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Mountain and meadow: A reconstruction of long-term pastoralist ecology in the Kashmir Valley

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Statement of Originality

This is to certify that to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

Michael Spate

12/12/2019

Abstract

The cultural history of the Kashmir Valley in the Western Himalayas spans at least 4500 years, beginning with some of the known Neolithic Agricultural villages in the mountainous regions of the northern Indian Subcontinent. The development of agriculture in the valley, and subsequent periods of cultural expansion have been attributed to economic growth that capitalised on warm-humid climate phases in the region, often followed by periods of supposed social collapse driven by the onset of cold-arid conditions. More recently, Kashmiri archaeologists have argued that these near-Malthusian interpretations result from a methodological focus on a handful of large sites, and that the Kashmir Valley contains multiple ecological niches suitable for a wide range of economic or ecological adaptation. This study therefore seeks to build on the growing palaeoenvironmental and archaeological data that suggests a more complex picture of social and ecological change in the valley.

It investigates seasonally mobile pastoralism in the upland mountain flanks of the Kashmir Valley as a specialised and environmentally resilient adaptation, away from large agricultural settlements on the valley floor. Rather than using archaeological remains, this study draws on environmental signatures of pastoralist usage, enrichment or modification of environmental niches at middle and high altitudes, primarily on the western flank of the Kashmir Valley. These data include changes in pollen spectra, charcoal and fungal accumulation or sediment deposition that are indicative of pastoralist activity in mountain regions, and are interpreted through the lens of niche construction theory.

The results presented here indicate that pastoralist land usage in the upland areas of Kashmir was spatially and temporally discontinuous, and likely entangled with other environmental and historical processes. The stronger signatures for pastoralism often appear contemporary with drier conditions and periods of regional agricultural intensification, indicating that upland summer season herding may be an adaptive strategy to mitigate other ecological or economic pressures. Seasonal exploitation of environmental niches by mobile agro-pastoralist groups across the “Inner Asian Mountain Corridor” enabled the development of systems of contact and exchange between pastoralist groups inhabiting the Himalaya, Hindu Kush, Pamir and Tien Shan ranges. In later periods these networks were central to the rise of historical “Silk Road” trade between China, Central and South Asia and beyond. The results of this study now permit consideration of the Kashmir Valley as a key node within these regional networks formed by Inner Asian pastoralists.

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

ASL – above sea level

BP – before present

Kya – thousand years ago

HCO – Holocene Climate Optimum

IAMC – Inner Asian Mountain Corridor

ISM – Indian Summer Monsoon

KPCP – Kashmir Palaeoclimate Project

LIA – Little Ice Age

Mya – million years ago

MWP – Medieval Warm Period

(N)AP – (non)–arboreal pollen

NPP – non-pollen palynomorph

NCT – niche construction theory

PCA – principal components analysis

SES – socio-ecological system

WD(s) – Western Disturbances

Chapter 1 Introduction

From the writers and poets of the Classical Age to the Romantic philosophers of the 19th century, nomadic and pastoralist populations have alternately been maligned or idealised as wanderers with no particular ties to place, free of the norms of sedentary society (Khazanov 1994). Ethnographic studies from the 20th century onwards have helped to overturn these simplistic stereotypes, instead describing mobile pastoralist societies as occupying a spectrum of social and economic organisation that emphasise the raising of herds but encompass a wide range of adaptations to environmental niches and productive activities (Kreutzmann 2012, Salzman 2004, Khazanov 1994, Barfield 1993). These more nuanced understandings of pastoralist societies have allowed for the examination of pastoralism as not only an economic adaptation that allows humans and their herds to occupy and exploit marginal environmental zones, but as a complex social-ecological system that contributes to the long-term sustainability of pastoralist ecological niches (Dong et al. 2016).

An area long associated with nomadic or pastoralist societies, the steppes, deserts and mountains of Inner Asia are now understood to have given rise to a diverse number of pastoralist adaptations (Frachetti 2011). Environmental and archaeological data now suggest that pastoralist ecology developed through a variety of niche-constructing activities, responding to the particulars of local environmental conditions as well as long term processes of regional or global climate change (Ulla et al. 2019, Spengler 2014, Frachetti 2008). In the Inner Asian mountain ranges of the Tien Shan, Pamirs, Hindu Kush and Himalayas, seasonal herding and ecological strategies are long-standing practices that both embedded the lives of pastoralist populations with the mountain landscapes as they follow productive pastures, as well as involved these populations with other herding and sedentary groups as a result of their mobility. This entanglement between the seasonal dynamics of pastoralist herding, the landscape and neighbouring populations allows for the argument that long-standing pastoralist ecologies were key drivers of cultural and economic contact and exchange in Eurasia, hundreds to thousands of years before historic trade networks such as the “Silk Roads” were formalised (Frachetti et al. 2017).

This thesis investigates the long-term development of pastoralist ecology in the Western Himalayan Kashmir Valley, at the southern end of the Inner Asian mountains. The study primarily draws on new data from palaeoenvironmental archives sampled from pastures on the valley flanks. Evidence for environmental change as well as indicators of pastoralist activity are used to contextualise pastoralism in the Kashmir Valley as a long standing and resilient social-ecological adaptation. In addition, these various environmental proxies provide a broader perspective for the examination of social change within the valley, from the Neolithic to early Historic periods..

1.1 Kashmir Valley

Positioned at the cultural and geographic intersection of the South Asian Subcontinent, Tibetan Plateau and Central Asia, the Kashmir Valley (Figure 1.1) is a fertile, temperate niche between the more arid regions to the north and east and the more unpredictable environments of monsoonal Asia to the south. The people of the valley have long understood the formation of this unique environment and the forces it has exerted on the local populations, with Kashmiri cultural-historical narratives such as the 6th century *Nilmata Purana* and the 12th century *Rajatarangini* describing environmental events that stretch back into mythological-geological time with surprising accuracy (Stein 1900). Outsiders too have taken note of the rich and varied geography of the valley, from early accounts by 7th and 8th century Chinese pilgrims Xuanzang and Ou-Kong to the Mughal emperor Jahangir's famous declaration of the valley as paradise on earth. It may have also been these conditions that attracted the attention of naturalists and geographers during the 19th and early 20th centuries (De Terra & Paterson 1939) and, in turn, the archaeological excavations which from the mid-20th century yielded some of the earliest then-known evidence for Neolithic agricultural villages in South Asia outside of the Harappan heartland (see overviews in Bandey 2009, Sharif & Thapar 1992,).

Since the mid-20th century the former princely state of Kashmir has been divided politically between India, Pakistan and China, with the Kashmir Valley and adjacent areas of Jammu and Ladakh acceding to India in 1947 (Snedden 2015). While for much of the latter 20th century collaborative archaeological and palaeoenvironmental fieldwork between Kashmiri, Indian and foreign researchers was possible, the last major cross-disciplinary project, the Kashmir Palaeoclimate Project (KPCP) was interrupted by the outbreak of unrest, military crackdown and rising militancy in the late 1980s (Agrawal 1992). Resumed archaeological excavation at the site of Kanispur in 1999 ended after one month following the outbreak of the Kargil War between India and Pakistan (Mani 2000). Despite the conflict from the 1990s to early 2000s, which took a tragic human and economic toll on the people of the valley, Kashmiri archaeologists continued to document new sites, as well as synthesise past fieldwork (Yatoo 2012, Bandey 2009, Yatoo 2005, Shali 2001).

If the 1990s and 2000s were somewhat of a "lost" period for researchers in Kashmir, at the same time the breakup of the Soviet Union opened up other parts of Central Asia to international fieldwork and renewed interest among non-Russophone scholars, examining the region as a driver of interaction between Old World centres of civilisation across Eurasia (Boyle et al. 2002). This allowed the reintegration of what was a relatively unknown "pastoralist realm" with a "Middle Asian Interaction Sphere" spanning Mesopotamia, the Persian Gulf, Iranian Plateau and the South Asian Subcontinent (Possehl 2002, Kohl 2008). During the same period, a consolidation of the preceding decades of archaeobotanical work in South Asia examined areas of crop diffusion and domestication as well as the adaptation of agricultural packages to varied ecological zones (Fuller 2006, Madella & Fuller 2006). These studies laid the basis for the examination of the "pastoralist realm" of Central Asia in its own right, rather than in relation to settled urban or agricultural centres. In particular, archaeobotanical and isotopic studies have brought to light the diverse and complex socio-ecological adaptations by pastoralist groups, including dietary choices, mobility patterns, engagement with networks of regional exchange and environmental niche construction (Frachetti, Benecke, et al. 2010, Motuzaite Matuzeviciute et al. 2015, Spengler 2015, Chang 2018).

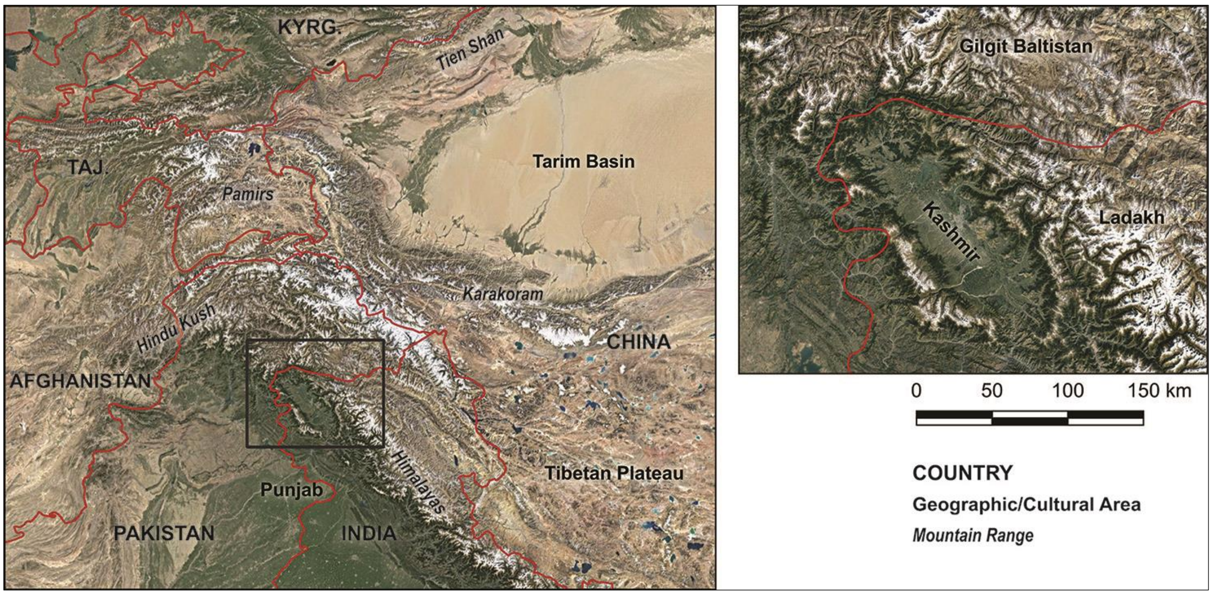

Figure 1.1: Location of Kashmir in Inner Asia with regions and mountain ranges referred to throughout this thesis. (Basemap source: Google Earth tiles for QGIS)

While these studies in Central Asia served to break down dichotomous concepts of herders and cultivators, distinctions were made between pastoralist groups of the Eurasian steppe and those of the “Inner Asian Mountain Corridor” (IAMC; Frachetti 2012), the Central Asian mountain massif comprising the Tien Shan, Pamirs and Hindu Kush that is now considered a vector for the prehistoric transmission of domesticated plants and animals between West, South and East Asia (Stevens et al. 2016). While these routes of translocation are commonly regarded as running southwest to northeast between southern Central Asia and Xinjiang (Stevens et al. 2016, Frachetti 2012), there has been suggested a southern branch of this network in the form of a west–east route running along the Himalaya, onto the Tibetan Plateau and into southwest China (d’Alpoim Guedes et al. 2014, Spengler 2015, d’Alpoim Guedes & Aldenderfer 2019).

This work on Inner Asian agro-pastoralism and the IAMC provide the context for recent archaeological studies in Kashmir, a combination of the publication and reconsideration of legacy data, as well as through new exploratory fieldwork (Yatoo & Bandey 2014, Spate et al. 2017, Pokharia, Mani, et al. 2017, Betts et al. 2019). These works generally focus on the prehistoric periods and position the Kashmir Valley as a key node in the IAMC, as well as an ecological niche where multiple systems of food production and resource extraction are possible within a bounded geography. Outside the Neolithic period, Yatoo’s (2012) survey work in Baramulla District in the northwest of the valley has taken a *longue durée* approach, considering differentiated settlement patterns and activity across the landscape.

Yatoo’s landscape-oriented work informs the direction of this thesis, which aims to explore the ecological heritage of pastoralism in the upland flanks of the Kashmir Valley. While pastoralist ecology in its mountainous margins may be one means of linking Kashmir with other areas of the

IAMC, it should be emphasised here that this investigation primarily aims to understand long-term socio-ecological systems within the valley itself.

