in Iran, which were also found to contain faecal spherulites where fired dung had been used as temper (Matthews 2013). It is interesting to note that at Turgen, a site interpreted as a 'summer camp' and therefore ephemeral in nature (Goryachev pers. comm.) there are very low concentrations of spherulites in the floor contexts, which might be explained by the fact that earthen construction (and associated dung temper) was not employed at the site as it was at Tuzusai, and to a lesser extent Tasbas.

Although representing a small sub-sample of the samples in this study, the spherulite data presented here demonstrate that animal dung was an important and ever-present resource for the peoples of Tuzusai, Tasbas and Turgen. The higher concentrations of spherulites from ashy contexts at the three sites are evidence that dung was an important fuel source. The presence of spherulites in the floor contexts is more difficult to interpret, but it is likely that they represent the use of dung in earthen architecture.

Chapter 8: Discussion and conclusions

It was proposed in Chapter 4 that the resilience model of adaptive cycles, and nested hierarchies might be a useful way with which to approach and explain the data presented in this thesis. Based on a review of the literature it was proposed that the earlier periods of the Bronze Age Semirech'ye might represent a K-phase of relative stability and conservation, and by inference lower resilience. The change in the archaeological record noted in the Final Bronze Age was proposed to represent the beginning of an Ω-phase of release or 'creative destruction' (Gunderson and Holling 2002, 41), when former strategies and systems of subsistence ceased to be viable. In this model, the pre-Saka period of the tenth and ninth centuries BC was suggested to represent the height of the Ω release phase.

In the Saka period of Semirech'ye in the eighth century BC, new forms of social hierarchy, artistic expression and subsistence strategies emerged, in particular an increase in agricultural activity, and this period was identified as an α-phase of renewal and reorganisation, a period of high resilience and adaptability. The later Iron Age witnessed a phase of exploitation and growth, as evidenced on the Talgar alluvial fan (Chang *et al.* 2002), which may be conceptualised as an r-phase according to the resilience model. The hypothesis suggested here was that the archaeological record for this period represented a near-complete cycle of stability, collapse, re-organisation, and re-growth.

As part of this model, four variables were identified as having the power to affect human choices of land use and subsistence and therefore the systems in which they operate. These are: 1) climate, which can act as both a fast and a slow variable, depending on perspective; 2) hydrology, including seasonal stream variability, flooding events; 3) social and demographic pressures, again these can be both fast and slow acting variables. For example, steady population growth can be considered a slow variable, whereas war or political upheaval can be very fast acting; 4) human land exploitation and its consequences, including factors such as deforestation and water management, which can be slow or fast acting depending on the type of change being made to the landscape.

The following discussion aims to provide a synthesis of the evidence that has been generated in this research for human exploitation of plant resources and land use over time at Tasbas, Tuzusai and Turgen, together with other relevant lines of evidence from previous research in the region. With this synthesis in place I will re-evalute the adaptive cycle model proposed at the beginning of this thesis, and assess whether this model might be of further use for future research directions in Semirech'ye.

8.1. Plant food resources

Phytoliths from the domesticated cereals wheat, barley, and millet (both broomcorn and foxtail) were identified from all three sites. Since it is the husk (lemma and palea) of the cereal which produces diagnostic multi-celled phytoliths, the phytolith evidence shows that grain was present in or around the sites as whole panicles, and that the husk made its way into the archaeological record either as the disposal or re-use of waste from crop processing, or through the storage of unprocessed cereals. Of course, this means that the absence of diagnostic phytoliths from a sample cannot be taken as evidence that the cereal was absent from the context in question, simply that the husk was not deposited. In this case it is useful to compare the phytolith dataset with other lines of evidence, in particular macrobotanical analyses and artefactual evidence, and then infer what the lack of phytolith evidence might imply.

At Tasbas, small numbers of wheat grains were identified in the macrobotanical assemblage from Phase 1 (2840 – 2496 cal BC) and Phase 2a (1491 – 1260 cal BC) (5 grains and 3 grains respectively) (Doumani *et al.* 2015), but wheat was not identified in the phytolith samples from these phases, although it was identified in phases 2b and 3. The wheat grains from Phase 1 were recovered from a human cremation burial context (*ibid.*), reflecting a similar find in a cremation burial cist at the Bronze Age site of Begash (2460 – 2450 cal BC), located in the foothills of the Dzhungarian mountains (Frachetti *et al.* 2010). The absence of phytoliths from the husk of wheat in these earlier phases combined with the low numbers and ritual context of the deposition in Phase 1 points to an interpretation that in these earlier phases wheat was most likely brought to the site as clean grain, probably as a valuable commodity, and was not cultivated at the site.

Another noteworthy case of the absence of phytolith evidence at Tasbas relates to that of barley in Phase 2a. Barley was identified only in Phase 2a in both the phytolith samples and the macrobotanical remains (although macrobotanical analysis was carried out only for phases 1 and 2b). Barley grains were identified in the macrobotanical remains from the contents of an oven (Feature 109), but no firm identification of barley husks could be identified from this context. The barley grains were identified as being naked barley (*Hordeum vulgare* var. *nudum*), which may explain why only evidence of clean grain was found in the oven, although the phytoliths from this sample were highly disarticulated, which also leads to difficulties in identifying silica skeletons.

It appears from the data that domesticated cereals played a very small role in diet at Turgen, with only one identified taxon present, and that with very low ubiquity (*Setaria italica*), at the site in Phase 3a. It is important to note that the structures from the Late/Final Bronze Age periods (most likely correlating to phases 3a and 3b). have been interpreted as having a ritual function, however many artefacts were recovered which seem to indicate that the site was used for domestic as well as ritual purposes during these periods, such as bone and stone tools (Goryachev 2010). Likewise, the ratio of dendritic to psilate single-celled phytoliths at Turgen is the lowest of the three sites for all phases (

Figure 7.17), indicating that husks were deposited in lower numbers in relation to other parts of grasses such as leaves and stems. This indicates that grass seeds (from domesticated and wild grasses) were brought to and deposited at the site in far lower quantities than at the other sites with proven agricultural activity. Phase 3a (1450 – 1400 cal BC) shows the highest relative proportion of dendritic single-celled husk phytoliths, also the phase in which *Setaria italica* was identified. Despite the lack of evidence for domesticated cereals at Turgen, secondary evidence for the collection and processing of plant resources in the form of grinding stones, pestles and mortars, and a bone sickle, has been found during excavations in phases 1, 3a, 3b, and 4 (Goryachev 2010) (Bronze Age to Early Iron Age). In addition, phytoliths identified as coming from the husks of wild grasses were identified in phases 1 – 5, in addition to other unidentified multi-celled husk phytoliths. In this case, therefore, it would seem that parallels can be drawn with research at the Krasnosamarskoye settlement in the Samara river valley (1950 – 1700 cal BC), where no cultivated grains were present, but there was evidence of the exploitation of a wide number of wild plant resources (Anthony *et al.* 2005). At Turgen it appears that grains from wild plants were exploited from the Bronze Age to the Early Iron Age, in addition to what appears to be small-scale cultivation of *Setaria italica* in Phase 3a (Late Bronze Age). It should be stressed here that the presence of domesticated cereals at Tuzusai and Tasbas does not preclude the exploitation of wild plant resources for food in addition to the cultivated cereals.

At Tasbas, which shares some of its chronology with Turgen, four domesticated cereals were present at the site and their distribution implies that while more prevalent than at Turgen, a certain amount of control was exercised in their use and deposition at the site, with the millet *Panicum miliaceum* being more widely distributed and wheat, barley and *Setaria italica* being more restricted in their presence at the site. At the later site of Tuzusai, overall ubiquities of cereals is far higher than at the other two sites, implying that cereals were more widespread across all contexts of the site, with grain or processing waste being brought into the site and deposited in a number of different contexts, some relating to construction such as mud brick and plaster floors. While Tuzusai has the same cereal 'package' as Tasbas, the distributions of these cereals is different, with wheat being the most widely distributed cereal, appearing in a majority of contexts at Tuzusai. Unspecified millets were found in just over fifty percent of the contexts at Tuzusai, also implying a wide accessibility to this cereal for all households. Barley was the least widely distributed cereal at both Tasbas and Tuzusai, found in a small number of contexts at both sites. Again, this could imply a more specific use of barley, thus restricting its deposition, more controls over who had access to barley and in what parts of the site it could be used in, or a lower overall importance of barley in diets at both Tasbas and Tuzusai.

Calculation of the ubiquities of identified economic plants for the three sites gives an insight into the changing nature of the exploitation of both domesticated and wild plant resources over time. The fact that this calculation relies on presence/absence data rather than absolute counts of phytoliths in samples mitigates for the effect of formation and preservation filters of phytoliths in sediments, such as water availability or soil chemistry (Jenkins et al. 2011; Rosen 1994), meaning that data from the sites can be compared with some confidence. In addition to the ubiquity data evidence for the relative proportion of grass husks in relation to the leaves and stems, represented by single-celled dendritic and elongate psilate phytoliths, can indicate whether there may have been a greater exploitation of grass seeds (wild or domesticated) in certain phases and at certain sites. Looking at the sites as a whole, this measure does seem to reflect the relative presence of crop processing waste since the site with the highest proportion of dendritic phytoliths is Tuzusai, which also has the greatest ubiquity of domesticated cereals and wild grass seeds in the phytolith data, a conclusion also supported by the macrobotanical remains (Spengler *et al.* 2013). Using all these datasets together, it is possible to propose the following summary for the exploitation of cereal grains and wild grass seeds over time at the three sites (absolute dates are given where possible) (Table 8.1):

Period:	Tasbas	Turgen	Tuzusai
Middle Bronze Age (2840 – 2496 cal BC)	**[Phase 1]** Wheat brought to the site in small quantities as clean grain, possibly socially valuable, ritually important commodity. Low proportion of single-celled dendritic husk phytoliths (comparable to modern topsoil sample).	**[Phases 1 and 2]** Exploitation of wild grass seeds? Low proportion of single-celled dendritic husk phytoliths	
Late Bronze Age (1491 – 1260 cal BC)	**[Phase 2a]** Wheat brought to site as clean grain? No husks. Millet most ubiquitous cereal (majority *Panicum miliaceum* husk, small number of *Setaria italica* grains, but no husk) processing waste at site. Naked barley used as mud brick temper, grains found in oven context, but no husk phytoliths. Processing of barley and mud brick production offsite? Higher proportion of single-celled dendritic husk phytoliths than in previous phase.	**[Phase 3a]** Exploitation of wild grass seeds? *Setaria italica* cultivated on a small scale during seasonal occupation in the summer months. Highest proportion of single-celled dendritic husk phytoliths of all phases.	
Final Bronze Age (1254 – 1053 cal BC)	**[Phase 2b]** Wheat husks present – cultivation at the site? Millet dominant cereal – *Panicum* in the majority, but also *Setaria* Exploitation of wild grass seeds? Highest proportion of single-celled dendritic husk phytoliths for all phases.	**[Phase 3b]** Exploitation of wild grass seeds? Low proportion of single-celled dendritic husk phytoliths	
Late Bronze/Early Iron Age (9^{th} – 5^{th} centuries BC	**[Phase 3]** Highest ubiquity of wheat husks for Tasbas. Millet remains dominant cereal, although fall from Phase 2a (Either *Panicum miliaceum* or *Setaria italica*) Lower proportion of single-celled dendritic husk phytoliths.	**[Phase 4]** Exploitation of wild grass seeds? Low proportion of single-celled dendritic husk	