Previous studies of ancient ecology in Kashmir have drawn on palaeoenvironmental data from KPCP fieldwork, as well as archaeological materials from the large excavated sites of Burzahom and Gufkral (Agrawal 1992, Shali 2001). The over-reliance on interpretation based on these data is complicated by the fact that complete excavation reports for Burzahom have not yet been published and Gufkral was only published in 2013 (Sharma 2013), while the KPCP focussed on the entire Quaternary with generally poorly resolved data for the mid- to late-Holocene (Agrawal 1988). Assumed parallelism between changes in the archaeological and palaeoenvironmental record led to the assumption of climate change-driven Malthusian cycles in the valley, where populations expanded during warm-humid periods such as the Neolithic and early Historic, interspersed with phases of population collapse and climate deterioration (Agrawal 1992, Lone et al. 1993, Shali 2001). As archaeological survey has revealed multiple sites of human activity outside the large agricultural villages of Burzahom and Gufkral (Yatoo 2012), and as new palaeoenvironmental data become available from geochemical lake sediment studies (Babeesh et al. 2019, Shah 2019, Lone et al. 2019), a reappraisal of these past interpretations is warranted.

The field and lab work in this study has produced new paleoenvironmental data, that aims to examine the long-term development of upland pastoralist land use as a specialised social-ecological adaptation away from large archaeological and present-day settlements on the valley floor. Key research questions may be summarised as:

- At what time did transhumant pastoralism develop in the valley, and was this a mechanism for interaction between Kashmir and adjacent regions?

- Can mobile, multi-resource pastoralism be considered a long-term strategy for resilience during periods of adverse climate conditions?

As these questions are linked to processes of environmental change, broader reconstruction and consideration of climate change, anthropogenic and natural forcings are also necessary.

1.2 Parameters of this study

Detecting mobile pastoralist material culture archaeologically is often problematic due to factors such as the spatially and temporally dispersed nature of pastoralist landscapes (Cribb 1991). Sites of pastoralist settlement, cultural production and resource use have been documented in parts of Central Asia, such as in the Dzungar Mountains Archaeological Project in southeast Kazakhstan (Frachetti 2008). However, this was the result of extensive and targeted survey undertaken over a number of years. In Kashmir, mountain pastures and forests are frequently infiltrated by militants or subject to control by the Indian Border Security Force, particularly on the western Pir Panjal flank of the valley where promising study areas lie close to the Line Of Control, the de facto border between

India and Pakistan. These circumstances present significant security, logistical or legal limitations on archaeological fieldwork in the mountainous rim of the Kashmir Valley.

In order to mitigate the risks associated with extensive survey in these remote parts of Kashmir, the strategy employed in this study has been to undertake a preliminary examination of the ecological legacy of pastoralism, to detect periods of pastoralist land use and abandonment through palaeoenvironmental data such as pollen, fungal spore and charcoal accumulations that are indicative of the presence of humans or large herds of animals in the mountain landscape (Jouffroy-Bapicot et al. 2013). These data are drawn from environmental cores sampled from water bodies or mires in suitable study areas. This method is partly a result of expediency, allowing fieldwork to be completed in a matter of weeks in areas that may be politically unstable. However, it will also help to narrow down geographic areas for future archaeological investigation. These environmental proxies are generally indicative of the sustained presence or absence of pastoralism in the landscape and are interpreted through theoretical frameworks such as resilience theory and niche construction theory. Periods of intensified pastoralist land use may be contextualised against other inferred or material changes in the palaeoenvironmental and archaeological record.

1.3 Organisation of this thesis

As outlined above, the primary aim of this study is to examine through environmental proxies long-term pastoralist ecology in the Kashmir Valley. To interpret these data, a critical understanding of the landscapes and history of the valley is required, as well as a more general engagement with pastoralist ecology.

Chapter 2 presents a comprehensive overview of the geography, palaeoenvironment and archaeological/historical background of the Kashmir Valley. The first section describes the topography, climate and vegetation right across the valley outside of the immediate study areas. Present-day agricultural and pastoralist activities are discussed and the impact of transhumant grazing in sub-alpine and alpine meadows is reviewed. The position taken in this thesis is that these present-day practices are the result of a long-term processes of ecological and economic adaptation. As these adaptations are often entangled with other environmental processes, a review of Late Quaternary regional palaeoenvironmental studies is then undertaken. This is followed by a synthesis of archaeological and historical evidence from the Neolithic to early modern periods, as well as a consideration of regional archaeological discussion surrounding the IAMC. The chapter closes by reiterating several gaps in knowledge relating to the archaeology and palaeoenvironment of the Kashmir Valley.

Chapter 3 outlines the theoretical and methodological positions of this thesis. The first section critically engages with the archaeological and palaeoenvironmental record in Kashmir, examining the ways in which environmental and social change have been approached in past studies. This chapter argues against the environmentally driven Malthusian cycles that have previously explained change in the archaeological record in Kashmir, reasoning that these interpretations result from excessive focus on one or two archaeological sites. Multi-resource pastoralism is posited as a specialised adaptation throughout the Inner Asian mountains and as a socio-ecological system well suited to the environment of the Kashmir Valley. This approach is framed within archaeological understandings of resilience theory (Redman 2005) and niche construction theory (Laland & O'Brien 2010). Drawing on archaeological, historical and environmental evidence, it is argued that pastoralist ecology developed through niche-constructing activities that may be detectable in the archaeological and palaeoenvironmental record. The second half of this chapter reviews studies in which various forms of agriculture or pastoralism may be practically detected using palaeoenvironmental proxies, making clear the technical approach of this thesis. Case studies are drawn from regions adjacent to the Kashmir Valley, followed by a discussion of the ways in which anthropogenic impacts may be disentangled from broader processes of climate or environmental change.

Chapter 4 describes the fieldwork program, including the rationale for selecting sites based on the geographic and environmental descriptions in Chapter 2. The methods used in coring for palaeoenvironmental reconstruction are described. The study sites are presented administrative district in the Kashmir Valley and descriptions of present-day land use, geography and any notable archaeological or cultural features are also described.

Chapter 5 outlines the methods used in the laboratory component of this thesis. Descriptions are given of the ways in which palynomorph, sediment size and magnetic, and charcoal influx data may be used as environmental proxies, as well as the extraction protocols used for generating these data. Also outlined are the methods for initial sediment core logging and the construction of chronological models. The chapter closes with a description of the quantification and statistical methods followed to examine proxies related to pastoralist activity in Kashmir.

Chapter 6 presents in detail the results of the analysis of environmental cores retrieved from the study area, following the methods outlined in Chapter 5. The results are presented core by core, detailing in order the initial logging, chronological modelling, sediment physical properties (size and magnetic susceptibility), charcoal influx, pollen/palynomorph abundances and principal components analysis (PCA). Results are presented without interpretation with the exception of the PCA plots which necessarily requires some initial analysis of the variables presented.

Chapter 7 analyses and interprets the results from Chapter 6, beginning with examination of data that may be indicative of broadscale environmental change in the valley which is then compared with other regional environmental studies. These changes form the background for examining data relating to long-term patterns of pastoralist land use across the study sites, and evidence for pastoralist niche constructing activities is discussed with the aim of addressing the issues raised in Chapter 3 regarding previous studies in the Kashmir Valley. The chapter concludes by considering long-term pastoralist activity in Kashmir in local and regional archaeological and historical context.

The final Chapter 8 summarises the findings of this thesis, particularly the discussion presented in Chapter 7. The second half of the chapter critically assesses the methods used in this thesis and their suitability for reconstruction pastoralist ecology in the past. A concluding section presents ways in which problems with these approaches may be addressed and raises potential directions for future study programs.

1.4 Terminological and chronological conventions

Given the confusion relating to the reorganisation of the borders of Kashmir and in Central Asia since the mid-20th Century, as well as the shifting of our understanding of ethnographic concepts of "pastoralism", a number of clarifications are required. The foremost explanation is where and what Kashmir refers to, a geography that has become convoluted due to the conflict in the region and the contested claims of India, Pakistan, China and the Kashmiris themselves. Prior to the partition of India and Pakistan, "Kashmir" was a shorthand for the princely state of Jammu and Kashmir or "Greater Kashmir", which governed the Kashmir Valley itself, as well as Ladakh to the east, Gilgit-Baltistan to the north, Muzzafarabad and Poonch to the west and Jammu to the south. Following partition, the "Kashmir conflict" referred to the competing claims right across this region and that for some "Kashmir" still comprises all of the former princely state (Snedden 2015). If this wider region is referred to in text, "Greater Kashmir" will be used. In this study "Kashmir" refers specifically to the Kashmir Valley and the immediate surrounding mountain flanks, a geographically and culturally circumscribed formation where the Kashmiri ethno-cultural group are the predominant population. The valley itself is entirely within the Indian administered of Jammu and Kashmir. Parts of the former princely state now administered by Pakistan include Azad Kashmir to the west of the Kashmir Valley and the mountain regions of Gilgit-Baltistan to the north. In August 2019 the Indian state of Jammu and Kashmir was further partitioned into the territories of Jammu and Kashmir comprising the Kashmir Valley and southern parts of the state, and Ladakh comprising the eastern regions.

Central Asia and Inner Asia are also terms used throughout this thesis. Traditionally, Central Asia has referred to the former Soviet republics of Turkmenistan, Tajikistan, Kyrgyzstan, Uzbekistan as well as southern Kazakhstan, which have historically been dominated by a Persianate or Turco-Persian culture. This thesis follows the expanded UNESCO definition of Central Asia, comprising all of the former Soviet "-stans", as well as northeast Iran, Afghanistan, northern Pakistan, Greater Kashmir, Tibet and northwest China and Mongolia (Dani & Masson 1992). While this is a large region, there may be long-standing shared economic, cultural and historical institutions as well as social-ecological adaptations (Cowan 2007). Inner Asia is generally interchangeable with Central Asia, though may refer specifically to the mountain massif comprising the Himalaya, Hindu Kush, Tien Shan, Pamirs, Karakoram, Altai mountains and Tibetan Plateau, all dominated by forms of transhumant pastoralism, rather than the open steppe pastoralism of central Kazakhstan and Mongolia (e.g. see Frachetti 2012) or the urban-agricultural world of southern Central Asia/Transoxiana.

South Asia in this thesis refers broadly to the subcontinental nation states of India, Pakistan, Bangladesh, Nepal, Bhutan and Sri Lanka. Much of the discussion in this thesis is constrained to the northern part of the South Asian subcontinent centred on the Indo-Gangetic Plain. This expanse comprises the Indus and Ganges drainage basins and is bounded by the Himalayan ranges to the north. The region spans from Sindh and Punjab in Pakistan in the west, across the Indian Punjab to parts of Rajasthan, the states of Bihar , Haryana, Uttar Pradesh, the foothill regions of Nepal and to the Bengal plains and basin of India and Bangladesh in the east. In addition to the Indo-Gangetic Plain, the northern Indian state of Gujarat is also discussed due to significant archaeological and palaeoenvironmental studies having been undertaken there. While politically in South Asia, historically the Kashmir Valley and Gilgit-Baltistan in Pakistan also been historically and geographically tied to Central Asia.

“Pastoralism” and “agro-pastoralism” are referred to throughout this thesis. Historically, Central Asian pastoralist societies such as the Saka-Scythians or Xiongnu have been perceived through the lens of Chinese or Persian written accounts that have generalised these societies as fully nomadic peoples who lack agriculture, often with a predatory or parasitic relationship upon sedentary state-based societies (Di Cosmo 1994). In contrast to this, twentieth century ethnographers with deep experience documenting Inner Asian pastoralist societies have described nomadic pastoralism as simply an economic or ecological adaptation where the herding of animals following pasture and water resources is the primary food producing activity (Khazanov 1994, Salzman 2004). As the availability of these resources changes seasonally pastoralism is necessarily a mobile mode of food production, however, there are multiple forms of division of labour across a spectrum. At one end herders are tethered to permanent agricultural settlements and migrate seasonally in a fixed pattern around this nucleus; at the other are systems where the entire population is fully mobile – “Each is an adaptation to a particular environment, approached through the culture of the specific community” (Salzman 2004, p.5). Ethnographic case studies from across the Inner Asian mountain regions demonstrate the ways in which pastoralist groups such as the Tibetans (Dong et al., 2016), Gujjars (Kassam et al., 2016), Kirghiz and Pamiris (Kreutzman et al., 2012) negotiate strategies through which they maintain access to their areas of primary economic activity, namely pasturelands and marketplaces. These economic and ecological adaptations are mediated by the often diverse environmental niches of the Inner Asian mountains.

The constraints on these adaptations imposed by environmental factors also bring pastoralist groups into contact with neighbouring populations. Khazanov (1994) describes the ways in which environment types gives rise to various pastoral adaptions:

“*(1) Nomads occupy the most exclusive or dominating position in the zone they inhabit… primarily marginal areas. In this respect the Eurasian steppes, semi-deserts and deserts are a good example… the nomads of High Inner Asia are not very different; in effect, the one difference is that here the geographical demarcation between nomads and agriculturalists is altitudinal rather than latitudinal…*

…(2) Nomads utilize several ecological zones which are separated by other zones, in which there are other people engaged in different economic activities, but usually in agriculture. Nomads themselves do not utilize these zones but have to travel across them during pastoral migrations…

…(3) Nomads do share, either fully or partially… the same zones with agriculturalists (with) *variations of this situation."* (Khazanov 1994, pp.33–34).