Period:	Tasbas	Turgen	Tuzusai
		phytoliths	
Iron Age (522 – 383 cal BC, 400 – 350 BC)			**[Phase 1]** Wheat dominant cereal, most likely cultivated near the site. *Setaria italica* and *Panicum miliaceum* husks identified, *Panicum* with a higher ubiquity. Barley. All cereals cultivated near the site. Grape seed in macrobotanical remains. Wild grass husks (probably as dung and mud brick temper). High proportion of single-celled dendritic husk phytoliths. **[Phase 2]** Wheat dominant cereal. *Panicum* dominant millet, *Setaria* less ubiquitous. Barley present with low ubiquity (in contrast to macrobotanical remains where it was the second most ubiquitous cereal). High proportion of single-celled dendritic husk phytoliths. **[Phase 3]** Lower ubiquity of all cereals. Hierarchy of ubiquity remains the same as for Phase 2 **[Phase 4]** Marked drop in ubiquity of all cereals
Iron Age Saka/Wusun period (200 BC – AD 1)		**[Phase 5 and 6]** Burial context Higher proportion of single-celled dendritic husk phytoliths in Phase 5	Ubiquity of *Setaria* rises from Phase 3, but *Panicum* has a higher ubiquity. No barley husks identified. Higher ubiquity of wild grass husks. Lowest proportion of

Period:	Tasbas	Turgen	Tuzusai
			single-celled dendritic husk phytoliths **[Phase 5]** Further drop in ubiquity for cereals. Only wheat and *Setaria italica* identified. Highest ubiquity of wild grass husks. Higher proportion of single-celled dendritic husk phytoliths than in Phase 4. **[Phase 6]** Single sample, therefore ubiquity cannot be used. Wheat, barley, and millet (unspecified) identified. High proportion of single-celled dendritic husk phytoliths.

Table 8.1. Summary of exploitation of plant food resources over time

Overall, the summary above shows that there is a general trend of increasing cereal cultivation in Semirech'ye over time from the Bronze Age to the Iron Age. In more detail, the evidence suggests that earlier in the Bronze Age, wheat was not cultivated in the highland sites of Tasbas and Begash, but rather brought into the sites as clean grain and deposited in a ritual context. The Late and Final Bronze Age seem to show a flourishing of agriculture, with evidence for the cultivation of cereals at both Tasbas (wheat, barley, *Setaria italica* and *Panicum miliaceum*) and the high mountain site of Turgen (*Setaria italica)*. During the Late Bronze/Early Iron Age there is no evidence for the cultivation of cereals at Turgen but the presence of grinding stones suggest wild plant resources may have been exploited. Wheat and millet continue to be present at Tasbas, but there is no phytolith evidence for barley during this time. The earlier half of the Iron Age marks a high point of engagement in agriculture, with evidence from Tuzusai suggesting that wheat, barley, and both millets were cultivated near the site.

Throughout the Iron Age at Tuzusai there appears to be a steady decline in the prevalence of crop processing waste towards Phase 4, which may represent a period of abandonment at the settlement from around 350 BC until 200 BC. During the apparent re-occupation of the Tuzusai settlement in Phase 5, only wheat and *Setaria italica* were identified, together with a higher proportion of wild grass husks, perhaps representing a shift in subsistence patterns and either a greater reliance on wild plant resources or a closer relationship between livestock and humans with wild grass seeds being deposited in dung at the site.

8.2. **Land use and local environments**

Having drawn together the evidence for the use of plant resources for food, I can now look to evidence for land use and what this might imply about the local environments around the sites. The first question to address is whether the sites can in fact be compared given their different geographical locations and, most importantly when considering plant assemblages, different altitudes. This question has been answered by the multivariate analysis (Section 7.5 in this thesis), which demonstrated that once the effect of altitude had been accounted for in the data, a significant percentage of the variation between the samples was explained by other variables, in this case the date (see Figure 7.26. Second RDA. Species, samples and environmental variables triplot. Samples classified by date. This figure shows that there was a distinction in the phytolith assemblages from contexts classified as Middle to Late Bronze Age (date classification 1-3) and those with a classification of Late Bronze/Early Iron Age, Iron Age, and Late Iron Age (date classification 4, 6, and 7), which occupy distinct areas in the ordination space. Since the effect of altitude has been accounted for, assumed in this model to be the biggest factor in determining local climatic variance, the data strongly suggest that the types of plant resources exploited in these periods had common trends across the three sites despite their varying climatic and by inference vegetation profiles (outlined in Chapter 5).

Given these underlying trends implied in the multivariate data, it can be assumed that the sites can indeed be compared with confidence. It is here that the climatic indices and calculation of the ratio of phytoliths from woody dicotyledonous plants versus those from grasses are useful to draw on and compare to the local site palaeoclimatic data. The reason for this is that the climatic indices calculated from the phytolith data are a reflection of the types of plant matter that was brought to and deposited at the site, and are therefore a reflection of human choices in which microenvironments and plants to exploit in the vicinity of the site, for example in the gathering of reeds (*Phragmites australis*) from wetlands, or the grazing of livestock on dry uplands and then using their dung for fuel, construction such as wattle and daub, or temper in mud brick. When assessed alongside the palaeoclimatic data for the sites, it may be possible to see where the archaeological and palaeoclimatic data agree and where they differ, thus enabling inferences about human choices in reaction to or in spite of environmental pressures. This comparison is presented in the table below (Table 8.2). In each case the data is presented as relative to the previous phase, and the first phase for each site is described in relation to the other sites. Absolute values for the indices can be found in Section 7.6.

Period:	**Tasbas**	**Turgen**	**Tuzusai**
Middle Bronze Age (2840 – 2496 cal BC)	**[Phase 1]** High proportion of Pooid grasses (96.7%) (indicative of more grasses adapted to cooler environments present at the site). No Chloridoid grasses. High D/P ratio (woody dicotyledenous to grass phytoliths). 50% ubiquity of *Phragmites australis* and Cyperaceae.	Palaeoclimatic evidence for warmer, drier climate (Nigmatova 2008). **[Phases 1 and 2]** High proportion of Pooid grasses (96.6%). Very low proportion of Chloridoid grasses (Phase 2). Highest D/P ratio (Phase 1), sharp fall in Phase 2. Cyperaceae 100% ubiquity (Phase 1). Slightly cooler and wetter conditions (*ibid.*)	Arid environment (Rosen 1997)
Late Bronze Age (1491 – 1260 cal	**[Phase 2a]** Slightly lower proportion	**[Phase 3a]** Slightly lower	

Period:	Tasbas	Turgen	Tuzusai
BC)	of Pooid grasses (indicative that grasses adapted to warmer environments present). Higher proportion of Chloridoid grasses to Panicoid grasses. Large fall in D/P ratio. High ubiquity of *Phragmites australis*, same ubiquity of Cyperaceae	proportion of Pooid grasses. No Chloridoid grasses. Higher D/P ratio. Low numbers of spherulites present (ash context). Lower ubiquity of Cyperaceae.	
Final Bronze Age (1254 – 1053 cal BC)	**[Phase 2b]** Lowest proportion of Pooid grasses for all phases. Higher proportion of Chloridoid grasses. Further fall in D/P ratio. Low numbers of spherulites present (floor context). Lower ubiquity of *Phragmites australis*, higher ubiquity of Cyperaceae. Humid, cooler and wetter climate than present day (Aubekerov *et al.* 2003; Frachetii 2008, 80).	Return to warmer, drier conditions (*ibid.*) **[Phase 3b]** Higher proportion of Pooid grasses. Spike in proportion of Chloridoid grasses. Highest for all phases. Lower D/P ratio. Very low numbers of spherulites present (floor context). Lower ubiquity of Cyperaceae	
Late Bronze/Early Iron Age (9th – 5th centuries BC	**[Phase 3]** Higher proportion of Pooid grasses (similar to Phase 1). Highest proportion of Chloridoid grasses for all phases. Slight fall in D/P ratio. Higher numbers of spherulites present (ash context). Higher ubiquity of *Phragmites australis*, higher ubiquity of Cyperaceae. Cold and wet climate (*ibid.*)	Drier and colder climate (*ibid.*) **[Phase 4]** Highest proportion of Pooid grasses for all phases. No Chloridoid grasses. Lowest D/P ratio. Cyperaceae 100% ubiquity. Colder and wetter climate (*ibid.*)	
Iron Age (522 – 383 cal BC, 400 – 350 BC)			Pluvial climate (*ibid.*), large seasonal amplitudes. **[Phase 1]** Relatively high proportion of Pooid grasses (compared

Period:	Tasbas	Turgen	Tuzusai
	Peak cold and humidity around 250 BC (*ibid.*).	Warmer, dry conditions (*ibid.*)	to other phases) (65.98%). Highest proportion of Chloridoid grasses. Low D/P ratio (0.11), but moderate for Tuzusai. Moderate numbers of spherulites present (ash context). Highest ubiquity of *Phragmites australis* for all phases. High ubiquity of Cyperaceae **[Phase 2]** Low proportion of Pooid grasses. Lower proportion of Chloridoid grasses. Highest D/P ratio. Higher numbers of spherulites present (ash context). Lower ubiquity of *Phragmites australis* and Cyperaceae. **[Phase 3]** Lower proportion of Pooid grasses. Very low proportion of Chloridoid grasses. Lower D/P ratio. Very high numbers of spherulites present (ash context). Lowest ubiquity of *Phragmites australis* for all phases, higher ubiquity of Cyperaceae. **[Phase 4]** High proportion of Pooid grasses. Lowest proportion of Chloridoid grasses for all phases. Lowest D/P ratio for all phases. Low to moderate numbers of spherulites present (floor context). Higher ubiquity of *Phragmites australis*, high ubiquity of

Period:	Tasbas	Turgen	Tuzusai
			Cyperaceae.
Iron Age Saka/Wusun period (200 BC – AD 1)		**[Phase 5 and 6]** Lower proportion of Pooid grasses. Slightly higher proportion of Chloridoid grasses (Phase 5). Higher D/P ratio. Cyperaceae 100% ubiquity Phase 5, none in Phase 6.	**[Phase 5]** Lowest proportion of Pooid grasses for all phases. Slightly higher proportion of Chloridoid grasses. Higher D/P ratio. No *Phragmites australis*. Highest ubiquity of Cyperaceae for all phases. **[Phase 6]** Slightly higher proportion of Pooid grasses. Slightly higher proportion of Chloridoid grasses. Higher D/P ratio. No *Phragmites australis*, no Cyperaceae.