Of these three forms of landscape utilisation, the latter two are most applicable to the Kashmir Valley in particular and across much of the IAMC in general, forming a "patchwork" of different and overlapping zones of herding and cultivation. Despite Khazanov's contention that mobile groups of High Inner Asia do not engage in cultivation, ethnographic evidence from Ladakh above 3000m ASL describes highly complex flexible systems of mixed pastoralism, cultivation and long distance trade (Jina 1995). Archaeobotanical evidence from across the mountain areas of Inner Asia indicates that cultivation may be a long-standing adaptation (Spengler 2015); however, in some regions such as parts of the Tibetan Plateau, environmental constraints may indicate that these were transported as processed foodstuff from other regions, and that archaeobotanical remains should not be assumed to be evidence of localised cultivation (d'Alpoim Guedes 2015). A stronger case for high altitude cultivation is supported through the convergence of archaeobotanical and zooarchaeological data as well as remains of irrigation features provide evidence for a mixed system of herding and cultivation above 2000m ASL at the site of Final Bronze Age-Iron Age site of Chap in Kyrgyzstan (Motuzaite Matuzeviciute et al. 2019).

One of the primary features of pastoralism in Inner Asian mountains is *transhumance*, where altitudinal movement is the primary means of following seasonal resources, rather than latitudinal migration in the deserts or open steppe (Frachetti 2008). In Kashmir this vertical movement is the primary adaptation of the Gujjar-Bakharwal community (Casimir & Rao 1985), whose system of transhumance is practised to the present day but is also the basis for a long-standing historical identity and tradition (Sharma 2018, Husein 2008). From this discussion we may define pastoralism in Kashmir as seasonally mobile vertical herding, generally with a secondary emphasis on cultivation of supplementary crops. In this context agro-pastoralism and pastoralism are often used interchangeably as cultivation is an implied component of both, though in the former the agricultural component has greater importance (McClure 2015). It is also important to clarify that due to the methods used in this study we are unable to approach the *identity* of pastoralist groups in Kashmir as discrete from agriculturalists in the valley. While hypothetical differentiation or integration between herders and farmers is discussed, the primary research aim is to examine evidence of pastoralism as a long-standing economic and ecological adaptation in the valley.

Similar to the distinction between the more mobile forms of nomadism and the diverse forms of agro-pastoralism described above, clarification of "agriculture" and "cultivation" as used in this thesis is also required. When "agricultural" societies are referred to this generally indicates that the primary economic and social organisation of that population is based around long-term stable settlement with a focus on extensive food production based on cereal or other crop farming. While this organisation comprises a wide spectrum of adaptations, the generalisation is to distinguish these societies from those such as pastoralists who engage in smaller scale "cultivation" of crops as a supplementary economic activity in addition to the primary focus of tending to herds and the seasonal exploitation of rangelands and pastures.

The final point of clarification regards the dating conventions used in this thesis. Archaeological chronologies in both Central and South Asia typically use BCE/CE or BC/AD dating systems, whereas the palaeoenvironmental datasets that this thesis ultimately revolves around work in years before present (BP). Here all archaeological and historical phases are converted to years BP. Calendar years or centuries (such as 1990s or 2000s in this chapter) all refer to the Common Era. When discussing long-term geomorphic processes beyond the range of tens of thousands of years, the shorthand Kya (thousand years ago) and Mya (million years ago) are used.

Chapter 2 Geographic, environmental and historical background

This chapter reviews the geographic, environmental, paleoclimatic and historical/archaeological background in the Kashmir Valley. Section 2.1 describes the geography of the valley broadly, including the geomorphology, topography, hydrology and climate of Kashmir. As this thesis is concerned with detecting past systems of pastoralist land use in the palaeoenvironmental record, Section 2.1.4 pays close attention to the impacts that present day herding and landscape modification by pastoralists have on the distribution of vegetation in Kashmir. Following this, Section 2.2 reviews past palaeoenvironmental studies in the Kashmir Valley, as well as recent literature from geographically adjacent regions of the Himalayas and Central Asia. This section identifies a number of difficulties with the palaeoenvironmental record in Kashmir that this study may address. Sections 2.3 and 2.4 review the major archaeological and historical changes in the valley, before relating these changes to processes across the IAMC more generally. Gaps in the archaeological and palaeoenvironmental data from Kashmir and complications with their interpretation are summarised in order to set up the theoretical premises of this thesis in Chapter 3.

2.1 Geography of Kashmir

2.1.1 Tectonic and geomorphological background

The Kashmir Valley is a longitudinal basin in the north-western Himalayan region, flanked by the Himalayan ranges in the northeast and the Pir Panjal in the southwest. The basin is around 140km long and 40km wide, classified by Wadia (1934) as the thrust-bounded Kashmir Nappe Zone. The Nappe Zone comprises a Palaeozoic-Mesozoic marine stratigraphy overlying a Precambrian basement. Of the Palaeozoic geology, the dominant feature are Panjal Traps, basalts formed by marine and terrestrial lava flows associated with the opening of the Tethys Ocean (Shellnutt et al. 2015).

Drainage of the Kashmir basin was impounded by Pir Panjal orogeny (Figure 2.1), causing the valley to become flooded by a large primeval lake, into which glacio-lacustrine Plio-Pleistocene sediments were deposited, up to 1300m thick (Dar et al. 2014). Both the lake and sediments are known as *Karewa*, the local term also used to describe the relict lacustrine and loess structures on the valley flanks in the present day. Spurs of the Greater Himalayas and Pir Panjal enclose the valley in the north and south.

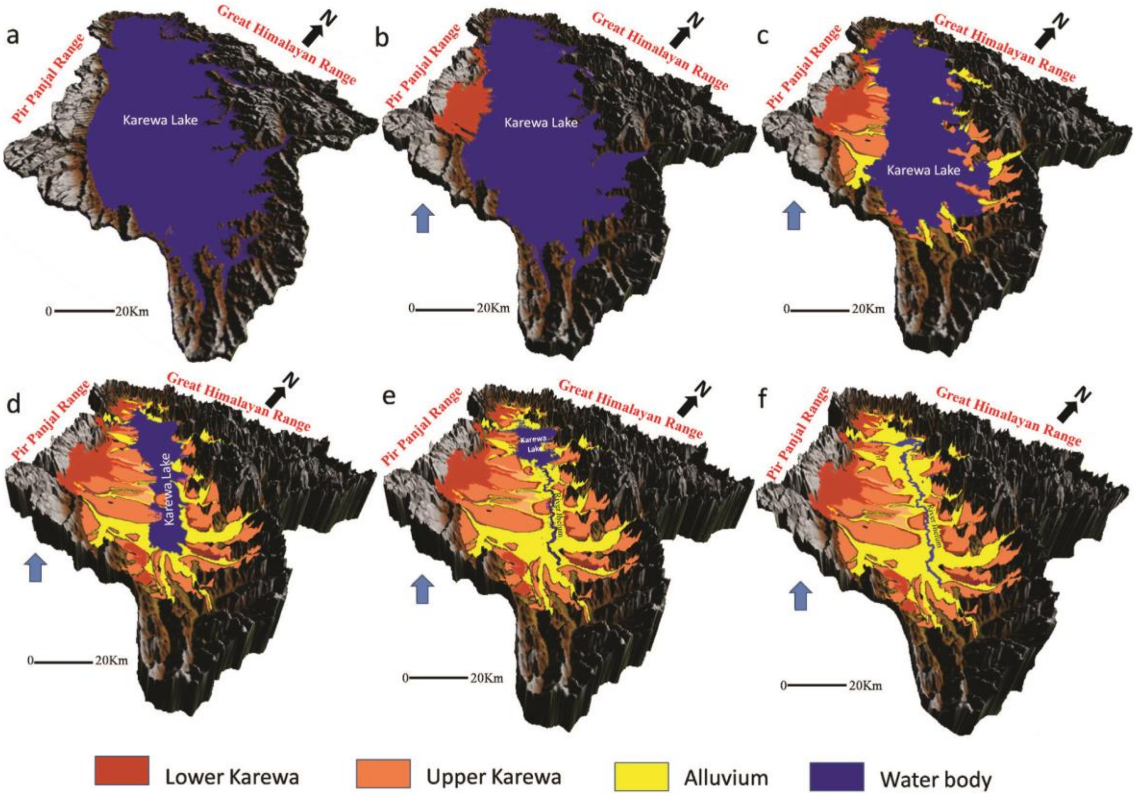

Figure 2.1:Landscape evolution of the Kashmir Valley. a) Karewa lake ca. 4Mya. b) Pir Panjal upthrust and emergence of Lower Karewa 4-2 Mya. c-d) Ongoing upthrust and climate driven dessication 2Mya-85Kya. e) Faulting at Baramulla gorge and emergence of Jhelum landscape ca.85Kya. f) Present day landscape. (Adapted from Dar et al. 2014).

Ongoing upthrust in the Pir Panjal pushed the Karewa Lake towards the Himalayan flank, leading to the lifting and emergence of the Lower Karewa deposits, primarily in the northeast of the valley, from around 4 Mya and continuing to 200 Kya (Agrawal 1992). Increasing aridity from around 200 Kya is evidenced by desiccation of the lake and the emergence of Upper Karewa deposit on both flanks of the valley (Dar et al. 2014).During this period aeolian loess began to be deposited over exposed Karewa sediments on the valley flanks (Agrawal 1992). At around 85 Kya faulting in the northwest of the valley at Baramulla gorge led to the draining of the remnant Karewa Lake and the emergence of the Jhelum River floodplain. Arising from these processes are the three major sedimentary structures within the valley, the Lower Karewa (4 Mya-200 Kya), Upper Karewa (200 Kya-85Kya) and Jhelum alluvium (85 Kya-present). The lacustrine records from the Karewas and modern lakes, as well as magnetostratigraphic and isotopic records from the loess-palaeosol sequences, provide a unique long-term climate archive in the valley (Agrawal 1992).

2.1.2 Physical Geography

Topography

Geographers (Husain 2008, Kaul 2014) have classified a number of physical and altitudinal zones within the Kashmir Valley, including: the valley floor, the Karewa tablelands; the upland (or sloping) Karewas; and the Mountain Girdle (Figure 2.2). Of these classifications, the Karewa tablelands correspond roughly with the younger Upper Karewa, while the uplands consist of various stages of the Lower Karewa (Kaul 2014). The Mountain Girdle consists of the high peaks of the Pir Panjal and Greater Himalaya.

The valley floor is an alluvial landscape on the Jhelum floodplain consisting of new alluvium and adjacent old alluvial areas. The lowest elevation of the valley floor is slightly below 1600m ASL, with a mean elevation around 1840m ASL including the Karewa tablelands, which typically stand up to 60m above the floodplain (Husain 2008). The Karewa uplands consist of the foothill zones and valley facing slopes, primarily concentrated on the Pir Panjal flank, ranging between 1600m and 3800m ASL. Due to the tilting of the palaeo-lake against the Himalayan flank, only the lower, younger Upper Karewas are typically found on this side of the valley (Dar et al. 2014). The high mountain peaks of the Pir Panjal reach around 4700m ASL, and present a sharp west-facing escarpment towards the Punjab forelands, sloping more gently towards the Kashmir Valley on the eastern side. The Greater Himalayas on the east flank of the valley maintain a crest line of around 5000m ASL, before rising as high as 6000m ASL in the adjacent Zanskar Trans-Himalayan ranges.

Historically these topographic features have given rise to three altitudinally differentiated zones of human activity. The valley floor and Karewa table lands are brought under extensive cultivation and settlement, to an elevation of around 2200m (Kaul 2014, p.56). Between 2500-2750m ASL are middle altitude meadows, known locally as *marg*, and high alpine meadows, *Ilak,* between around 3000-3500m ASL (Lawrence 2005 [1895], p.362), watered by summer snow melt. During the present day, both types of these meadows are exploited seasonally by Gujjar transhumant pastoralists (Husain 2008). Each of these altitudinal steps are divided by forest bands of varying composition.