Table 8.2. Comparison of evidence for land use (green text) and palaeoclimatic data (blue text)

As can be seen from the above table, the climatic indices generated from the phytolith data seem to be in broad agreement with the palaeoclimatic data that is currently available. This, in combination with the presence of faecal spherulites, might indicate that the climatic indices are most strongly a reflection of grazing practices, with herds being grazed close to the settlements, and their dung being deposited at the site either through corralling or secondary uses such as fuel. The use of dung as fuel is confirmed by the presence of faecal spherulites in ash contexts from all three sites. At Tasbas, and perhaps also at Tuzusai there appears to be evidence of deforestation, with a falling D/P ratio and an increase in the presence of faecal spherulites over time. It is possible that this process was human-induced, or at least exacerbated, at Phase 3 of Tuzusai, where climatic indicators point to warm, wet environs at the site which one might consider favourable to the growth of trees, and yet the low D/P ratio and high numbers of spherulites indicate that dung was the primary source of fuel in this period.

In both sets of data, Phase 4 at Tuzusai seems to indicate a period of decline in human activity, with a lower ubiquity of cereals, and a higher proportion of Pooid grasses (indicating that Panicoid cereals are less well represented). Occurring later in the Iron Age, this might represent a short Ω-phase of destruction when the population at Tuzusai declined. The same cannot be said for the picture presented for the Final Bronze Age and the Late Bronze/Early Iron Age at Tasbas, which seems to represent the steady adoption of agriculture over this period, rather than a complete reorganisation of subsistence strategies. In contrast, the evidence for Turgen in this period suggests that *Setaria italica* was being cultivated in the Late Bronze Age, but that in the Final Bronze Age this had ceased and perhaps only wild grasses were exploited for food.

8.3. Resilience theory and the archaeological record in Semirech'ye

What is clear from the above syntheses is that the picture of land use and subsistence strategies is far more nuanced and complicated than it might appear from the record in the material culture or from changes in burial practices. While in general resilience theory has proven useful in conceptualising and ordering the approach to the data, it appears to be limited in its explanatory or predictive power when applied to small-scale, specific case-studies such as this one.

As can be seen from the models of climate mechanisms and palaeoclimatic reconstructions presented above, the past climate of Semirech'ye cannot be considered as a single entity, but is better approached and understood as a mosaic of micro-environments that respond locally to wider climatic forcing factors through the influence of site-specific influences such as elevation, topography and aspect. What is clear from the data is that at around 850 BC, corresponding to the Early Iron Age in Semirech'ye, the region experienced a period of climate change that was not uniform in its effects on local hydrological regimes and vegetation cover, but which in all zones appears to have led to greater moisture availability and a generally cooler climate in contrast to a previously warmer and more arid period in the Bronze Age. As has been demonstrated above for the three sites in this study, mountainous regions experienced different effects of this change than the lower-lying plains and piedmont zones. In the case of the sites of Tasbas and Turgen, both in mountainous regions but at varying elevations (1488 and 2283m asl respectively), elevation is expected to have played a part in the severity and extent of seasonal ice cover, which when combined with aspect and insolation at the sites themselves would result in varying availability of land for human occupation and exploitation throughout the year. The potential for land use at Tuzusai would have also been influenced by the same glacial regime as at Turgen, although being at a much lower elevation (723m asl) this influence was felt through periods of glacial melt in the spring and summer, influencing the availability and manageability of water for human groups.

Humans, of course, cannot be considered the passive and static recipients of climatic change. It is reasonable to assume that human groups reacted to and influenced vegetation cover through practices such as deforestation and grazing of herds, and exploited water sources and channels by either changing settlement locations according to varying hydrological regimes, or actively managing the channels themselves by physically changing their character. All these actions would have local effects on evapotranspiration rates, the erosion and deposition of sediments, and soil chemistry and formation. Thus, climatic proxies such as pollen records, soil profiles and sediment cores do not necessarily show the outcome of natural events, but are rather a reflection of the interaction between humans and the environment over time. In the case of Semirech'ye, natural and human responses to climate change were non-uniform across the region, meaning that while general trends can be found across the whole area, it is the localised, mosaic-like quality of this corner of arid central Asia that is of most interest to archaeologists.

8.4. **Conclusions**

In attempting to answer questions about human land use and subsistence strategies at times of change, specifically the changes seen from the Late Bronze to the Iron Ages, the non-uniformity of landscapes and climate dynamics appear to be the most important factors to consider with regards to the palaeoclimate of Semirech'ye (Frachetti 2008). While from afar the phasic nature of change and stability might appear to fit neatly into a resilience theory model of adaptive cycles, up close the picture is far more complicated, and cannot be satisfactorily explained by such a broad sweeping model. However, the concept of complex adaptive systems has certainly been very useful in conceptualising the approach to these data, and future research might focus on related middle-range theories to further refine the theoretical approach and begin to build a theoretical model with predictive as well as descriptive power.

This research has provided fresh insights into the transitional period from the Late Bronze Age to the Iron Age in the Semirech'ye region of Kazakhstan. Newly generated phytolith and faecal spherulite data has allowed the synthesis of a complex and nuanced picture of land use and the exploitation of plant resources, both for subsistence and non-food uses. The systematic recovery and analysis of more palaeobotanical data is greatly needed in the territory of the former Soviet Union and in the Semirech'ye region in particular, and this research adds to a growing body of new research that seeks to provide integrated datasets for the further understanding of land use and subsistence strategies in prehistory. As was stated in Chapter 3, Semirech'ye has long been understood to be a unique case-study in the context of the wider Eurasian steppe zone, particularly with regards to the relationship between pastoralism and agriculture. In this thesis the results have been presented and analysed within the context of previous archaeological and in particular palaeoclimatic studies in order to provide new insights into human-landscape interactions over time. It is hoped that future research will allow the creation of a phytolith reference collection for the region, the identification, dating and analysis of ancient buried soils, and the study of a larger number of settlement sites in order to refine the many-faceted human story that is beginning to emerge for Semirech'ye.

Bibliography

Abbreviations

ANKSSR - Akademiya Nauk Kazakhskoy SSR, Sektor Geografii

CAREC - Regional Environmental Centre for Central Asia

NAN RK – Natsional'noy Akademii Nauk Respubliki Kazakhstan

PFAF – Plants for a Future

Abel, T. and J.R. Stepp, 2003. A new ecosystems ecology for anthropology. *Conservation Ecology* 7(3): 12 [Internet]. Retrieved on 24 November 2010 from the World Wide Web: http://www.consecol.org/vol7/iss3/art12

Adhami, E., S. Hosseini, H. Owliaie, 2014. Forms of phosphorus of vermicompost produced from leaf compost and sheep dung enriched with rock phosphate. International *Journal of Recycling of Organic Waste in Agriculture* 3:68 [Internet]. Retrieved on 17 March 2014 from the World Wide Web: http://link.springer.com/article/10.1007%2Fs40093-014-0068-9.

Akishev, K.A., 1972. *K probleme proiskhozhdeniya nomadizma v aridnoi zone drevnovo Kazakhstana. Poiski i raskopki v Kazakhstane*. Almaty: Nauk.

Akishev, K.A., 1977. Semirech'ye i Yuzhnyi Kazakhstan. *Istoriya Kazakhskoi S.S.R.,* T.1, Moscow: Iskusstvo.

Akishev, K.A., 1978. *Kurgan Issyk Iskusstvo Sakov Kazakhstana*. Moscow: Iskusstvo.

Akishev K.A., Kushayev G.A.. 1963. *Ancient Culture of Sakas and Wusuns in the Ili River Valley*. Alma-Ata: Kazakh SSR Academy of Sciences.

Albert, R.M. and S. Weiner, 2001. Study of phytoliths in prehistoric ash layers from Kebara and Tabun Caves using a quantitative approach. In: Meunier, J.D. and F. Colin (eds.), *Phytoliths: Applications in Earth Sciences and Human History*. Lisse, Abingdon, Exton (Pa.), Tokyo: A.A. Balkema, 251–266.

Alexandre, A., M. Bouvet and L. Abbadie, 2011. The role of savannas in the terrestrial Si cycle: a case-study from Lamto, Ivory Coast. *Global andPlanetary Change*, 78, 162–169.

Alexandre, A., J.-D. Meunier, F. Colin and J.M. Koud 1997. Plant impact on the biogeochemical cycle of silicon and related weathering processes. *Geochimica et Cosmochimica Acta*, 61, 677–682.

Alexandre, A., J.D. Meunier, A.M. Lézine, A. Vincens and D. Schwartz, 1997. Phytoliths: indicators of grassland dynamics during the Late Holocene in intertropical Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 136(1), 213–229.

Alisov, B.P., 1956. *Climate of the USSR*. Moscow: Moscow State University.

An C., Y. Lu, J. Zhao, S. Tao, W. Dong, H. Li, M. Jin and Z. Wang, 2011. A high-resolution record of Holocene environmental and climatic changes from Lake Balikun (Xinjiang, China): Implications for central Asia. *The Holocene*, 22(1), 43–52.

Andrianov, B.V., 1969. *Drevnie orositelnye sistemy Priaralya: v svyazi s istoriey vozniknoveniya i razvitiya oroshaemogo zemledeliya*. Moscow: Nauka.

ANKSSR 1982. *Atlas Kazakhskoy SSR: Tom 1*. Moscow: GUGiKPSM SSSR.

Anthony, D., 2006. Three deadly sins in steppe archaeology: culture, migration and Aryans. In: Peterson, D.L., L.M. Popova and A.T. Smith, *Beyond the Steppe and the Sown: Proceedings of the 2002 University of Chicago Conference on Eurasian Archaeology*. Leiden: Brill, 40–62.

Anthony, D.W., D. Brown, E. Brown, A. Goodman, A. Kokhlov, P. Kosintsev, P. Kuznetsov, O. Mochalov, E. Murphy, D. Peterson, A. Pike-Tay, L. Popova, A. Rosen, N. Russel and A. Weisskopf, 2005. The Samara Valley project. Late Bronze Age economy and ritual in the Russian Steppes. *Eurasia Antiqua*, 397–419.

Arrow, K., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C.S. Holling, B.O. Jansson, S. Levin, K.G. Mäler, C. Perrings, and D. Pimentel, 1995. Economic growth, carrying capacity, and the environment. *Science*, 268, 520–521.

Aubekerov B., S. Nigmatova, and S. Sala, 2003. Changes of Atmospheric Circulation, Paleoclimate and Paleogeography in the Tienshan-Balkhash System. *PAGESnews*, 11, n.1 [Internet]. Retrieved on 22 September 2011 from the World Wide Web: www.pages-igbp.org

Baipakov, K.M. and A.N. Mar'yashev, 2008. *Byan-Zhurek Petroglyphs*. Almaty: Credo.

Baipakov, K.M. and Z.K. Taimagambetov, 2006. *Arheologiya Kazakhstana: Uchebnoe posobye dlya studentov vysshikh uchebnykh zavedeniy*. Almaty: Kazakh State University-Al Farabi.

Ball, T.B., J.D. Brotherson, J.S. Gardner, 1993. A typologic and morphometric study of variation in phytoliths from einkorn wheat (Triticum monococcum). Canadian Journal of Botany, 71 (9), 1182–1192.

Ball, T.B., J.S. Gardner and, N. Anderson, 1999. Identifying inflorescence phytoliths from selected species of wheat (Triticum monococcum, T. dicoccon, T. dicoccoides, and T. aestivum) and barley (Hordeum vulgare and H. spontaneum) (Gramineae). American Journal of Botany 86 (11), 1615–1623.

Ball, T., J.S. Gardner and J.D. Brotherson, 1996. Identifying Phytoliths Produced by the Inflorescence Bracts of Three Species of Wheat (Triticum monococcum L., T. dicoccon Schrank., and T. aestivum L.) Using Computer-Assisted Image and Statistical Analyses. *Journal of Archaeological Science*, 23, 619–632.

Beardmore, R., 2007a. Arkheologia na sluzhbe natsional’noy idei (na primere arkheologicheskikh nakodok v Semirech’ye). *Vestnik Evrazii*, 4(38), 91–114.

Beardmore, R., 2007b. How useful is the notion of ‘environmental security’ to Kazakhstan? A case-study of the Ili-Balkhash Basin. Unpublished MLitt thesis, University of St Andrews.

Berger, J.F., L. Nuninger and S. van der Leeuw, 2007. Modeling the role of resilience in socioenvironmental co-evolution: the middle Rhône Valley between 1000 BC and AD 1000. In: Kohler, T.A. and S.E. van der Leeuw (eds.), The *Model-Based Archaeology of Socionatural Systems*. Santa Fe: School for Advanced Research Press, 41–59.

Bernshtam, A.N., 1952. *Istoriko-arkheologicheskie ocherki tsentralnogo Tian-shania i Pamiro-Alaia*. Moscow: Nauka.

Blackman, E., 1968. The pattern and sequence of opaline silica deposition in rye (*Secale cereale* L.). *Annals of Botany*, 32, 207–218.

Blackman, E. and D. W. Parry, 1969. Observations on the development of the silica cells of the leaf sheath of wheat (*Triticum aestivum*). *Canadian Journal of Botany*, 47, 827–838.

Bonney, E.M., K.J. Franklin and J.A. Johnson, 2016. *Incomplete Archaeologies: Assembling Knowledge in the Past and Present*. Oxford: Oxbow Books.

Bremond, L., A. Alexandre, E. Vela, J. Guiot, 2005. Grass water stress estimated from phytoliths in West Africa. *Journal of Biogeography*, 32, 311–327.

Bremond, L., A. Alexandre, M.J. Wooller, C. Hély, D. Williamson, P.A. Schäfer, A. Majule and J. Guiot, 2008. Phytolith indices as proxies of grass subfamilies on East African tropical mountains. *Global and Planetary Change*, 61, 209–224.

Bremond, L., A. Alexandre, C. Hely, J. Guiot, 2005. A phytolith index as a proxy of tree cover density in tropical areas: calibration with Leaf Area Index along a forest–savanna transect in southeastern Cameroon. *Global and Planetary Change*, 45, 277–293.

Bronk Ramsey C., 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon*, 51(1), 337–360.

Cabanes, D., C. Mallol, I. Exposito and J. Baena, 2010. Phytolith evidence for hearths and beds in the late Mousterian occupations of Esquilleu cave (Cantabria, Spain). *Journal of Archaeological Science*, 37 (11), 2947–2957.

Cabanes, D., S. Weinera and R. Shahack-Gross, 2011. Stability of phytoliths in the archaeological record: a dissolution study of modern and fossil phytoliths. *Journal of Archaeological Science*, 38, 2480–2490.

Campos, S., L. del Puerto and H. Inda, 2001. Opal phytolith analysis: its applications to the archaeobotanical record in Eastern Uruguay. In: Meunier, J.D. and F. Colin (eds.), *Phytoliths: Applications in Earth Sciences and Human History*. Lisse, Abingdon, Exton (Pa.), Tokyo: A.A. Balkema, 129–142.

Canti, M.G., 1997. An Investigation of Microscopic Calcareous Spherulites from Herbivore Dungs. *Journal of Archaeological Science*, 24, 219–231

CAREC, 2000. *Ili-Balkhash Basin Sustainable Development Conception*, [Internet] Almaty: CAREC. Retrieved on 04 January 2011 from the World Wide Web: http://www.uneptie.org/pc/cp7/PDFs/otherpaper/yconcept.pdf

Carpenter, S., W. Brock, and P. Hanson, 1999. Ecological and social dynamics in simple models of ecosystem management. *Conservation Ecology* 3(2):4. [Internet]. Retrieved on 12 June 2011 from the World Wide Web: http://www.consecol.org/vol3/iss2/art4.

Carpenter, S. R., and L. H. Gunderson, 2001. Coping with collapse: ecological and social dynamics in ecosystem management. *BioScience*, 51(6), 451–457.

Chang, C., 2007. *Taldy Bulak 2: A Saka-Usunei Settlement on the Talgar alluvial fan (ca. floruit BC 780 to AD 960).* Unpublished excavation report.

Chang, C., 2015. The Study of Nomads in the Republic of Kazakhstan. In: Kardulius, P.N. (ed.), *The Ecology of Pastoralism*. Boulder: University Press of Colorado, 17–40.

Chang, C. forthcoming. *Lines of Power*. Cambridge: Cambridge University Press.

Chang, C., K.M. Baipakov, F.P. Grigoriev and P. Tourtellotte 2002. *The evolution of steppe communities from the Bronze Age through medieval periods in southeastern Kazakhstan (Zhetysu) : the Kazakh-American Talgar Project 1994-2001*. Sweet Briar: Sweet Briar College.

Chang, C. and R. Beardmore. (2015). The Tale of a Mud Brick: Lessons from Tuzusai and De-Assembling an Iron Age site on the Talgar Alluvial Fan in South-eastern Kazakhstan. In Bonney, E. M., J.A. Johnson, K.J. Franklin, and L. Šmejda (eds) *Incomplete Archaeologies: Assembling Knowledge in the Past and Present*. Oxford: Oxbow

Chang, C., N. Benecke, F.P. Grigoriev, A.M. Rosen and P. Tourtellotte, 2003. Iron Age society and chronology in south-east Kazakhstan. *Antiquity*, 77, 298–312.

Chang, C. and K. Guroff, eds., 2006. *Of Gold and Grass: Nomads of Kazakhstan.* Washington: Foundation for International Arts and Education.

Chang, C. and P. Tourtellotte, 2008. *Final Report for Excavations at Tuzusai 2008: Kazakh-American Archaeological Expedition (KAAE)*. Unpublished excavation report.

Chang, C. and P. Tourtellotte, 2012. *Preliminary Report for 2012 Excavations at Tuzusai, an Iron Age settlement on the Talgar Fan, Kazakh American Archaeological Expedition (KAAE)*. Unpublished report.

Chang, C., P. Tourtellotte, K.M. Baipakov and F.P. Grigoriev, 2002. *The Evolution of Steppe Communities from the Bronze Age through Medieval Periods in Southeastern Kazakhstan (Zhetysu)*. Almaty: Sweet Briar.

Charles, M. and A. Bogaard, 2010. Charred plant macro-remains from Jeitun: Implications for early cultivation and herding practices in western Central Asia. In D.R. Harris, *Origins of Agriculture in Western Central Asia*, Philadelphia: University of Pennsylvania Museum, 150–65; 256–59.

Chen F., Z. Yu, M. Yang, E. Ito, S. Wang, D.B. Madsene, X. Huang, Y. Zhao, T. Sato, H.J.B. Birks, I. Boomer, J. Chen and B. Wunnemann, 2008. Holocene moisture evolution in arid central Asia and its out-of-phase relationship with Asian monsoon history. *Quaternary Science Reviews* 27, 351–364.

Christian, D. 1995. *History of Russia, Central Asia and Mongolia, Volume I: Inner Eurasia from Prehistory to the Mongol Empire*. Oxford and Malden, Massachusetts: Blackwell Publishers.

Clarke, D.L., 1968. *Analytical Archaeology*. London: Methuen.

Coil, J., M.A. Korstanje, S. Archer and C.A. Hastorf, 2003. Laboratory goals and considerations for multiple microfossil extraction in archaeology. *Journal of Archaeological Science*, 30, 991–1008.

Coolidge, J., 2010. The Mesolithic and Neolithic periods: sites, sequences, and subsistence. In D.R. Harris, *Origins of Agriculture in Western Central Asia*, Philadelphia: University of Pennsylvania Museum, 53–69.

Cornelis, J.-T. and B. Delvaux, 2016. Soil processes drive the biological silicon feedback loop. *Functional Ecology*, 30, 1298–1310. doi:10.1111/1365-2435.12704

Cornelis, J.-T., B. Delvaux, R.B. Georg, Y. Lucas, J. Ranger and S. Opfer-gelt, 2011. Tracing the origin of dissolved silicon transferred from various soil–plant systems towards rivers: a review. *Biogeosciences*, 8, 89–112.

Davidson, D.J., 2010. The Applicability of the Concept of Resilience to Social Systems: Some Sources of Optimism and Nagging Doubts. *Society and Natural Resources*, 23(12), 1135–1149.

Davis-Kimball, J., V. Bashilov and L. Yablonski (eds.), 1995. *Nomads of the Eurasian Steppes in the Early Iron Age*. Berkeley: Zinat Press.

Dean, J.S., 2000. Complexity Theory and Sociocultural Change in the American Southwest. In: McIntosh, R.J., J.A. Tainter and S.E. McIntosh, (eds.), *The Way the Wind Blows: Climate, History and Human Action*. New York: Columbia University Press, 89–118.

Dearing, J.A., 2008. Landscape change and resilience theory: a palaeoenvironmental assessment from Yunnan, SW China. *The Holocene* 18(1), 117–127 [Internet]. Retrieved on 10 December 2010 from the World Wide Web: http://hol.sagepub.com/content/18/1/117.

Di Cosmo, N., 1994. Ancient inner Asian nomads: their economic basis and its significance in Chinese history. *The Journal of Asian Studies*, 53(4), 1092–1126.

Dickau, R. M.C. Bruno, J. Iriarte, H. Prümers, C. Jaimes Betancourt, I. Holst, F.E. Mayle, 2012. Diversity of cultivars and other plant resources used at habitation sites in the Llanos de Mojos, Beni, Bolivia: evidence from macrobotanical remains, starch grains, and phytoliths. *Journal of Archaeological Science*, 39, Issue 2, 357–370.

Dinacuze, D.F., 2000. *Environmental Archaeology: principles and practice*. Cambridge: Cambridge University Press.