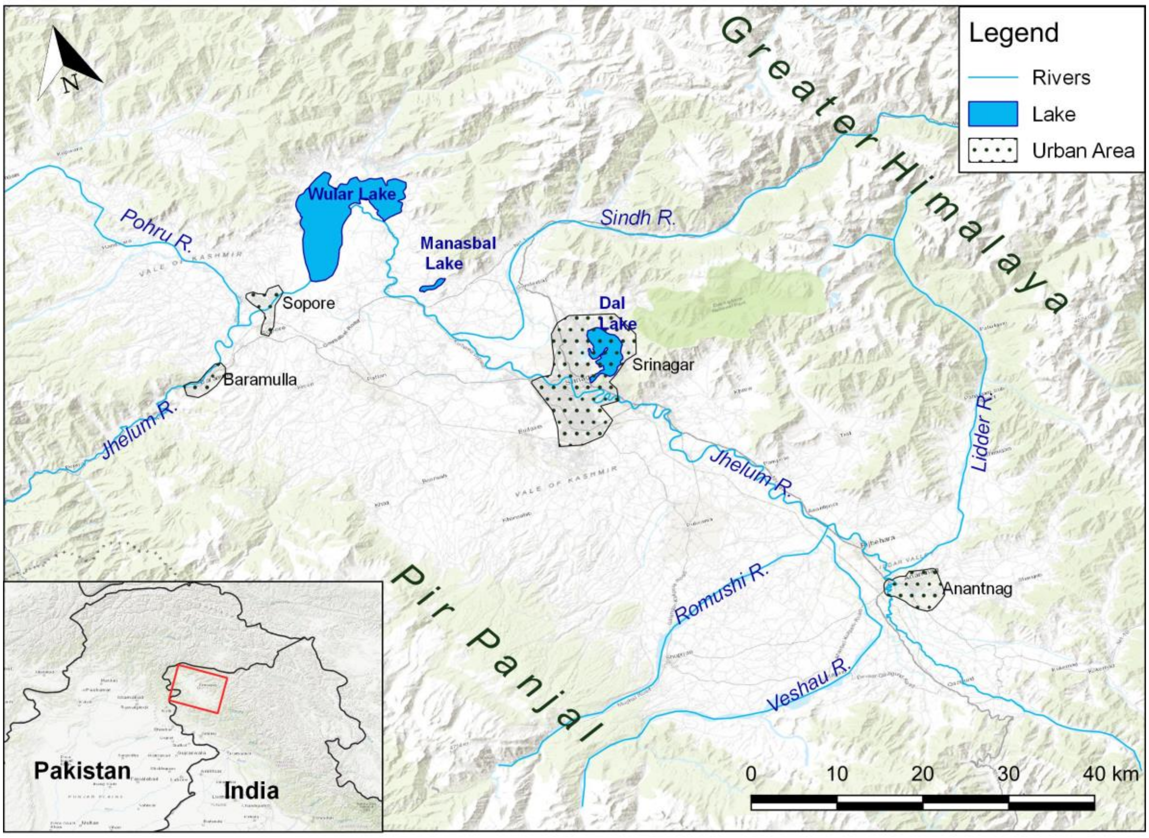

Figure 2.2: Present day geography of the Kashimir Valley showing major rivers, lakes and cities. (Basemap source: ESRI World Topo).

The Kashmir Valley basin contains a number of side valleys, several of which form important hydrological, vegetative and cultural niches. The Lolab Valley is a sub-basin running from the northeast to the northwest of the greater Kashmir Valley, bounded by the Northern Ranges, and separated from the main body Kashmir by the Nagmarg hills to the south. The Lolab is generally ovoid in shape, running 15km long laterally and is between 0.3-5km wide, opening into the Kashmir Valley in a wide gorge north of the town on Kupwara and is drained by the Pohru River (Figure 2.2). In its general form and vegetation, the Lolab may be considered a scaled down version of the Kashmir Valley. Notable in the valley are the presence of copper deposits in the form of chalcopyrite at Lashteal and Kalaroos (Chowdury & Banerjee 1957), described by the Geological Survey of India as old workings. Reedy (1997) surveyed the shafts at Lashteal, hypothesising copper extraction dating to the medieval period, though no systematic study into the age of workings has been undertaken.

The two other major side valleys, those of the Sindh and Lidder rivers (Figure 2.2), were formed through denudation by glacial and fluvial action on the Himalayan flank. Geologically, their structures are both similar, with their headwaters beginning in the Panjal Trap dominated highlands around the Kolahoi Massif, before descending into Karewa and alluvial landscapes at middle and low altitudes (De Terra & Paterson 1939, Malik et al. 2016). The Sindh is the more northerly of the two valleys, beginning as a narrow gorge slightly south of the Amarnath cave – a pilgrimage site for Kashmiri Pandits and other Indian Hindus – at 3800m ASL, before passing the middle altitude pastures at Sonmarg, 2800m ASL. Below Sonmarg at Gagangir the valley opens into a wider boulder-strewn landscape. The Lower Sindh valley begins around Preng, where a number of rivulets join the Sindh River, before opening into the Kashmir Valley and discharging into the Jhelum around 30k northeast of Srinagar.

The Lidder River originates with a west and east upper valley beginning around Kolahoi and Sheshnag respectively, before forming a Y-shaped fork at the middle altitude pastures at Pahalgam, around 2100m ASL. As well as serving as grazing lands, these pastures are an important modern tourist destination and a basecamp for Amarnath Pilgrims (Kaul 2014, p.60). The river valley then descends to the Ananantnag district of South Kashmir, bounded by the Himalayas and the Southern ranges, where the Lidder River joins the Jhelum. Two exhausted or low quality chalcopyrite ore bodies have also been recorded near Pahalgam (Reedy 1997, p.91). This discussion emphasises the fact that at present and historically, the Lidder and Sindh are culturally and economically important regions of Kashmir, containing mineral and grazing resources as well as numerous temples and pilgrimage sites. The current Sindh Valley road also follows the historic caravan route to Ladakh and Gilgit-Baltistan, where passes to Tibet, Xinjiang and Central Asia were accessed.

Prior to the partition of India and Pakistan, a number of passes allowed for travel between Kashmir, China, Tibet and Central and South Asia (Lawrence 2005 [1895]), forming several historical trade routes of which the Jhelum and Gilgit-Baltistan routes have been stressed by Yatoo (2012) as the most important. Due to their altitude, these passes are closed by snow for a number of months each year, though historical records of Kashmir such as the *Rajatarangini* gave extensive descriptions of tribal migrations between Kashmir and Tibet, Central and South Asia via these routes. In a description of 19th century trade between Kashmir and Central Asia, Warikoo (1996) describes the favoured route for many merchants to pass from northern India to Srinagar, Leh and onto Kashgar in the Tarim Basin before diverting either to the Feghana Valley or eastwards into China. This route also linked to other passes through Gilgit, the Pamirs and the Ferghana Valley to the north. Warikoo (1996, p. 114) that these routes were often preferred for merchants and pilgrims travelling between India, Central Asia and China as despite their more difficult topography were safer from bandits and political turmoil than the more direct Punjab-Afghanistan-Bukhara routes. These facts give weight to the historical importance of the west-east route through the Kashmir Valley via the Baramulla gorge and Sindh Valleys, positioning Kashmir as a link in systems of contact and exchange in Asia. Yatoo (2012) has argued that these routes must also be considered in relation to the Palaeolithic and Neolithic settlement in the valley, though this may be complicated by the timing of the advance and retreat of potential glacial barriers and bridges prior to the Holocene Climate Optimum (Dambricourt Malassé & Gaillard 2011).

Hydrology

The primary drainage feature of the valley is the Jhelum River (Figure 2.2), with its source at the spring of Verinag, situated on the Pir Panjal flank in the Anantnag District of south Kashmir. The Upper Jhelum occupies a longitudinal furrow through the valley floor and like other Western

Himalayan rivers flows in a northwest direction, until entering Wular Lake in the north of the Kashmir Valley. The river exits the lake east of the city of Sopore, travelling in a southwest direction, before entering the Baramulla-Uri gorge and passing through the Himalayas and into the Pakistani Punjab in the Jhelum District (Husain 2008, Kaul 2014). The total length of the Jhelum in the valley is around 170km, with a number of side tributaries including the Sindh and Lidder on the Himalayan flank and the Romushi and Veshau on the Pir Panjal flank. The Pohru also drains the Lolab Valley from near the town of Kupwara, delivering a sediment and gravel loaded input to the Jhelum west of Sopore (Mir & Jeelani 2015).

Precipitation in Kashmir is delivered as both snow and rain, primarily in the winter and spring months with surface water also delivered through snow melt in summer. Summer precipitation during the months of July and August has also been linked to variable incursions of the Indian Summer Monsoon (Jeelani et al 2017). The Jhelum tributaries on the Himalayan flank receive the larger percentage of snow melt, whereas the Pir Panjal tributaries are supplemented by a higher amount of rainfall. Given that precipitation as snow is dependent on the strength and frequency of Western Disturbances and that snow melt is driven by variable summer insolation, the volume of Jhelum discharge at Baramulla is most closely correlated with input by warm frontal rainfall beginning in May, with peak discharge by volume in May and lowest levels in January (Kaul 2014, p.104).

The high volume of water delivered into the Jhelum from these tributaries leads to frequent spring and summer flooding in the valley, exacerbated by the low energy of the river which struggles to carry the sediment load (Mir & Jeelani 2015) leading to backflow from downstream areas and flooding right across the valley (Kaul 2014, p.107). These factors mean that at times, major flood events have been triggered by a single cloud burst (De Terra & Paterson 1939, p.15). These floods have been documented since early historic times in accounts such as the *Rajatarangini* and al-Biruni's *Kitab al-Hind*, which contain descriptions of dredging, construction of levees and other attempts at water management (Stein 1900). Frequent flood events may have influenced the nature of settlement pattern in Kashmir since the Neolithic, often clustering on terraces above the river floodplain (Yatoo 2012). Despite these destructive events, the river is treated with cosmological significance in the valley, as a source of water as well as the historic means of trade and transport between the valley and other regional centres (Kaul, 2014:88).

In addition to the Jhelum River, three major lakes are the primary water bodies on the valley floor. From south to north these are Dal Lake, Manasbal Lake and Wular Lake (Figure 2.2). Dal Lake flanks the city of Srinagar, and drains the surrounding valley basin through a number of streams and channels (*nullahs*) (Husain 2008, p.38). The morphological origins of the lake are debated; De Terre and Paterson (1939, p.12) argue that based on the position of the lakes in relation to the Jhelum, they are oxbows formed in palaeochannels, while (Agrawal 1992) believes them to be relict water bodies derived from the ancient Karewa lake. Due to its relationship with Srinagar, Dal Lake is central to much of the valley's economic and cultural life.

Manasbal Lake is located in Ganderbal District, northeast of Srinagar. The lake is a closed system, deriving its water from the surrounding catchment, as well as being fed by an underground spring (Babeesh et al. 2019). Kaul (2014, p.96) argues for the genesis of the lake through the subsidence of the underlying strata, forming the deepest water body in the valley with a maximum depth of 14m.

Wular Lake is the largest freshwater lake in India, with a surface area of 80 square kilometres. The lake forms a lacustrine delta on the Jhelum and serves as a settling tank for river sediments (Kaul 2014, p.97). Like many other lakes on the valley floor, Wular is subject to ongoing reclamation, primarily for the purposes of irrigated rice agriculture. Due to the input of the Jhelum and several other rivers, the areas around Wular Lake are some of the most prone to flooding in the valley.

In addition to these main lakes on the valley floor, a number of smaller oxbow lakes exist in the Jhelum floodplain. Above the alluvial landscape, tectonic lakes of at least Pleistocene age may be found in the middle altitude pasturelands (Zutshi et al. 1980) and numerous oligotrophic glacier fed lakes are found above the tree-line from 3000-4000m ASL (Zutshi 1975).

Soil Landscape

At the broadest categorisation, the valley is comprised of two main soil types, residual soils on the hill tops and mountain slopes, and alluvial and morainic soils along the river catchments and valley floors (*State of Environment Report J&K* 2013; Figure 2.1). Due to the undulating topography, variation in depth, erosion, runoff and available water capacity occurs among the hilly and mountainous soils (Sidhu 2016). These soils, typically associated with forest or meadow vegetation and referred to locally as *Tand* (Husain 2008, p.98), are loamy and mildly acidic with varying quantities of organic carbon, though deficient in potassium, phosphorus and calcium. Some clearing of these forests for small-scale cultivation of maize or pulses occurs, although after 2-3 years the land is generally returned to pasture due to quality of the soil. Meadows between 2500-4000m ASL are typically reserved for grazing of flocks by transhumant Gujjar-Bakarwal peoples (Husain 2008, p.74).

Alluvial soils are classified into old and new alluvium morphologically grouped as river terrace and flood plain soils (Sidhu 2016). River terrace soils generally sit above the Jhelum flood plain, while the flood plain soils are subject to regular inundation. Both soil types are rich in organic carbon, and though both are typically loamy, the older soils generally contain more silt, while the younger alluvium is sandier. The soils are mildly acidic to mildly alkaline and are used for the cultivation of rice, maize and orchards. Within the soil classification system employed by Kashmiri farmers, these soils are known as *Bhangar* (old alluvium) and *Khadar* (new alluvium) (Husain 2008). These soils are rich in potassium, phosphorus, calcium and magnesium and accumulation of nitrogen occurs in significant quantities, allowing for high agricultural potential (Qazi 2005).

Karewa soils forming flat-topped features, known locally as *Wudur*, are comprised of fine loam, with medium organic and water content (Sidhu 2016). Cultivation of Wudur soils is generally reserved for horticultural crops such as almond and saffron, though other fruit orchards are also grown on these terraces.

Aside from these primary soil features, farmers in Kashmir have a number of sub-classifications of soil types, derived from their content, and typically used for the cultivation of rice. These are: *Gruti* (clayey loam), found in low-lying areas of the valley and used for rice paddy during times of low rainfall due to high water retention; *Behil* (loam), loamy soil with high humic content and ideal for paddy cultivation; *Sekil* (sandy loam), cultivated if irrigation is available; and *Dazanlad* (sandy silt), occurring in low-lying areas around swamps (Yatoo, 2012:49). Peaty *Nambal* soils also occur on the margins of Wular, Anchar and Mansbal Lakes and are used for the cultivation of secondary crops such as oat, maize, mustards and pulses (Husain 2008, p.78).

2.1.3 Climate

The majority of the valley is classified as a humid subtropical climate (Köppen Cfa) with upland pastures on the eastern flanks classed as humid continental (Köppen Dfb) (Kottek et al. 2006; Figure 2.3). There is pronounced seasonality, with maximum July summer temperature around 30°C and a winter minimum in January around -3°C (Figure 2.4). Westerly driven winter/spring precipitation reaches a maximum in March (up to 100mm) with additional July-August summer rains up to 60mm. While the orographic effect of Pir Panjal uplift was believed to block the influence of the Indian Summer Monsoon (ISM) causing a climate shift around 2Mya (Agrawal 1992), recent oxygen and hydrogen isotopic studies of annual rainfall across the valley indicates a significant ISM contribution to summer precipitation in July and August (Jeelani et al. 2017). Local seasonal classification breaks the year into six seasons of two months each (Hussein 2008, p.56):

- *Sonth*/spring (mid-March to mid-May)
- *Grishm*/summer (mid-May to mid-July)
- *Wahrat*/rainy season (mid-July to mid-September)
- *Harud*/autumn (mid-September to mid-November)
- *Wand*/winter (mid-November to mid-January
- *Sheshur*/severe cold season (mid-January to mid-March)

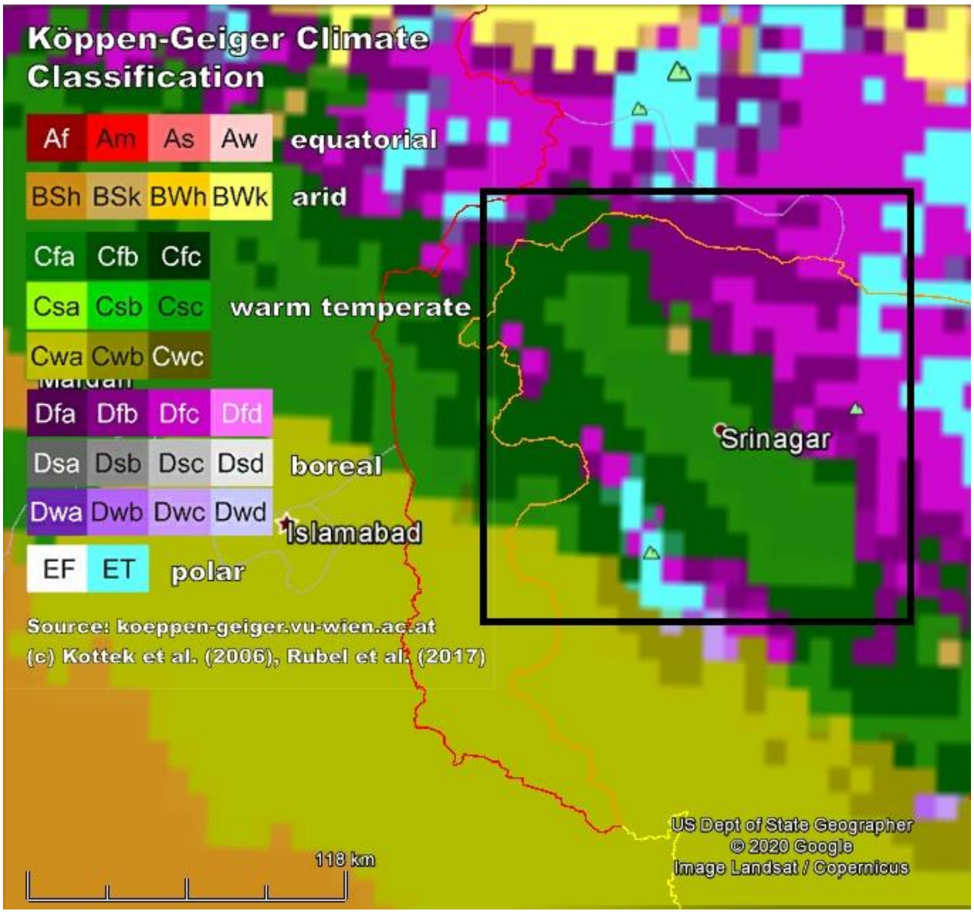

Figure 2.3: Köppen climate classification map, Kashmir Valley indicated in black box. Map source: keoppen-geiger 5 arc minute .kmz overlay for Google Earth (Kottek et al. 2006, Rubel et al. 2017)

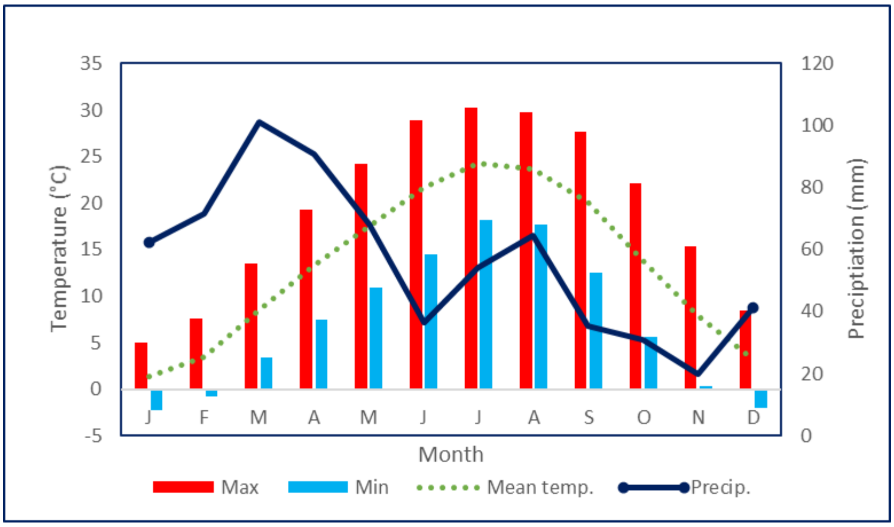

Figure 2.4: Mean monthly precipitation, maximum and minimum temperatures for Srinagar between 1901-2000 (Data source: Indian Meteorological Department 2018)

In a summary of data from five weather stations across the valley, Kaul (2014) notes little latitudinal variation in climate, with the only recognisable difference in data being from the higher altitude Pahalgam station (2100m ASL) experiencing one winter month of mean temperatures ranging −10-0°C and all other winter means between 0-10°C. Despite this variation and its implication for upland habitation of the valley flanks in cold months, Kaul notes that all economic and food-producing activity takes place between mid-March to mid-November as any cultivation is impossible during the cold months.

2.1.4 Biogeography

Altitudinal distribution of vegetation

Due to the topography of the valley, vegetation in Kashmir varies along an altitudinal gradient and can be broadly grouped into four zones – the valley floor (1600-1800m ASL), foothill (1800-2200m ASL), mountain (2200-3500m ASL) and alpine zones (above 3500m ASL) (Rao 1961, Vishnu-Mittre 1966, Dhar & Kachro 1983, Khuroo et al. 2011, Dar & Khuroo 2013). The valley floor zone comprises artificial habitats under cultivation, as well as marshy and disturbed areas on the margins of lakes and settlements (Figure 2.5). The foothill and mountain zones are generally composed of temperate needle leaf forests that grade into subalpine birch forest above 2700m ASL. These zones also contain a number of natural and artificial meadows, and cultivation of cereals takes place up to around 2500m ASL. Vishnu-Mittre (1966) describes a 20-year succession following clearing in these zones as initial colonisation by annual herbs and shrubs (*Rumex*, *Sambucus*, Chenopods, grasses) followed by a broad leaf pioneer trees (*Betula*, *Corylus, Acer*). Broad leaf taxa are replaced by blue pine (*Pinus wallichiana*) followed by a final colonisation of west Himalayan Fir (*Abies pindrow*). Alpine vegetation consists of open meadow herbs and scrub as well as xerophytes growing on scree slopes and higher areas (Dhar & Kachro 1983, Dar & Khuroo 2013). A summary of these zones and dominant vegetation types is given in Table 2.1.

In a review of Himalayan forest vegetation, Singh & Singh (1987) identify forests of Kashmir as a unique Western Himalayan biome that shares some affinities with the adjacent areas of Himachal Pradesh but, owing to the control of the climate by Western Disturbances, with a significantly larger temperate needle-leaf forest component. A Phytogeographical study by Mani (1978) finds a high degree of affinity between the flora of Kashmir and adjacent Central Asian mountain regions of the Alai-Pamir (85%) and Central Tien Shan (75%), grouping these floristic zones as separate to other areas of the Himalaya, and ultimately derived from Boreal Eurasian origins. In addition to forest vegetation, meadows and pastures are an economically and historically important component of this Central Asian mountain biome.

Table 2.1: Altitudinal distribution of dominant plant taxa in the Kashmir Valley (summarised from (Rao 1961, Vishnu-Mittre 1966, Dhar & Kachro 1983, Khuroo et al. 2011, Dar & Khuroo 2013)

	Trees	**Shrubs & understory**	**Herbs**	**Aquatics**
Valley floor	*Platanus orientalis*, ***Juglans regia***, ***Prunus***., *Salix, Populus*, ***Malus***, *Acer*	*Virburnum, Rosa, Geranium, Rubus, Clematis*	*Polygonum, Rumex, Chenopodium, Angelica, Urtica dioica, Carex, Impatiens, Acontium, Trifolium, Artemisia, Taraxcum, Circium, Plantago*, Poaceae (inc. ***Oryza sativa***), ***Pisum sativum,*** **Brassicaceae**	***Typha***, ***Trapa***, *Potamogeton, Nymphaea*
Foothill	*Pinus wallichiana, Cedrus deodara,, Acer, Alnus, Prunus, Salix, Corylus*	*Berberis, Cotoneaster, Viburnum, Rosa, Clematis, Sambucus*, ***Vitis vinifera***	*Polygonum, Rumex, Chenopodium, Angelica, Urtica dioica, Carex, Impatiens, Acontium, Trifolium, Artemisia, Taraxcum, Circium, Plantago*, ***Crocus sativus***, Poaceae (inc. ***Zea Mays***, ***Hordeum Vulgare*** **& millets**).	-
Mountain	*Pinus wallichiana, Cedrus deodara, Abies pindrow, Picea smithiana, Acer, Betula utilis, Corylus, Carpinus, Juglans, Ulmus*	*Viburnum, Rosa, Clematis, Sambucus, Juniperus, Salix*	*Polygonum, Rumex, Ranunculus, Thalictrum Trifolium, Medicago, Potentilla, Taraxcum, Taraxcum, Circium, Plantago, Arabis, Galium, Carex, Cyperus, Urtica, dioica, Veronica Silene*, Apiaceae, Caryophyllaceae, Poaceae	-
Alpine	*Betula utilis, Abies Pindrow*	*Juniperus, Rosa, Salix, Rhododendron*	Generally as above.	-

Floristic composition of mountain meadows in Kashmir

In a systematic study of diversity and productivity of vegetation in grazed and ungrazed pastures across a number of altitudinal niches, Khuroo (2013) identified 52 families, 199 genera and 302 species among vegetation. Of the 302 species, the 15 largest families contributed 232 types with the largest families being Asteraceae (daisy family - 45 species), Poaceae (grasses - 32 species) and Lamiaceae (mint/sage family - 21 species). Other significant contributions include Brassicaceae (mustard family - 19 species), Fabaceae (legume family 16 species), and Rosaceae and Ranunculaceae (rose and buttercup families - 13 species each). Of the genera, *Galium, Poa* and *Ranunculus* contributed the most species (six each), followed by *Polygonum, Carex* and *Potentilla* with five species each. Classification of species grouped 242 as herbs with a further 32 grasses. Remaining classes includes shrubs, sedges, rushes, climbers and one species of fern. A study of species richness and flowering periods identified the highest pasture biomass productivity between June-August for alpine sites, where longer and heavier snow cover leads to shorter and faster growth seasons, whereas mid-elevation pastures such as Draphoma had 7-month productive periods between March-October. Across all sites, little to no pasture productivity was recorded between November-March (Khuroo 2013).

In addition to altitude, grazing intensity has an impact on overall composition of pastures. A number of studies of protected and lightly to heavily grazed pastures at Anantnag (ca. 1800m ASL; Ahmad et al. 2013), Aru (ca. 2500m ASL; (Khuroo 2013), Gurez (ca. 3000m ASL; Dad & Reshi 2013), Sonmarg (ca. 3000m ASL; Mir et al. 2015) and Matri (3500m ASL; Dad & Khan 2010) have recorded the impact of various intensities of grazing on meadow composition. Although these studies used different statistical indices and their results are not directly comparable, they generally found high species diversity at long-term protected sites, with this diversity enhanced at sites subject to light grazing or short-term protection. Dad & Khan (2010) also note both the effects of slope and aspect on species distribution, as well as the effect of mythological protection conferred by the presence of nomad graves or tombs in the pasture. Table 2.2 summarises the dominant taxa from these studies.