Dörner, D., 1996. *Logic of Failure: Why Things Go Wrong and What We Can Do To Make things Right*. Translated from German by Kimber, R. and R. Kimber (translators). New York: Metropolitan Books.

Doumani P.N., M.D. Frachetti, R. Beardmore, T.M. Schmaus, R.N. Spengler and A.N. Mar'yashev, 2015. Burial ritual, agriculture, and craft production among Bronze Age pastoralists at Tasbas (Kazakhstan). *Archaeological Research in Asia*, 1-2, 17–32.

Dzhurkashev, T.N., 1972. *Antropogenovaya Istoriya Balkhash-Alako'sckoy Vpadiny*. Almaty: Nauk.

Epimakhov, A.V. 2010. O Sintashtinskom zemledelii (bronzoviy vek Yuzhnogo Urala). *Vestnik arkheologii, antropologii i etnografii*., No. 2(13).

Field, H. and K. Price, 1947. Review of Soviet archaeology, 1919-1945, in historical perspective. *Southwestern Journal of Anthropology*, 3(3), 212–229.

Fisher, R.A., 1925. *Statistical Methods for Research Workers in the Biological Monographs and Manuals Series*. Edinburgh: Oliver and Boyd.

Fishkis, O., J. Ingwersen, M. Lamers, D. Denysenko, T. Streck, 2010. Phytolith transport in soil: a field study using fluorescent labelling. *Geoderma*, 157, 27–36.

Flannery, K., 1969. Origins and Ecological Effects of Early Domestication in Iran and the Near East. In Ucko, P.J. And G.W. Dimbleby (eds.) *The Domestication and Exploitation of Plants and Animals.* Chicago: Aldine Publishing Co., 73–100.

Frachetti, M.D., 2006. Ancient Nomads of the Andronovo Culture: The Globalization of the Eurasian Steppe during Prehistory. In Chang, C. and K. Guroff (eds.), *Of Gold and Grass: Nomads of Kazakhstan.* Washington: Foundation for International Arts and Education, 21–28.

Frachetti, M.D., 2008. *Pastoralist Landscapes and Social Interaction in Bronze Age Eurasia*. Berkeley: University of California Press.

Frachetti, M., N. Benecke, A.N. Mar'yashev and P. Doumani, 2010. Eurasian pastoralists and their shifting regional interactions at the steppe margin: settlement history at Mukri, Kazakhstan. *World Archaeology,* 42(4), 622–646.

Frachetti, M.D. and A.N. Mar'yashev, 2007. Long-term settlement, mobility, and landscape formation of Eastern Eurasian pastoralists from 2500 CAL B.C. *Journal of Field Archaeology,* 32(3), 221–42.

Frachetti, M.D., R.N. Spengler, G.J. Fritz and A.N. Mar'yashev, 2010. Earliest direct evidence for broomcorn millet and wheat in the central Eurasian steppe region. *Antiquity*, 84, 993–1010.

Fredlund. G.G. and L.L., 1994. Tieszen Modern Phytolith Assemblages from the North American Great Plains. *Journal of Biogeography,* 21(3), 321–335.

Funakawa, S., A. Kadono, K. Morioka, K. Pachikin and G. Wang, 2010. Distribution patterns of soils and vegetation in the foothills of the Tienshan and Altai Mountains in Central

Eurasia. In: Watanabe, M. and J. Kubota (eds.), *Reconceptualizing Cultural and Environmental Change in Central Asia: An Historical Perspective on the Future*. Kyoto: Research Institute for Humanity and Nature, 29–48.

García-Granero, J.J., C. Lancelotti, and M. Madella, A tale of multi-proxies: integrating macro- and microbotanical remains to understand subsistence strategies. *Vegetation History and Archaeobotany*, 24, Issue 1, 121–133.

Genin, D., P. Abasto, S. Choque and J. Magne, 2002. Dung ash treatment of a native forage to improve livestock feeding in low-input Andean pastoral systems. *Livestock Research for Rural Development* 14 (2) [Internet]. Retrieved on 8 October 2010 from the World Wide Web: http://www.lrrd.org/lrrd14/2/geni142.htm.

Goldberg, P. and R.I. Macphail, 2005. *Practical and Theoretical Geoarchaeology*. Hoboken: Wiley-Blackwell.

Goryachev, A.A. 2007. Mogil'nik rannego zheleznogo veka arkheologicheskogo kompleksa v verkhov'yakh ushchel'ya Turgen'. *Isvestiya NAN RK*, *Seriya obshchestvennikh nauk*, No.1, 3–14.

Goryachev, A.A. 2010. Arkheologicheskiy complex uscchel'ya Turgen'. *Annual International Scientific Conference of the faculty on the basis of Almaty branch SPbGUP – 20th Jan 2010*. [Internet]. Retrieved 24 November 2011 from the World Wide Web: https://sites.google.com/site/metodsovet09/korkutovskie-ctenia2009/2-goracev-a-a

Gosden, C. and J. Meadows, 2010. Jeitun: Dating and analysis of excavated materials. In D.R. Harris, *Origins of Agriculture in Western Central Asia*, Philadelipa: University of Pennsylvania Museum, 119–124.

Gotts, N.M., 2007. Resilience, Panarchy, and World-Systems Analysis. *Ecology and Society* 12(1) [Internet]. Retrieved on 04 September 2014 from the World Wide Web: http://www.ecologyandsociety.org/vol12/iss1/art24/.

Greene, R.R., 2004. Holocaust Survivors: A Study in Resilience. *Journal of Gerontological Social Work*, Volume 37(1) [Internet]. Retrieved on 18 October 2014 from the World Wide Web: http://www.researchgate.net/publication/238621433_Holocaust_Survivors_A_Study_in_Resilience.

Grigoriev, F.P., 1995. *Pozdne Sakskoe Poselenie Tuzusai: Predvaritelynie itogi issledovaniy*. Chimkent: Ata-Mura.

Gryaznov, M.P., 1957. Etapy razvitiya khozyaistva skotovodcheskikh plemen Kazakhstana i Yuzhnoi Sibiri v epokhu bronzy. *KSIE*, 26.

Gunderson, L.H. and C.S. Holling, 2002. *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington D.C.: Island Press.

Gunderson, H., C. S. Holling, and S.S. Light, 1995. *Barriers and Bridges to the Renewal of Regional Ecosystems.* New York: Columbia University Press.

Gulyamov, Y.G., I. Islamov and A. Askarov, 1966. *Pervobytnaya Kultura v Nizovyakh Zeravshana*. Tashkent: FAN.

Gumerman, G.J. and M. Gell-Mann, 1994. *Understanding Complexity in the Prehistoric Southwest*. Reading, Massachusetts: Addison-Wesley, Advanced Book Program.

Hacking, I., 1983. *Representing and intervening: Introductory topics in the philosophy of natural science*. Cambridge: Cambridge University Press.

Hagg, W. and L. Braun, 2005. The Influence of Glacier Retreat on Water Yield from High Mountain Areas: Comparison of Alps and Central Asia. In: de Jong, C., D. Collins and R. Ranzi, *Climate and Hydrology in Mountain Areas*. Chichester: Wiley, 263–276.

Hall, M.E., 1997. Towards an absolute chronology for the Iron Age of Inner Asia. *Antiquity*, 71, 863–874.

Hanks, B., 2002. The Eurasian Steppe 'nomadic world' of the first millennium BC: inherent problems within the study of Iron Age nomadic cultures. In: Boyle, K., C. Renfrew and M. Levine (eds.), *Ancient Interactions: east and west in Eurasia*. Cambridge: McDonald Institute for Archaeological Research, 183–197.

Hanks, B.K., A.V. Epimakhov and A.C. Renfrew, 2007. Towards a refined chronology for the Bronze Age of the southern Urals, Russia. *Antiquity*, 81, 353–367.

Harris, D.R. (ed.), 2010. *Origins of agriculture in Western Central Asia: an environmental-archaeological study*. Philadelphia: University of Pennsylvania.

Hart, D.M. and G.S. Humphreys, 1997. The mobility of phytoliths in soils: pedological considerations. In A. Pinilla, J. Juan-Tresserras and M.J. Machado (Eds.), *The State-of-the-art of Phytoliths in Soils and Plants*. Madrid: Centro de Ciencias Medioambientales (CSIC), 93–100.

Harvey, E. L. and D. Q. Fuller, 2005. Investigating crop processing through phytolith analysis: the case of rice and millets. *Journal of Archaeological Science*, 32, 739–752.

Hill, R.,1958. Generic features of families under stress. *Social casework*, 49, 139–150.

Holling, C. S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4, 1–23.

Holling, C. S. 1978. The Spruce-Budworm/Forest-Management Problem. In: Holling, S.C. (ed.), *Adaptive Environmental Assessment and Management*. *International Series on Applied Systems Analysis, 3*. Hoboken: John Wiley & Sons, 143–182.

Holling, C. S., and L. H. Gunderson, 2002. Resilience and adaptive cycles. In Gunderson, L.H. and C. S. Holling (eds.), *Panarchy: understanding transformations in human and natural systems*. Washington D.C.: Island Press, 25–62.

Holling, C. S., L. H. Gunderson, and D. Ludwig, 2002. In quest of a theory of adaptive change. In Gunderson, L.H. and C. S. Holling (eds.), *Panarchy: understanding transformations in human and natural systems*. Washington D.C.: Island Press, 3–24.

Horrocks, M. A combined procedure for recovering phytoliths and starch residues from soils, sedimentary deposits and similar materials. *Journal of Archaeological Science*, 32, Issue 8, 1169–1175.

Hsü, K.J., 1998. Did the Xinjiang Indo-Europeans Leave Their Homes Because of Global Cooling? In: Mair, V. (ed.), *The Bronze Age and Early Iron Age peoples of Eastern Central Asia*. Washinton D.C.: Institute for the Study of Man, 683–696.

Hubbard, R. N. L. B., 1975. Assessing the botanical component of human paleo-economies. *Bulletin of the Institute of Archaeology*, 12, 197–205.

Hunt H.V., M.V. Linden, X. Liu, G. Motuzaite-Matuzeviciute, S. Colledge and M.K. Jones, 2008. Millets across Eurasia: chronology and context of early records of the genera Panicum and Setaria from archaeological sites in the Old World. *Vegetation History and Archaeobotany*, 17(1), 5–18.

Hurcombe, L.M. 2014. *Perishable material culture in prehistory: investigating the missing majority*. London: Routledge.

IUSS Working Group WRB. 2006. World Reference Base for Soil Resources 2006. *World Soil Resources Reports*, No. 103., Rome: FAO.

Jenkins, E., 2009. Phytolith taphonomy: a comparison of dry ashing and acid extraction on the breakdown of conjoined phytoliths formed in *Triticum durum*. *Journal of Archaeological Science*, 36, Issue 10, 2402–2407.