Table 2.2: Impact on vegetation composition of varying intensities of grazing (summarised from Ahmad et al. 2013, Kurhoo 2013, Dad & Reshi 2013. Dad & Khan 2010, Mir et al. 2015)

	Ungrazed	**Formerly/lightly grazed**	**Moderate grazing**	**Heavy grazing**
Matri	*Frageria, Taraxcum, Achillea,* *Poa annua, Sibbaldia, Impatiens, Geranium*	*Poa annua, Sibbaldia, Rumex nepalensis* *Taraxcum, Circium, Urtica dioica, Plantago, Galium*	*Poa annua, Trifolium, Impatiens, Circium, Rumex nepalensis*	*Trifolium, Rumex nepalensis, Poa annua, Plantago*
Sonmarg	N/A	*Bothricloa pertusa, Cynodon dactylon, Stipa sibirica, Poa annua, Sambucus, Urtica dioica, Taraxcum, Rumex,*	N/A	*Poa annua, Stipa sibirica, Bothricloa pertusa, Cynodon dactylon, Urtica, Circium*
Anantnag	*Bothricloa pertusa, Plantago lanceolata, Trifolium* *Poa annua, Plantago major, Crepis, Ranunculus, Lathyrus, Cynodon dactylon*	*C. dactylon, Medicago, Bothricloa pertusa, Trifolium* *Plantago lanceolata, Taraxacum,* *Poa annua* *Capsella, Ranunculus, Heteropogon contortus*	N/A	*Cynodon dactylon, Bothricloa pertusa, Trifolium, Cyperus, Plantago, Polygonum*

These studies all generally correlate grazing pressures with the loss of species diversity and the dominance of grasses such as *Cyndodon dactylon, Poa annua* and *Borthricloa pertusa.* In addition, several genera such as *Plantago, Polygonum, Rumex*, *Circium* and *Trifolium* are associated with heavy grazing. Authors of these studies also note that several of these taxa are nitrophilous and colonise formerly grazed areas and nomad campsites, while ruderals such as *Taraxcum, Circium*, *Plantago* and *Urtica dioica* colonise heavily disturbed areas (Mir et al. 2015, Dad & Khan 2010). Increases in *Trifolium repens* and *Plantago* species are also associated with intensified grazing at the high altitude (3400m ASL) meadow Chandanvari (Casimir & Rao 1985). From these studies we may draw out the taxa that compose natural meadows, as well as those most strongly associated with pastoralist ecology in Kashmir.

Present-day land use

The economy of Kashmir today is primarily agricultural with an estimated 40% (95000ha) of alluvial landscape on the valley floor between Srinagar and Sopore utilised for cultivation of *kharif*/summer or *rabi*/winter crops in 2015 (Alam et al. 2019). This agricultural system is dominated by the cultivation of summer crops, primarily paddy rice on the valley floor and lake margins, followed by maize, mustard and summer pulses on Karewa terraces and upland areas (Husain 2008). Rice paddy is irrigated using canals that draw on meltwater inundation of the Jhelum basin during spring (Husain 2008, p. 182). In years where poor snow loading is observed on mountain flanks, farmers often reserved large areas of rice paddy for foxtail millet, a crop with far lower water requirements (Lawrence (2005 [1895], p. 337). Winter vernalising wheats are sown in October/November and harvested in spring, while spring varieties of wheat are grown at higher altitudes on the eastern margins of the Kashmir Valley (Lawrence 2005 [1895], p. 341). In addition to cultivation of seasonal crops, an additional estimated 30% (65000ha) of the alluvial zone is utilised for horticultural plantations of almond, apple, stone fruits and saffron crocus (Alam et al. 2016, Hussein 2008).

Pastoralism accounts for the primary land use in upland areas on the valley flanks, mainly undertaken by the Gujjar-Bakharwal ethnic group (Hussein, 2008). Prior to the partition of India and Pakistan, Gujjar nomadic groups migrated seasonally between the north Indian plains and mountainous areas of the Himalayas, Afghanistan and Central Asia. Following partition, the Gujjar-Bakharwal winter in the plains around Jammu, before migrating through the Pir Panjal to the flanks of the Kashmir Valley during spring, and onto highland pastures of the Greater Himalaya in summer (Casimir & Rao 1985). Pastoralist ecology in Kashmir has been described by Casimir & Rao (1985) through participant observation of a seasonal migration of Bakharwal nomads. In addition to simply moving goats and sheep from the Jammu forelands, pastoralists cut corridors through mature *Pinus* forests on the northern slopes on the Pir Panjal at the southern pass into Kashmir (2500 m ASL), suppressing forest taxa and promoting the growth of *Poa* and *Chrysopogon* grasses as well as of *Trifolium repens* for the grazing of animals. Pastoralists also engage in foraging and propagation of various *Polygonum*, *Chenopodium* and *Cerastium* species for their own food and medicinal uses. In addition to herding and foraging, Gujjar-Bakharwal communities in Kashmir also cultivate maize, a summer cereal with a growing season and ecology suited to the pastoralist patterns of migration (Hussein 2008).

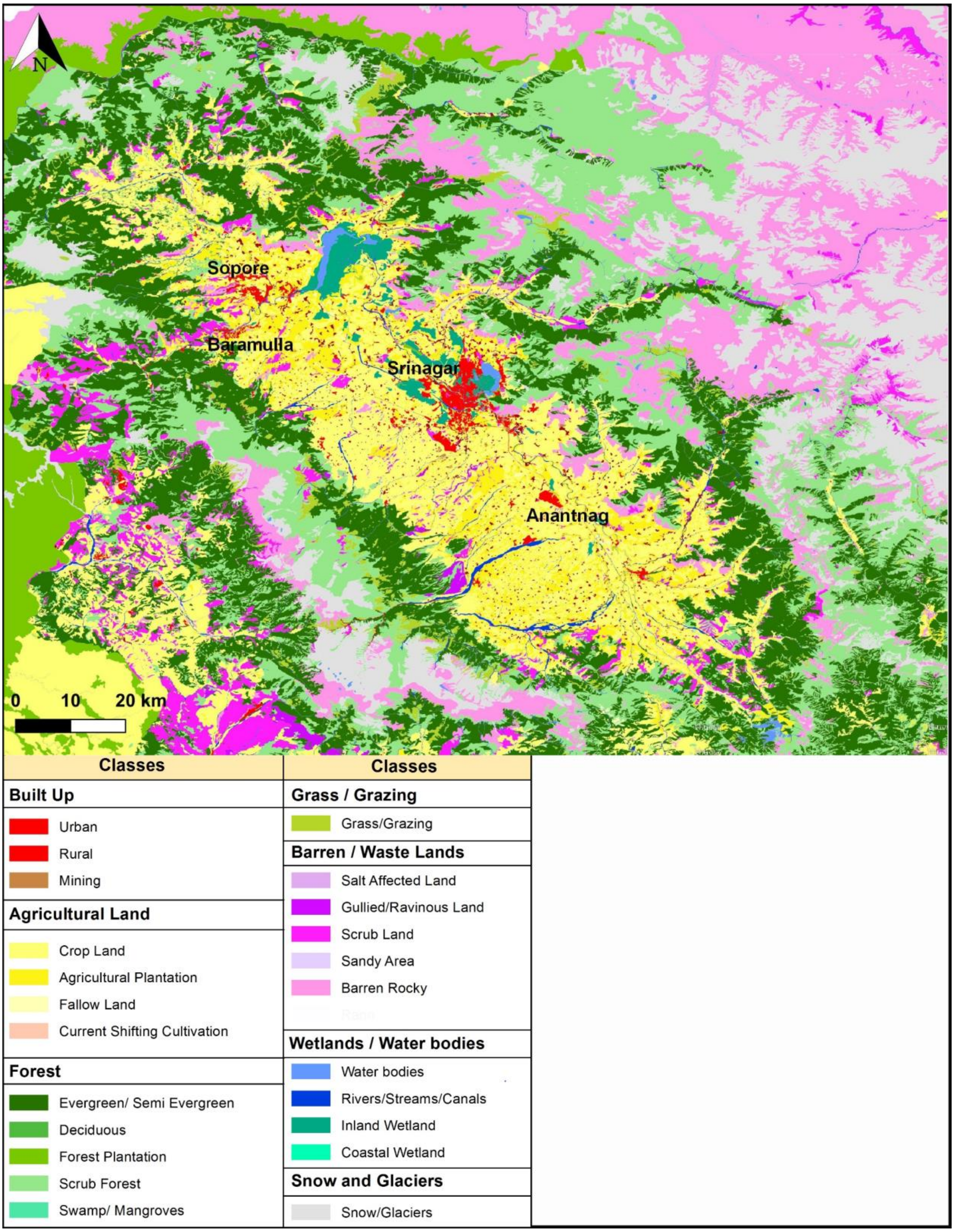

Figure 2.5: Present day Land Use/Land Cover map for Kashmir Valley. (Data source: National Remote Sensing Centre, Govt. of India. Accessed through WMS https://bhuvan-vec2.nrsc.gov.in/bhuvan/wms. Map layer "lulc:JK_LULC50K_1516"

2.2 Terminal Pleistocene and Holocene environmental change

This section reviews palaeoenvironmental studies from the Kashmir Valley and aims to outline the major phases of climate and environmental change. This is followed by a review of regional records from immediately adjacent areas of the Siwalik foothills in Jammu and the Trans-Himalayan areas of Ladakh and Himachal Pradesh. Speleothem records from Westerly controlled areas of Central Asia and ISM dominated areas of the Himalaya are also described to outline variability in precipitation patterns. While numerous well resolved palaeoenvironmental records are available for other areas of northwest South Asia, the focus of this review is limited to the Himalayan areas with climate and ecology more closely comparable to the Kashmir Valley.

2.2.1 Kashmir Valley

Quaternary palaeoenvironmental reconstructions in the Kashmir Valley generally focus on either chronological, geochemical and isotopic studies of palaeosol and loess sequences bedded over Karewa landscapes (Babeesh et al. 2019, Meenakshi et al. 2018, Dar et al. 2015, Krishnamurthy et al. 1982) or pollen studies of Pleistocene and Holocene vegetation change from valley floor lakes or higher altitude mires (Dodia 1983, Vishnu-Mittre & Sharma 1966, Singh 1963,). A synthesis of various environmental and archaeological data from the Kashmir Palaeclimate Project (KPCP) was published by Agrawal (1992), while more recent lake sediment studies have incorporated multi-proxy data sets (Babeesh et al. 2019, Lone et al. 2019, Shah 2019). As the deposition of loess and the formation of palaeosols take place at chronological scales beyond the Holocene focus of this study (Meenakshi et al., 2018) this review focuses on studies from lake and mire sediments (Figure 2.6).

Singh (1963) produced a preliminary pollen study of post-glacial vegetation changes from a 4.1m long core from a mire at Tosa Maidan (3500m ASL, **Error! Reference source not found.**). Initially, no absolute chronology was devised for this model and stratigraphic and pollen changes were correlated with stages in the Blytt–Sernander sequence (Singh, 1963). A later resampling of the site returned dates from a number of stratigraphic units, dating as old as ca. 18,000 BP (Singh & Agrawal 1976). Though these cannot be directly linked to depths from the original pollen core, they do allow for rough chronological bracketing of vegetation stages. Based on ratios of broad-leaf (primarily *Quercus* and *Betula*) to coniferous arboreal pollens, Singh (1963) identified a period of transitional warming and maximum humidity in pollen stages “d” and “e” roughly dated to the post-glacial period ca. 10,000BP. The absolute dating of a subsequent cooling period is unclear, and the next absolute dates available are for pollen stage “g” ca. 3000 BP, during which Poaceae, fern spores and Asteraceae pollen frequencies reach maximal values, while *Artemisia* declines to its lowest representation. Rather than these changes being linked to human activity, Singh attributed them to a wetter period where ferns suppressed *Artemisia* and other steppic taxa.

Another pollen study from Hygam Lake (1600m ASL) (Vishnu-Mittre & Sharma, 1966) was dated relative to the development of Neolithic agriculture, based on the presence of cereal and *Plantago lanceolata* pollens in stage “b” near the base of the core, as well as the historical introduction of tree taxa such as poplar to the valley during the medieval period. Vishnu-Mittre (1966) has also linked vegetational changes in the Hygam record to the Blytt–Sernander sequence, but the lack of absolute chronology inhibits any deeper understanding of localised environmental change in Kashmir.