Jenkins, E., K. Jamjoum and S. Al Nuimat, 2011. Irrigation and phytolith formation: an experimental study. In: Mithen, S. and Black E. (eds.), *Water, Life and Civilization: Climate, Environment and Society in the Jordan Valley*. Cambridge: Cambridge University Press, 347–372.

Jianjun, M. and C. Shell, 2002. The Iron Age Cultures in Xinjiang and their Steppe Connections. In: Boyle, K., C. Renfrew and M. Levine (eds.), *Ancient Interactions: east and west in Eurasia*. Cambridge: McDonald Institute for Archaeological Research, 213–234.

Johannessen, S., 1984. Paleoethnobotany. In: Bareis, C.J. and J.W. Porter (eds.), *American Bottom Archaeology: A Summary of the FAI-270 Project Contribution to the Culture History of the Mississippi River Valley*. Urbana: University of Illinois Press, 197–214.

Johnson, M., 2010. *Archaeological Theory: An Introduction*. Oxford: Wiley-Blackwell.

Jones, S., 1997. *The Archaeology of Ethnicity: Constructing identities in past and present*. London: Routledge.

Jones, L.H.P. and K.A. Handreck, 1965. Studies of silica in the oat plant. III. Uptake of silica from soils by the plant. *Plant and Soil*, 23, 79–96.

Karin, E. and A. Chebotarev, 2002. The Policy of Kazakhization in State and Government Institutions in Kazakhstan. In: Oka, N. (ed.), *The Nationalities Question in Post-Soviet Kazakhstan* [Internet]. Retrieved on 15 December 2010 from the World Wide Web: http://www.ide.go.jp/English/Publish/Mes/51.html

Khotinskiy, N.A., 1984. Holocene Climatic Change. In: Velichko, A.A. (ed.) 1984. *Late Quaternary Environments of the Soviet Union*. London: Longman, 305–309.

Kohler, T.A. and S.E. van der Leeuw, 2007. Introduction: Historial Socionatural systems and Models. In: Kohler, T.A. and S.E. van der Leeuw, *The Model-Based Archaeology of Socionatural Systems.* Santa Fe: School for Advanced Research Press, 1–12.

Koronovsky, N., 2002. Tectonics and Geology. In: Shahgedanova, M. (ed.), *The Physical Geography of Northern Eurasia*. Oxford: Oxford University Press, 1–35.

Kotov, M.I., 1960. High-mountain vegetation of the southeastern part of central Tien Shan. In: Sukachev, V.N. (ed.), *Studies on the Flora and Vegetation of High-Mountain Areas*. Moskva-Leningrad: Akademii Nauk SSSR.

Kremenetski, K.V., 2003. Steppe and Forest-Steppe Belt of Eurasia: Holocene Environmental History. In: Levine, M., C. Renfew and K. Boyle, *Prehistoric Steppe Adaptation and the Horse*. Cambridge: McDonald Institute for Archaeological Research, 11–27.

Kristova-Grakova, O.A., 1948. *Alekseevskoe poselenie I mogil'nik*. Trudy Gosudarstvennogo Istoricheskogo Muzeya XVII. Moskva: Nauka.

Kuzmina, E.E., 1958. Mogilnik Zaman-Baba. *Sovetskaya Etnografiya,* 2, 24–33.

Kuzmina, E.E., 1966. Metallicheskie izdeliya eneolita i bronzovogo veka v Srednei Azii. *Svod arkheologicheskikh istochnikov,* 4(9).

Kuzmina, E.E., 1994. *Otkuda prishli indoarii? Material'naya kultura plemen andronovskoi obshchnosti i proizkhozhenie indoariantsev*. Moskva: MGP "Kalina".

Kuzmina, E.E., 2003. Origins of Pastoralism in the Eurasian Steppes. In: Levine, M., C. Renfrew and K. Boyle (eds.), *Prehistoric Steppe Adaptation and the Horse*, 203–232.

Kuzmina, E.E., 2007. *The Origin of the Indo-Iranians*. Leiden: Brill.

Kuzmina, E.E., 2008. *The Prehistory of the Silk Road*. Philadelphia: University of Pennsylvania Press.

Lancelotti, C. and M. Madella. 2012. The 'invisible' product: Developing markers for identifying dung in archaeological contexts. *Journal of Archaeological Science*, 39, 953–963

Lebedeva, E.Y., 1996. O zemledelii v stepyakh i lesostepyakhVostochnoi Evropy v epokhu bronzy. *Uralskoe arkheologi-cheskoe soveshchanie*, 13, 53–55.

Lentfer, C.J. and W.E. Boyd, 1998. A Comparison of Three Methods for the Extraction of Phytoliths from Sediments. *Journal of Archaeological Science*, 25, Issue 12, 1159–1183.

Leps, J. and P. Smilauer, 2003. *Multivariate Analysis of Ecological Data using CANOCO*. Cambridge: Cambridge University Press.

Lu, H., J. Zhang, K-b. Liu, N. Wu, Y. Li, K. Zhou, M. Ye, T. Zhang, H. Zhang, X. Yang, L. Shen, D. Xu, and Q. Li, 2009a. Earliest domestication of common millet (Panicum miliaceum) in East Asia extended to 10,000 years ago. *Proceedings of the National Academy of Sciences,* 106(18), 7367–7372.

Lu, H., J. Zhang, N. Wu, K-b. Liu, D. Xu, Q. Li, 2009b. Phytoliths analysis for the discrimination of foxtail millet (Setaria italica) and common millet (Panicum miliaceum). *PLoS One* 4(2): 4448. [Internet]. Retrieved on 30 November 2010 from the World Wide Web: http://www.plosone.org/article/info:doi/10.1371/journal.pone.0004448

Lua, H., K-b. Liu, 2003. Phytoliths of common grasses in the coastal environments of southeastern USA. *Estuarine, Coastal and Shelf Science*, 58, 587–600.

Lyublyanovics, K. 2012. Faunal remains. In Chang, C. and P. Tourtellotte, 2012. *Preliminary Report for 2012 Excavations at Tuzusai, an Iron Age settlement on the Talgar Fan, Kazakh American Archaeological Expedition (KAAE)*. Unpublished report.

Macphail R.I., M.J. Allen, G.M. Cruisea, J. Linderholm and P. Reynolds, 2004. Archaeological soil and pollen analysis of experimental floor deposits; with special reference to Butser Ancient Farm, Hampshire, UK. *Journal of Archaeological Science*, 31, 175–191.

Madella, M., 2001. Understanding archaeological structures by means of phytolith analysis: a test from the Iron Age site of Kilise Tepe – Turkey. In: Meunier, J.D. and F. Colin (eds.), *Phytoliths: Applications in Earth Sciences and Human History*. Lisse, Abingdon, Exton (Pa.), Tokyo: A.A. Balkema, 173–182.

Madella M., A. Alexandre and T. Ball, 2005. International Code for Phytolith Nomenclature 1.0. *Annals of Botany*, 96, 253–260.

Madella, M., M.K. Jones, P. Echlin, A. Powers-Jones and M. Moore, 2009. Plant water availability and analytical microscopy of phytoliths: implications for ancient irrigation in arid zones. *Quaternary International*, 193(1), 32–40.

Madella, M., A.H. Powers-Jones and M.K. Jones, 1998. A Simple Method of Extraction of Opal Phytoliths from Sediments Using a Non-Toxic Heavy Liquid. *Journal of Archaeological Science*, 25**,** 801–803.

Maksimova, A.G., 1961. Mogil'nik epokhi bronzy v urochishche Karakuduk. *Novye Materialy po Arkheologii i Ethnographii Kazakhstana.* Alma-Ata: Nauk.

Martin-Breen, P. and J.M. Anderies, 2011. *Resilience: a literature review*. New York: The Rockefeller Foundation.

Mar'yashev, A.N., 2002. Novye Materialy o Poseleniyakh Epokhi Bronzy v Gorakh Bayan Zhurek. *Izvestiya*, 1 (236), 23–30.

Mar'yashev, A. and M. Frachetti, 2007. Issledovanie mogil'nikov i poseleniya u sela Bigash v vostochnom Semirech'ye. *Istoria i Arkeologiya Semirech'ya,* 3, 100–105.

Mar'yashev, A.N. and A.A. Goryachev, 2002. *Naskal'nye Izobrazheniya Semirech'ya*. Almaty: Fond "XXI vek".

Matyushin, G., 2003. Problems of inhabiting central Eurasia: Mesolithic-Eneolithic Exploitation of the central Eurasian steppes. In Levine M., C. Renfrew, K. Boyle (eds.), *Prehistoric steppe adaptation and the horse*. Cambridge: McDonald Institute for Archaeological Research, 367–393.

Merzlyakova, I., 2002. The Mountains of Central Asia and Kazakhstan. In: Shahgedanova, M. (ed.), *The Physical Geography of Northern Eurasia*. Oxford: Oxford University Press, 377–402.

Miehe, G., S. Miehe, and F. Schlütz, 2009. Early human impact in the forest ecotone of southern High Asia. *Quaternary Research*, 71(3), 255–265.

Miller, N.F., 1999. Agricultural development in western central Asia in the Chalcolithic and Bronze Ages. *Vegetation History and Archaeobotany,* 8(1-2), 13–19.

Miller, N.F., 2003. The Use of Plants at Anau North. In F. T. Hiebert and K. Kurdansakhatov, eds., *A Central Asian Village at the Dawn of Civilization: Excavations at Anau, Turkmenistan*. Philadelphia: University of Pennsylvania Museum, 127–138; 201–215.

Minaeva, G.M. and A.D. Fursaev, 1934. Botanicheskie nakhodki v arkheologicheskom materiale. *Sovetkaja Botanika*: 3, 150.

Motuzaite-Matuzeviciute, G., S. Telizhenko and M.K. Jones, 2012. Archaeobotanical investigation of two Scythian-Sarmatian period pits in eastern Ukraine: Implications for floodplain cereal cultivation. *Journal of Field Archaeology*, vol. 37, no. 1

Mulholland, S.C. and G.R. Rapp, 1992. A morphological classification of grass silica- bodies. In G.R. Rapp and S.C. Mulholland, (Eds.), *Phytolith Systematics*. New York: Plenum Press, 65–89.

Nesbitt, M., 1994. Report. In Herrmann G. and K. Kurbansakhatov (eds.), The international Merv project: preliminary report on the second season (1993). *Iran*, 53–75.

Newton, C. 2004. Plant tempering of Predynastic pise at Adaima in Upper Egypt: building material and taphonomy. *Vegetation History and Archaeobotany*, 13(1), 55–64.

Nigmatova, S.A. 2008. Klimatostratigrafiya golotsena aridnoy zony Kazakhstana. *Izvestiya NAN RK, Seriya geologicheskaya*, 5(415), 4–15.

Nurumov, T.N. 1999. O kostnykh otstankakh zhivotnykh iz poseleniy Turgen-II, Butakty-I i Kuygan-I. In Mar'yashev, A.N. and A.A. Goryachev. *Otchet: o polevykh issledovaniyakh Semirechenskoy ekspeditsii po izucheniyu pamyatnikov epokhi bronzy (SEIPEB-99) v sezone 1999 goda*. Almaty: Institut arkheologii im. A.Kh. Margulana.