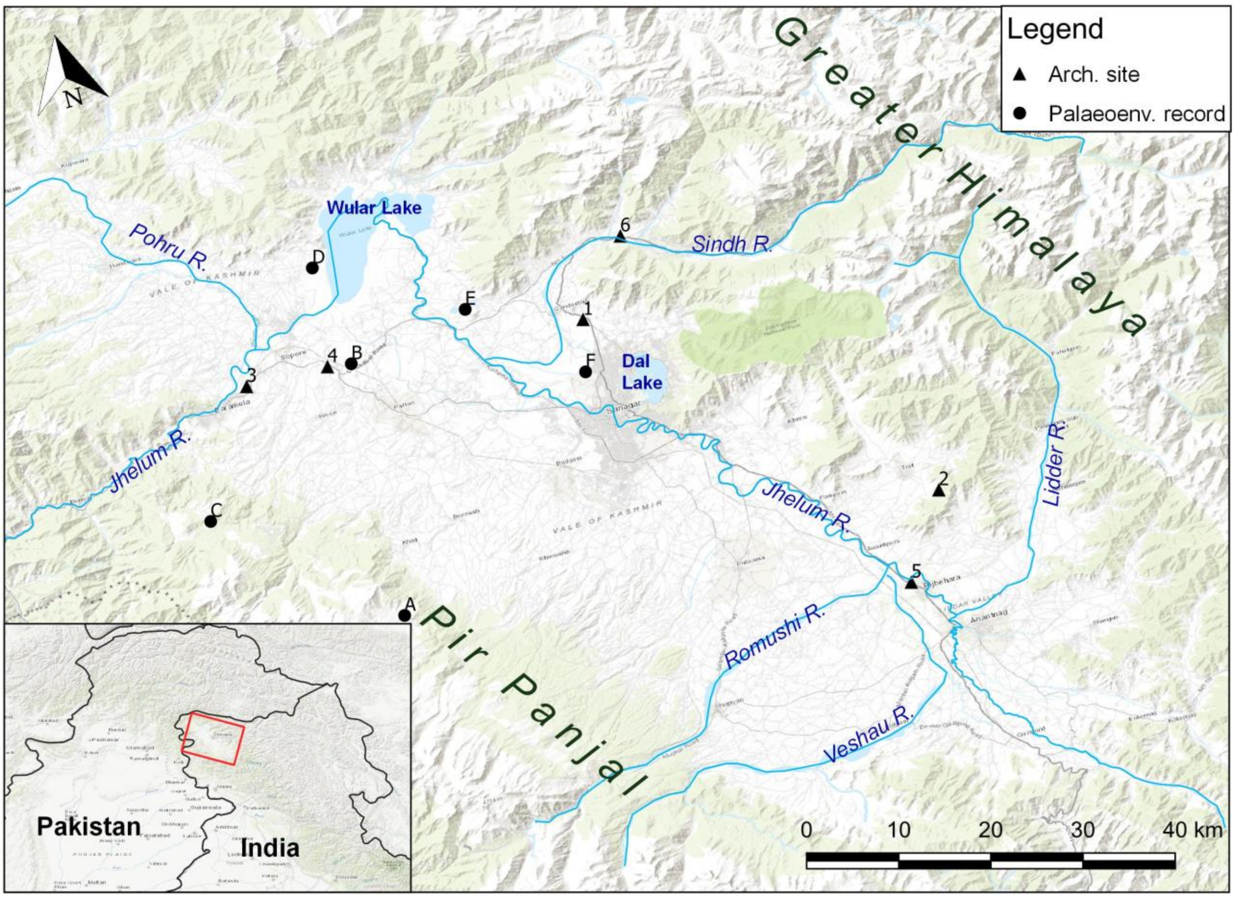

Figure 2.6: Palaeoenvironmental records and archaeological sites discussed in text. Environmental records: A) Tosa Maidan (Singh 1963); B) Hygam (Vishnu-Mittre & Sharma 1966); C) Butapathri (Dodia 1983); E) Manasbal Lake (Babeesh et al. 2019); D) Wular Lake margin (Shah 2019); F) Anchar Lake (Lone et al. 2019). Archaeological sites: 1) Burzahom; 2) Gufkral; 3) Kanispur; 4) Qasim Bagh; 5) Semthan; 6) Pethpuran Teng (summary in Betts et al. 2019).

Dodia's (1983) PhD thesis aimed to refine the chronology of post-glacial vegetation changes through pollen sequences from a mire at Butaphathri (3000m ASL) as well as two valley floor lakes (ca. 1600m ASL) at Anchar and Horkasar. While these cores do have absolute dates available, they were acquired through the conversion of organic carbon to CO_2 and then methane gas, often from sediment sections up to 60cm long (Dodia, 1983:Table 15), leading to a reduction in chronological resolution. The oldest records at Butaphathri found a period of warming interpreted between ca. 18,000-10,000 BP, followed by a cool-dry transition. Clay beds barren of pollen have been interpreted as evidence of pluvial conditions and higher precipitation associated with the onset of the Holocene Climate Optimum (HCO) ca. 5000 BP, followed by a shift again to cooler drier conditions. Though there are some absolute dates associated with these changes they are again primarily correlated with the Blytt–Sernander sequence.

Agrawal's synthesis (1992) draws on Dodia's pollen studies, studies of loess-palaesol sequences (Kusumgar et al. 1986) as well as isotope studies from palaeosols (Krishnamurthy et al. 1982) to identify four warm humid periods in the valley, ca. 18,000, 5000, 2000 and 1000 BP. While the convergence of these lines of evidence may indicate periods of environmental change, poor chronology of the above pollen studies, as well as new programs of re-dating palaeosol formation (Meenakshi et al. 2018) complicates the timing of these climate shifts.

Shah's (2019) PhD thesis contains a multi-proxy (Total Organic Content; C/N ratio; $\delta^{13}C$; geochemical; diatom) study from a sediment trench dug on the margins of Wular Lake with a robust chronology based on 8 AMS dates. These data indicate a warm climate phase between ca. 10,500-8500 BP, followed by cold-dry conditions ca. 8500-7500 BP, associated with the 8.2k cold event. An onset of warm conditions is interpreted between 7500-6200 BP, followed by a second cold-dry period between ca. 6200-5700 BP. This is again followed by a warm humid phase to ca.4000BP, where a drying up of the lake margin is interpreted as a result of aridification associated with the 4.2k event as well as tectonic lifting of the lakeside along the EF-2 fault line (Shah 2019, p.120-121). An additional diatom and geochemical study from a core from the Wular Lake floor indicated an arid phase associated with the Little Ice Age (LIA) ca. 500 BP, followed by a transitional warming period and the onset of modern warm-humid conditions from ca. 200BP (Shah 2019, p.124-125). Aridity associated with the LIA has also been linked to an extreme precipitation minima in tree ring records from the Western Himalaya, between the late 15th and early 16th centuries CE (Yadava et al. 2016).

Another multi-proxy study on a core from Manasbal Lake (Babeesh et al. 2019) dates to ca. 3500 BP. Diatom, geochemical and weathering indices indicate cold-dry conditions around the lake from ca.3500-3300 BP, followed by a cold-wet phase ca. 3300-2500 BP. The period 2500-1800 BP was interpreted as having cold-dry conditions before a second cold-wet phase ca. 1800-1300 BP. The authors of the study argue that environmental changes around Manasbal Lake find only partial agreement with westerly precipitation records from Arid Central Asia (e.g Chen et al. 2008) or fluctuations in ISM precipitation in the Trans-Himalaya (Demske et al. 2009), concluding the study area is subject to significant control by local katabatic systems particular to the Manasbal Lake basin.

A final geochemical multi-proxy study from Anchar Lake in Srinagar provides a record to ca. 6000 BP (Lone et al. 2019). Higher input of terrestrial sediment and proxies indicating higher lake levels ca. 6000-3900 BP were interpreted as evidence of intensified precipitation, followed by a period of aridification ca. 3900-1600 BP. Generally drier conditions persisted to ca. 500 BP when the impacts of urbanisation in Srinagar became the dominant environmental signature (Lone et al. 2019, p.9).

2.2.2 Regional palaeoclimate

A number of recent studies from Himalayan regions adjacent to the Kashmir Valley provide data relating to climate shifts in the region, particularly fluctuations in ISM precipitation. A multi-proxy study of the high altitude (ca. 4200m ASL) Chandra peat trench in the Lahaul region of Himachal Pradesh (Rawat, Gupta, Sangode, et al. 2015, Rawat, Gupta, Srivastava, et al. 2015) identified a period of increased ISM precipitation evidenced by magnetic enhancement, increased Total Organic Content (peat formation) and declining steppic vegetation between ca. 10,000-8800BP, followed by a period of declining precipitation to ca. 6600BP. Between 6600-3300 BP pollen proxies and low $\delta\ ^{13}C$ values indicate a wetter climate, with a drier fluctuation between ca. 4800-4200 BP. Coniferous and steppic *Ephedra* and *Artemisia* increase between 3300-1100 BP indicating drier conditions, followed by an increase in broad leaf taxa and other thermophilous elements to ca. 600 BP. Modern alpine-arid steppic conditions develop after 600 BP. A second peat trench study from Himachal Pradesh (Phadtare 2000) found humid periods roughly corresponding with the Chandra study, however, this study interpreted elevated levels of evergreen *Quercus* as indicating arid conditions, with coniferous taxa as proxies for colder-wetter conditions.

Two lake cores from alpine desert lakes Tso Kar (Demske et al. 2009) and Tso Moriri (Liepe et al. 2014) in Ladakh reconstruct precipitation patterns through pollen proxies. Both studies utilise *Artemisia/Chenopodium* (A/C) ratios as indicators of fluctuating aridity. The Tso Kar record found a warm humid phase ca. 12,000-9000 BP, followed by a drier period interpreted as a weakening of the ISM and strengthening of Western Disturbances ca. 9000-7000 BP (Demske et al. 2009). Both studies indicated warm-humid conditions to ca. 4500 BP when an arid reversal occurs, and is the dominant environmental condition to ca. 1100 BP (Demske et al. 2009, Liepe et al. 2014). In the Tso Kar record, anthropogenic markers are present from ca. 3500 BP and increase after 1800 BP likely indicating increased pastoralist activity in the area.

Holocene climate records from the Siwalik hills around Jammu include a pollen core from Surinsar Lake (Trivedi & Chauhan 2009) and geochemical study from Mansar Lake (Das et al. 2010). The Surinsar study suggests two warm humid periods ca. 9500-7700 and 6100-4300 BP, based on dominance of oak in mixed oak-chirpine forest pollen assemblages (Trivedi & Chauhan 2009, p.411). Three cool dry periods at 7700-6100BP, 4000-2100BP and 800BP-Present are indicated by advance of *Pinus roxburghii* and attributed to weaker ISM precipitation. The Mansar study found a general correlation between lower C/N ratios and higher $\delta^{13}O$ values in shallower sediments and the inverse relation in deeper sediments, indicating fluctuating lake levels (Das et al., 2010). These relationships were used to interpret a warm wet climate at the base of the column ca. 7800-5500 BP and cool dry conditions ca. 4000 BP to present. However, the authors concede the chronology of the record was weak due to the carbonate content of dated sediments.

2.2.3 High resolution precipitation records from speleothems

Two speleothems from Sahiya Cave (Kathayat et al. 2017, Sinha et al. 2015) provide an annually resolved record of ISM precipitation in the Central Himalayan foothills during the last 5700 years. Lower $\delta^{18}O$ levels in the Sahiya record have been interpreted at periods of strengthened ISM precipitation, closely linked to global climate events such as the Medieval Warm Period (MWP) ca. 800-1200 BP, the Roman Warm Period ca. 1600-2300 BP or the later phase of the HCO ca. 4800-3800 BP (Kathayat et al. 2017). Elevated $\delta\,^{18}O$ was interpreted as weaker ISM excursion and linked to climate intervals such as the LIA or 4.2k event. Kathayat et al. (2017) argue that these climate shifts closely overlap with periods of upheaval or social and economic reorganisation on the South Asian subcontinent, including the de-urbanisation of the Harappan Civilisation, the development of the Vedic period or the integration of the Mauryan empire.

The Uluu-Too (Wolff et al. 2017) cave site from the southern Ferghana Valley, Kyrgyzstan, is a 5000 year record of westerly precipitation over Central Asia. The study links $\delta^{18}O$ levels to $\delta^{13}C$, as proxies of precipitation and local vegetation productivity respectively. Lower fractionation of each of these was ultimately interpreted as stronger winter/spring rain resulting from strengthened Western

Disturbances and retreat of the Siberian High. This record identified arid periods between ca. 4700-3500 BP (with a wet event ca. 4200 BP) and ca.3000-2500 BP, with wet periods at 2500 BP and 1700 BP to present. Wolff et al. (2017) conclude these patterns indicate localised conditions that reflect the complex interrelationship between several climate systems including the Westerlies, Siberian Anticyclone, the ISM and North Atlantic Oscillation. Precipitation delivery by both the ISM and Westerlies is also interpreted as driving $\delta^{18}O$ and $\delta^{13}C$ fluctuations in a speleothem from Sainji Cave (1478m ASL) in the Central Himalaya (Kotlia et al. 2015). This study was in partial agreement with the Ulu-Too record, finding declining precipitation ca. 4000-3000 BP, an increase between ca. 3000-2000 BP before a slight decline, then maximal precipitation ca. 500 BP to present.

2.2.4 Palaeoenvironmental summary

The above review indicates some agreement between in palaeoclimate and environmental records from Kashmir and adjacent regions of the Himalaya and IAMC. Despite this general agreement, the varied geography of the region means that local environments responded to these shifts in differing ways. In the Kashmir Valley, pollen records are poorly resolved, and while the Wular Lake and Manasbal Lake records provide good data for periods of humidity and aridity, they do not provide insight into biotic responses to climate change in the valley. New palynological studies that can be closely correlated with these records would address this lacuna in the Kashmir Valley.