Okamoto G., T. Okura and K. Goto, 1957. Properties of silica in water. *Geochimica et Cosmochimica Acta*, 12, 123–132.

Outram A.K., R. Bendrey, R.P. Evershed, A. Kasparov, S. Olsen, N.A. Stear, N. Thorpe and V. Zaibert, 2009. The Earliest Horse Harnessing and Milking. *Science*, Vol.323, 1332–1335.

Parr, J.F., 2002. A comparison of heavy liquid floatation and microwave digestion techniques for the extraction of fossil phytoliths from sediments. *Review of Palaeobotany and Palynology*, 120, Issues 3–4, 315–336.

Parr, J.F., 2006. Effect of fire on phytolith coloration. *Geoarchaeology*, 21(2), 171–185

Parr, J. F., C.J. Lentfer, and W.E. Boyd, 2001. A comparative analysis of wet and dry ashing techniques for the extraction of phytoliths from plant material. *Journal of Archaeological Science*, 28(8), 875–886.

Parry, D.W., and M.J. Hodson, 1982. Silica distribution in the caryopsis and inflorescence bracts of foxtail millet [Setaria italica (L.) Beauv.] and its possible significance in carcinogenesis. *Annals of Botany*, 49(4), 531–540.

Parry, D.W. and F. Smithson, 1958. Techniques for studying opaline silica in grass leaves. *Annals of Botany*, 22, 543–549.

Parry, D.W. and F. Smithson, 1964. Types of opaline silica depositations in the leaves of British grasses. *Annals of Botany*, 28, 169–185.

Parry, D.W. and F. Smithson, 1966. Opaline silica in the inflorescence of some British grasses and cereals. *Annals of Botany*, 30, 525–538.

Pearsall, D.M., 2000. *Palaeoethnobotany: a handbook of procedures*. New York: Academic Press.

Pearsall, D.M., D.R. Piperno, E.H. Dinan, M. Umlauf, Z. Zhao, and R.A. Benfer, Jr., 1995. Distinguishing rice (*Oryza sativa* poaceae) from wild Oryza species through phytolith analysis: results of preliminary research. *Economic Botany*, 49(2), 183–196.

Peeples, M.A., C.M. Barton and S. Schmich, 2006. Resilience lost: intersecting land use and landscape dynamics in the prehistoric southwestern United States. *Ecology and Society* 11(2): 22 [Internet]. Retrieved on 21 November 2010 from the World Wide Web: http://www.ecologyandsociety.org/vol11/iss2/art22/

Petr, T. and V.P. Mitrofanov, 1998. The impact on fish stocks of river regulation in Central Asia and Kazakhstan. *Lakes and Reservoirs: Research and Management*, 3, 143–164.

PFAF, 2012. *Caragana jubata* [Internet]. Retrieved on 4 March 2013 from the World Wide Web: http://www.pfaf.org/user/Plant.aspx?LatinName=Caragana+jubata

Pickett, S.T.A., and M. L. Cadenasso. 2002. The ecosystem as a multidimensional concept: meaning, model, and metaphor. *Ecosystems,* 5, 1–10.

Piperno, D.R., 1988. *Phytolith analysis*. New York: Academic Press.

Piperno, D.R., 2006. *Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists*. Oxford: AltaMira Press.

Pleshakov, A. A. and S. V. Zakharov. 2012. Osnovniye etapy razvitiya skotovodstva i zemledeliya na territorii Kazakhstana v epokhu Bronzy. [Internet] Retrieved December 2013 from the World Wide Web: http://elib.nklibrary.kz/kolekci/arhivy-severokazahstanskih-kraevedov/zaharov-s-v/osnovnye-yetapy-razvitija-skotovodstva-i-zemledelija-v-kazahstane-v-yepohu-bronzy.html

Popova, L.M., 2006. Pastoralism during the Late Bronze Age in Russia: past interpretations and new goals for future research. In: Peterson, D.L., L.M. Popova and A.T. Smith, *Beyond* *the Steppe and the Sown: Proceedings of the 2002 University of Chicago Conference on Eurasian Archaeology*. Leiden: Brill, 459–468.

Powers-Jones, A.H. and J. Padmore, 1993. The use of quantitative methods and statistical analyses in the study of opal phytoliths. In D. Pearsall, D.R. Piperno (Eds.), *Current Research in Phytolith Analysis: Applications in Archaeology and Palaeoecology*, Philadephia: University of Pennsylvania, 47–56.

Rapp, G. and S.C. Mulholland (eds.), Phytolith Systematics. *Emerging Issues: Advances in Archaeological and Museum Science 1*. New York: Plenum Press.

Redman, C.L., 1999. *Human Impact on Ancient Environments.* Tuscon: University of Arizona Press.

Redman, C.L., 2005. Resilience theory in archaeology. *American Anthropologist*, 107(1), 70–77.

Redman, C. L. and A. P. Kinzig, 2003. Resilience of past landscapes: resilience theory, society, and the *longue durée*. *Conservation Ecology* 7(1): 14 [Internet]. Retrieved on 21 November 2010 from the World Wide Web: http://www.consecol.org/vol7/iss1/art14

Reimer, P. J., E. Bard, A. Bayliss, J.W. Beck, P.G. Blackwell, C. Bronk Ramsey, P.M. Grootes, T.P. Guilderson, H. Haflidason, I. Hajdas, C. HattŽ, T.J. Heaton, D.L. Hoffmann, A.G. Hogg, K.A. Hughen, K.F. Kaiser, B. Kromer, S.W. Manning, M. Niu, R.W. Reimer, D.A. Richards, E.M. Scott, J.R. Southon, R.A. Staff, C.S.M. Turney and J. van der Plicht, 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon*, 55(4), 1889–1903.

Rhodes, T.E., F. Gasse, L. Ruifen, J.C. Fontes, W. Keqin, P. Bertrand, E. Gibert, F. Mélières, P. Tucholka, W. Zhixiang and C. Zhi-Yuan, 1996. A Late Pleistocene-Holocene lacustrine record from Lake Manas, Zunggar (northern Xinjiang, western China). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 120(1-2), 105–121.

Riehl S. and K. Pustovoytov, 2006. Comment on ‘Climate change and the expansion of the Scythian culture after 850 BC: a hypothesis' by B. van Geel et al., *Journal of Archaeological Science* 31, (2005). *Journal of Archaeological Science* 33, 143–144.

Risse, M., 2002. Best Management Practices for Wood Ash as Agricultural Soil Amendment. *UGA Cooperative Extension Bulletin*, 1142.

Roberts, N., 1998 (2nd ed.). *The Holocene: An Environmental History*. Oxford: Blackwell.

Rosen, A.M., 1992. Preliminary identification of silica skeletons from Near Eastern archaeological sites: an anatomical approach. In: Rapp, G.R. and S.C. Mulholland (eds.), *Phytolith Systematics*. New York, NY: Plenum Press, 129–147.

Rosen, A.M., 1997. *Geoarchaeological Investigations on the Talgar Alluvial Fan, Kazakhstan 1997*. Unpublished excavation report.

Rosen, A.M. 1999. Phytoliths as indicators of prehistoric irrigation farming. In Anderson, P. (ed.), *Prehistory of Agriculture: New Experimental and Ethnographic Approaches.* Los Angeles: UCLA Institute of Archaeology, 193–198.

Rosen, A.M., 2001. Phytolith evidence for agropastoral economies in the Scythian period of southern Kazakhstan. In: Meunier, J.D. and F. Colin (eds.), *Phytoliths: Applications in Earth Sciences and Human History*. Lisse, Abingdon, Exton (Pa.), Tokyo: A.A. Balkema, 183–198.

Rosen, A.M., C. Chang and F.P. Grigoriev, 2000. Paleoenvironments and economy of the Iron Age Saka-Wusun agro-pastoralists in southeastern Kazakhstan. *Antiquity*, 74, 611–623.

Rosen, A.M., and S. Weiner, 1994. Identifying ancient irrigation: a new method using opaline phytoliths from emmer wheat. *Journal of Archaeological Science*, 21(1), 125–132.

Ryan, P., 2011. Plants as material culture in the near Eastern Neolithic: perspectives from the silica skeleton artifactual remains at Çatalhoyük. *Journal of Anthropological Archaeology*, 30 (3), 292–305.

Schiffer, M.B., 1988. The Structure of Archaeological Theory. *American Antiquity*, Vol. 53, No. 3, 461–485.

Schlütz, F. and F. Lehmkuhl, 2007. Climatic change in the Russian Altai, southern Siberia, based on palynological and geomorphological results, with implications for climatic teleconnections and human history since the middle Holocene. *Vegetation History and Archaeobotany*, 16: 101–118.

Shahgedanova, M. (ed.), 2002. *The Physical Geography of Northern Eurasia: Russia and Neighbouring States*. Oxford University Press.

Shennan, S. 2007. The Spread of Farming into Central Europe and its Consequences. In: T.A. Kohler and S.E. van der Leeuw, *The Model-Based Archaeology of Socionatural Systems,* Santa Fe: School for Advanced Research Press, 141–155.

Sommer, M., D. Kaczorek, Y. Kuzyakov, and J. Breuer, 2006. Silicon pools and fluxes in soils and landscapes-a review. *Journal of Plant Nutrition and Soil Science*, 169, 310–329.

Song, J., Z. Zhao, and D.Q. Fuller, 2013. The archaeobotanical significance of immature millet grains: an experimental case study of Chinese millet crop processing. *Vegetation History and Archaeobotany*, 22(2), 141–152.

Sorokin, V.S. and P.M. Gryaznov, 1966. *Andronovskya Kultura*. Moscow: Nauka.

Spengler, R. N., C. Chang, and P.A. Tourtellotte, 2013a. Agricultural production in the Central Asian mountains: Tuzusai, Kazakhstan (410-150 b.c.). *Journal of Field Archaeology*, *38*(1), 68–85.

Spengler, R.N., M.D. Frachetti and G.J. Fritz, 2013b. Ecotopes and Herd Foraging Practices In the Steppe/Mountain Ecotone of Central Asia During the Bronze and Iron Ages. *Journal of Ethnobiology*, 33(1):125–147.

Street-Perrott, F.A. and P. Barker, 2008. Biogenic silica: a neglected component of the coupled global continental biogeochemical cycles of carbon and silicon. *Earth Surface Processes and Landforms*, 33, 1436–1457.

Strömberg, C.A., 2002. The origin and spread of grass-dominated ecosystems in the Late Tertiary of North America: preliminary results concerning the evolution of hypsodonty. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 177(1), 59–75.

Strömberg, C.A., 2004. Using phytolith assemblages to reconstruct the origin and spread of grass-dominated habitats in the great plains of North America during the Late Eocene to Early Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 207(3), 239–275.

Strömberg, C.A., 2009a. Methodological concerns for analysis of phytolith assemblages: Does count size matter? *Quaternary International*, 193(1), 124–140.

Strömberg, C.A., 2009b. Reply to comment on "Methodological concerns for analysis of phytolith assemblages: Does count size matter?" (A. Alexandre and L. Brémond). *Quaternary International*, 193(1), 143–145.

Strömberg, C.A., L. Werdelin, E.M. Friis, and G. Saraç, 2007. The spread of grass-dominated habitats in Turkey and surrounding areas during the Cenozoic: phytolith evidence. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 250(1), 18–49.

Sukachev, V.N., (ed.) 1960. *Studies on the Flora and Vegetation of High-Mountain Areas*. Moskva-Leningrad: Akademii Nauk SSSR.

Tansley, A.G., 1935. The use and abuse of vegetational concepts and terms. *Ecology* ,16, 284–307.

Tarasov, P., J. W. Williams, A. Andreev, T. Nakagawa, E. Bezrukova, U. Herzschuh, Y. Igarashi, S. Müller, K. Werner, Zhuo Z., 2007 Satellite- and pollen-based quantitative woody cover reconstructions for northern Asia: Verification and application to Late-Quaternary pollen data. *Earth and Planetary Science Letters*, 264, 284–298

Ter Braak, C.J., 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology*, 67(5), 1167–1179.

Thorn, V., 2007. Phytoliths in palaeoecology. *Geology Today*, 23, 153–157

Tolstov, S.P., 1962. *Po drevnim del'tam Oksa i Yaksarta*. Moskva-Leningrad: Akademiya Nauk SSSR.

Transboundary Freshwater Dispute Database, 2002. *Asia International River Basin Register*. Retrieved on 03 January 2011 from the World Wide Web: http://www.transboundarywaters.orst.edu/publications/register/tables/IRB_asia.html

Tsartsidou, G., S. Lev-Yadun, R.M. Albert, A. Miller-Rosen, N. Efstratiou and S. Weiner, 2007. The phytolith archaeological record: strengths and weaknesses evaluated based on a quantitative modern reference collection from Greece. *Journal of Archaeological Science*, 34(8), 1262–1275.

Tsartsidou, G., S. Lev-Yadun, N. Efstratiou and S. Weiner, 2008. Ethnoarchaeological study of phytolith assemblages from an agro-pastoral village in Northern Greece (Sarakini): development and application of a Phytolith Difference Index. *Journal of Archaeological Science*, 35(3), 600–613.

Tsartsidou, G., S. Lev-Yadun, N. Efstratiou and S. Weiner, 2009. Use of space in a Neolithic village in Greece (Makri): phytolith analysis and comparison of phytolith assemblages from an ethnographic setting in the same area. *Journal of Archaeological Science*, 36(10), 2342–2352.

Tubb, H.J., M.J. Hodson and G.C. Hodson. 1993. The Inflorescence Papillae of the Triticeae: a New Tool for Taxonomic and Archaeological Research. *Annals of Botany*, 72 (6), 537–545.

Turner, D., 2007. *Making Prehistory: Historical Science and the Scientific Realism Debate*. Cambridge: Cambridge University Press.

Twiss, P.C., 1992. Predicted world distribution of C3 and C4 grass phytoliths. In: Rapp, G. and S.C. Mulholland (eds.), Phytolith Systematics. *Emerging Issues: Advances in Archaeological and Museum Science 1*. New York: Plenum Press.

Twiss, P.C., E. Suess, and R.M. Smith, 1969. Morphological classification of grass phytoliths. *Soil Science Society of America, Proceedings*, 33, 109–115.

Uniyal, S.K., A. Awasthi and G.S. Rawat, 2005. Biomass availability and forage quality of Eurotia ceratoides Mey in the rangelands of Changthang, eastern Ladakh. *Current Science Bangalore*, *89*(1), 201–205.

Van Beck, G. W. and O. Van Beck, 2008. *Glorious Mud! Ancient and Contemporary Earthen Design and Construction in North Africa, Western Europe, and the Near East, and South Asia*. Washington, DC: Smithsonian Institution Scholarly Press.

Vasiliev, S.S., N.A. Bokovenko, K.A. Chugunov, V.A. Dergachev, A.A. Sementsov, Ju. Sljusarenko and G.I. Zaitseva, 2001. Tree-rings, "wiggle matching" and statistics in the chronological study of Scythian age sites in Asia. *Geochronometry*, 20, 61–69.

Velichko, A. and I. Spassyka, 2002. Climatic Change and the Development of Landscapes. In: Shahgedanova, M. (ed.), *The Physical Geography of Northern Eurasia*. Oxford: Oxford University Press, 36–69.

Ventresca Miller, A., E.R. Usmanova, V.N. Logvin, I. Shevnina, S. Kalieva, A. Logvin, A. Kolbina, A. Simonich, K. Privat, K. Haas and M. Rosenmeier, 2014. Subsistence and Social Change in Eurasia: Stable Isotope Analysis of Populations Spanning the Bronze Age Transition. *Journal of Archaeological Science* 42: 525–538.

Venus, B.G., 1983. O razvitii ozera Balkhash v pozdnenogolotsene. *Isvestia Russogo Geographicheskogo Obschestva*, 1, 58–64.

Walter, H. and E.O. Box, 1983. Semi-deserts and deserts of central Kazakhstan. In: West, N.E. (ed.), *Ecosystems of the World, Volume 5*. Amsterdam: Elsevier, 43–78.

Walters, C.J., 1986. *Adaptive Management of Renewable Resources*. New York: Macmillan.

Wang, Y., H. Lu, 1993. *The study of phytolith and its application*. China Ocean Press.

Wang, C.F., G.Q. Jia, H. Zhi, Z.G. Niu, Y. Chai, W. Li, P. Lu, B. Zhao and X. Diao, 2012. Genetic diversity and population structure of chinese foxtail millet [Setaria italica (L.) Beauv.]. *G3: Genes, Genomes, Genetics,* 7, 769–777.

Waziri, M. and J. S. Suleiman, 2013. Analysis of Some Elements and Antimicrobial Activity of Evaporated Extract of Cow Dung Against Some Pathogens. *Journal of Scientific Research* 5 (1), 135–141.

Weisskopf, A.R., 2013. Archaeobotanical implications of phytolith assemblages from cultivated rice systems, wild rice stands and macro-regional patterns. *Journal of Archaeological Science*, 51, 43–53.

Weisskopf, A.R. 2014. *Millets, Rice and Farmers Phytoliths as indicators of agricultural and social change in Neolithic and Bronze Age Central China*. Oxford: British Archaeological Reports.

Weisskopf, A., Z. Deng, L. Qin and D.Q. Fuller, 2015 The interplay of millets and rice in Neolithic central China: Integrating phytoliths into the archaeobotany of Baligang. *Archaeological Research in Asia*, 4, 36–45.

Weisskopf, A., E. Harvey, E. Kingwell-Banham, M. Kajale, R. Mohanty and D.Q. Fuller, 2014. Archaeobotanical implications of phytolith assemblages from cultivated rice systems, wild rice stands and macro-regional patterns. *Journal of Archaeological Science*, 51, 43–53.

Weisskopf, A.R. and G. Lee, 2014. Phytolith identification criteria for foxtail and broomcorn millets: a new approach to calculating crop ratios. *Archaeological and Anthropological Sciences*, 1-14 [Internet]. Retrieved January 2015 from the World Wide Web: http://link.springer.com/article/10.1007%2Fs12520-014-0190-7.

Weisskopf, A, L. Qin, J. Ding, P. Ding, G. Sun and D.Q. Fuller, 2015. Phytoliths and rice: from wet to dry and back again in the Neolithic Lower Yangtze. *Antiquity*, 89 (347), 1051–1063.

Werner, E., 1993. Risk, resilience, and recovery: Perspectives from the kauai longitudinal study. *Development and Psychopathology*, 5(04): 503–515.

Westley F, S.R. Carpenter, W.A. Brock, C.S. Holling and L.H. Gunderson, 2002. Why systems of people and nature are not just social and ecological systems. In: Gunderson L.H. and C.S. Holling (eds.), *Panarchy: understanding transformations in human and natural systems*. Washington D.C.: Island Press, 103-119.

White, A.F., D.V. Vivit, M.S. Schulz, T.D. Bullen, R.R. Evett, and J. Aagarwal, 2012. Biogenic and pedogenic controls on Si distributions and cycling in grasslands of the Santa Cruz soil chronosequence, California. *Geochimica et Cosmochimica Acta*, 94, 72–94.

Wilkinson, T.J. et al., 2007. Modeling Settlement Systems in a Dynamic Environment: Case Studies from Mesopotamia. In: Kohler, T.A. and S.E. van der Leeuw, *The Model-Based Archaeology of Socionatural Systems.* Santa Fe: School for Advanced Research Press, 175–208.

Wu, X., N.F. Miller and P. Crabtree, 2015. Agro-Pastoral Strategies and Food Production on the Achaemenid Frontier in Central Asia: A Case Study of Kyzyltepa in Southern Uzbekistan. *Iran*, LIII, 93–117.

Yablonsky, L.T., 1995. The Material Culture of the Saka and Historical Reconstruction. In: Davis-Kimball, J., V.A. Bashilov and L.T. Yablonsky, *Nomads of the Eurasian Steppes in the Early Iron Age*. Berkeley, CA: Zinat Press, 202–239.

Yoshida, S., Y. Onishi and K. Kitagishi, 1959. The chemical nature of silicon in rice plants. *Soil and Plant Food* (Tokyo), 5, 127–133.

Zaitseva, G.I., N.A. Bokovenko, A. Yu. Alekseev, K.V. Chugunov and E.M. Scott (eds.), 2005. *Eurasia in the Scythian Era: Radiocarbon and archaeological chronology*. St. Petersburg.

Zamotaev, I., 2002. Soils. In: Shahgedanova, M. (ed.), *The Physical Geography of Northern Eurasia*. Oxford: Oxford University Press, 103–121.

Zhang, J., H. Lu, N. Wu, X. Yang, X. Diao, 2011. Phytolith analysis for differentiating between foxtail millet (*Setaria italica*) and green foxtail (*Setaria viridis*). *PLoS One*, 6 (5), e19726. doi:10.1371/journal.pone.0019726.

Zhao, Z. and D.M. Pearsall, 1998. Experiments for Improving Phytolith Extraction from Soils. *Journal of Archaeological Science*, 25, 587–598.

Zhao, Z.J., D.M. Pearsall, R.A. Benfer, D.R. Piperno, 1998. Distinguishing rice (*Oryza sativa*, Poaceae) from wild *Oryza* species through phytolith analysis, II, finalized method. *Econonic Botany*, 52, 34–45.

CD-ROM List of Contents

01_Absolute_Counts [Folder]
02_VBA [Word File]
03_CANOCO_coding [Excel File]
04_Samples_DB [Access File]
05_Single_Cell [Word File]
06_Multi_Cell [Word File]