2.3 Archaeological and historical context

Early historical texts from Kashmir such as the 6th century *Nilmata Purana* and the 12th century *Rajatarangini* stretch into deep mythological-geological time, giving accounts of the formation and drainage of the Karewa lake as well as stories of the migrations and past seasonal movements of various tribes and peoples in and out of the valley (Stein 1900). Despite these local traditions describing Pleistocene age events and some undated stray lithic finds (Agrawal 1992, Pant et al. 1982) there is no directly dated evidence for Palaeolithic or Mesolithic occupation in the valley (Dambricourt Malassé & Gaillard 2011). The earliest direct dated human occupation in the valley relates to a Neolithic complex of early agricultural villages (**Error! Reference source not found.**).

Neolithic period (ca. 5000-3000 BP)

The Kashmir Neolithic has been documented through excavations at three sites: Burzahom (Ghosh 1961, Ghosh 1964, Ghosh 1965, Ghosh 1969, Ghosh 1973, Ghosh 1975, Lal 1971, Deshpande 1975, Thapar 1979), Gufkral (Sharma 1982, Sharma 2013) and Kanispur (Mani 2000). Though Burzahom remains the type site for the valley, and Kanispur the oldest, complete excavation reports of these have not been published, though separate archaeobotanical reports from each have been produced (Lone et al. 1993, Pokharia, Mani, et al. 2017). Recent survey work (Yatoo 2012) has led to a program of archaeological sampling and dating at sites that has refined the chronology of the Neolithic (Betts et al., 2019) and produced new archaeobotanical studies (Spate et al. 2017). Neolithic sites are typically cut into and then built upon loessic Karewa terraces above the Jhelum floodplain (Yatoo 2012). A chronology of three major Neolithic Phases and sites is given in Table 2.3.

Table 2.3: Neolithic archaeological phases (modified after Betts et al. 2019)

	Aceramic Neolithic (5000-4500 BP)	**Early Neolithic (4500-4000 BP)**	**Late Neolithic (4000-3500 BP)**	**Megalithic (3500-3000 BP)**
Sites	Kanispur Gufkral	Kanispur Gufkral Burzahom Pethpuran Teng	Gufkral Burzahom Qasim Bagh	Gufkral Burzahom Semthan

The Neolithic begins with an Aceramic phase ca. 5000-4500 BP evident in a thin occupation deposit from Kanispur (Pokharia, Mani, et al. 2017) and a later dated (ca. 4700-4500 BP), thicker deposit at Gufkral (Betts et al. 2019, Sharma 2013). Ground stone and bone points are reported from both sites. While no botanical remains were recovered from Kanispur, Sharma (2013, p.38-39) reports the presence of carbonised wheat (*Triticum aestivum/durum*), barley (*Hordeum vulgare*), lentil (*Lens culinaris*) and pea (*Pisum sativum*) from the this phase at Gufkral. Faunal remains from this period are almost entirely (95%) of wild animals including hangul (*Cervus canadensis hangul*), nilgai (*Boselaphus tragocamelus*), and wild urial and argali sheep (*Ovis orientalis vignei* & *Ovis ammon*). Domestic caprids (*Capra/Ovis*) and dogs make up 3% and 2% of the assemblage respectively. Settlement structures during this first phase at Gufkral consist of subterranean circular and rectangular pits cut into the loess up to 1.2m deep, with postholes indicating a timber superstructure.

The Early Neolithic (ca.4500-4000 BP) is a ceramic period typically characterised by a hand-made coarse grey-ware ceramic type (Betts et al. 2019). The agricultural economy of this period includes the above wheat and barley, as well a small amount of emmer wheat (*Triticum dicoccum*) and field pea (*Lathryus sativus*) recovered at Kanispur (Pokharia, Mani, et al. 2017). Fruit endocarps recovered from Burzahom include walnut (*Juglans regia*) – endemic to Kashmir – as well as East/Central Asian peach (*Prunus persica*) and apricot (*Prunus armenica*) (Lone et al. 1993). Agriculture during this phase has generally been understood to be entirely based on West Asian winter cultivation systems (Lone et al. 1993), though recent testing at the site of Pethpuran Teng has yielded summer broomcorn millets (*Panicum miliaceum*) of East Asian origin dated ca. 4400 BP (Betts, pers. comm.). Faunal remains from this period are evenly split between wild and domestic types, with cattle (*Bos indicus*) dominating the domestic types, with small amounts of sheep and goat, as well as newly introduced domestic fowl (*Gallus* sp.)

In addition to a broadening of the agricultural package, two Kot Diji style ceramic painted pots have excavated at Burzahom have been interpreted as evidence of contact between Kashmir and proto-Harappan populations to the south (Khazanchi & Dikshit 1980). Settlement architecture during this period shifts from semi-subterranean dwellings to above-ground rammed earth structures (Sharma 2013, Bandey 2009). Highly formalised deep conical pits of a disputed use were also cut into the Karewa terraces (Coningham & Sutherland 1997) from this period onwards.

The Late Neolithic (ca. 4000-3500BP) sees the development of a formalised burnished and fine-combed ceramic industry (Betts et al. 2019). Material culture including tools and structures are generally comparable to the Early Neolithic, although agate and carnelian beads from Burzahom and Gufkral (Sharma 2013, Ghosh 1969) indicate some form of economic exchange with the Harappan centres to the south. Endocarps of Central Asian almond (*Prunus amygdalus*) and East Asian plum (*Prunus domestica*) were recovered from Burzahom, and grape seeds (*Vitis* sp.) and broomcorn millets were recorded from a conical pit at Qasim Bagh (Spate et al. 2017). In addition to these domesticates from East and Central Asia, a number of polished stone blade harvesters were recovered from Burzahom and Gufkral that have been compared with Chinese Yangshao Neolithic types (Yatoo & Bandey 2014). While some scholars have interpreted these uncritically as evidence of direct contact between Kashmir and China (Han 2012), the "non-uniform" timing of their arrival is more likely evidence of indirect diffusion and adoption (Stevens et al. 2016). Faunal remains from Gufkral are now almost entirely (80%) domesticates dominated by sheep and goat (45%) followed by cattle (20%) and dog (10%) (Sharma, 2013). Sharma (2013, p.64) notes that caprids were generally slaughtered at late immaturity and interprets this as a pastoralist practice to minimise impact on forage resources, though also notes that animals were free of pathologies associated with intensive herding. The Late Neolithic of Kashmir does not terminate but maintains cultural continuity with the succeeding Megalithic period.

The Megalithic period (ca. 3500-3000 BP) is differentiated by the erection of large stone Menhirs at Burzahom and Gufkral as well as the introduction of a wheel-made gritty red ceramic (Ghosh 1961, Sharma 1982). A Megalithic phase has also been excavated at Semthan towards the south of the valley (Mittra 1983). Lone et al. (1993) report the introduction of rice (*Oryza sativa*) at Burzahom and Semthan, as well as mung bean (*Vigna radiata*), interpreted as evidence for a shift towards summer cropping and bi-seasonal agriculture.

During the Neolithic, Kashmir seems to be one of the major centres of a regional cultural complex grouped as the Northern Neolithic (Betts et al., 2019). Similar sites are found in the Swat Valley, northern Pakistan (Stacul et al. 1987, Vidale et al. 2011). Settlement in these regions appears to be initially driven by non-irrigated cultivation of winter cereals and pulses, followed by the incorporation of shorter season summer crops which may have been more suitable due to available runoff from winter/spring westerly precipitation as well as monsoonal summer rain. Archaeologically, these cultures disappear following appearance of material culture associated with the Iron Age in the northern South Asian Subcontinent.

Iron Age/Proto-Historic (ca. 3000-2000 BP)

This period has traditionally been considered to represent a chronological gap in the archaeology of Kashmir, only evident in several thin archaeological phases at Semthan (Mittra 1983). These include a Northern Black Polished Ware (dated relative ca. 2700-2300 BP) phase, a material culture found throughout northern South Asia. This was followed by a very thin deposit of Indo-Greek material dated relatively to ca. 2100 BP. New botanical remains from this phase include the South Asian summer pulse Urd Bean (*Vigna mungo*) (Lone et al. 1993). Yatoo (2015) has identified several sites of iron working in the north of the valley that appear to be associated with this period, though they have not yet been dated absolutely. Overall this period appears to be both poorly represented and understudied in Kashmir, with the preceding Megalithic phase generally succeeded by the Kushan phase at archaeological sites in the valley (Yatoo 2012), leaving a chronological break of around 1000 years.

Kushan Period (ca. 2000-1500 BP)

The Kushans were a confederated empire of Central Asian nomadic origins (Mukhamedjanov 1996) whose eastern states comprised the northern subcontinent, including Kashmir. Excavations at Semthan (Mittra 1983, Lone et al. 1993) and Kanispur (Pokharia, Mani, et al. 2017) indicate an expansion of settlement size and a broadening of the agricultural base dominated by summer pulses and cereals – typically rice, millet, urd bean and mung bean (*Vigna radiata*). The Kushans controlled substantial overland trade between Central and South Asia (Dani 1996) and were believed responsible for the codification and dispersal of Mahayana Buddhism into Central Asia. Shah (2012) argues that the Kushan presence in Kashmir primarily aimed to control the passes in and out of the valley, linking Kashmir to the Tarim Basin and Tibetan Plateau to the northeast and Gandhara and Taxila to the west. These political-historical events are typically drawn from numismatic and epigraphic evidence and the chronicles of Chinese historians and mendicants , which obscure the lives of populations living under Kushan control (Rezakhani 2017, p.47). While the archaeobotanical evidence from Semthan and Kanispur allows some insight into the economic adaptations of the Kashmir population during this time, the context of these materials is poorly reported and it is unclear whether they were recovered from elite level store houses or domestic dwellings. The *Rajatarangini's* historical-mythological accounts of the Kushan period in the valley include descriptions of a deteriorating climate, sent as punishment by the old gods whose worship was disrupted by the advent of Buddhism in the valley, forcing the elite population into a period of seasonal migration:

> *"*[179] *When the traditional customs were broken in the land, the Nagas, who had lost their [accustomed] oblations, sent down excessive snow, and thus destroyed the people.* [180] *As deep snow was falling every year to cause distress to the Bauddhas, the king resided for six months in the cold season in Darvabhisara, and in other [neighbouring regions]"* (Stein 1900:I.179-180).

Environmental scientists and archaeologists have debated as to how seriously to take these semi-mythological accounts human-environmental interaction in Kashmir (Agrawal 1992). Despite these descriptions of the lives of Kushan rulers being disrupted, remains of their monumental architecture and religious institutions may be the first material evidence of state-level control and political integration in the Kashmir Valley (Shah 2012, 2016). Though Rezakhani (2017, p. 66) notes that the archaeology of the Kushan period has focused on monumental architecture and artefact typology rather than questions of "urbanism, agriculture and rural life", he notes that Kushan period advancements in water management technologies and administrative control contributed to some of the highest levels of agricultural production in the pre-modern world. It may have been these changes that allowed environmental constraints on the development of summer agriculture in the Kashmir Valley to be overcome, particularly as archaeobotanical evidence indicates the presence of rice and summer pulses in adjacent areas of northwest South Asia at least 1000 years before their arrival in Kashmir (Bates 2019).

Hunnic Period (ca. 1500-1400 BP)

The Hunnic period in Kashmir is associated with the in-migration of Central Asian nomadic confederations including the Kidarites and Hepthalites (Mukhamedjanov 1996). More recently the Alkhans have been recognised as an Iranian Hunnic group exercising suzerainty over Kashmir and other mountainous areas south of the Hindu Kush (Rezakhani 2017). Though studies of material evidence from this period across this region have generally reconstructed dynastic details, Rezakhani (2017, p. 106) notes that the Alkhan period left an impression on South Asian historical sources, such as accounts of conflict between the rulers of Kashmir and Kabul in the *Rajatarangini*. Rezakhani (2017, p.123) argues that this period may have contributed the formation of an Eastern Iranian cultural realm comprising Gandhara, Kashmir and norther areas of the South Asian subcontinent, as distinct from the Iranian heartland further to the west. In Kashmir, material remains from this period include thin deposits and coin hoards from Kanispur (Mani 2000), though these tell us little about the dynamics of local agro-pastoralist life. Shali (2001) argues that change during this and the preceding Kushan period was driven by increased competition for pasture land across Central Asia.

Historic Period (ca. 1400-400 BP)

This period saw the integration of Kashmir under the rule of several indigenous kingdoms including the Karkota, Lohara and Shah Mir Dynasties. Multiple socio-economic reorganisations took place, including the centralisation of bureaucracy and labour beginning with the Karkotas, the transition from Buddhism to Hinduism and finally Islam, and the development of Kashmir as a cultural-historical polity and identity (Bamzai 1994). Under the Karkotas, Kashmir became the seat of a regional empire, reputedly stretching into Central Asia and Tibet after aligning politically with the Tang Dynasty in China, though historians have questioned the extent to which this was a genuine expansion of the state rather than peripheral agro-pastoral communities living under nominal patronage (Kapur 1992). Under the rule of Zain-ul-Abidin of the Shah Mir Dynasty, concentrated engineering efforts were undertaken to transform the landscape of the valley, cutting canals through Karewa terraces and the construction of levees and drainage systems to mitigate flooding and improve agriculture across the valley floor (Bamzai 1994). Following this period, Kashmir was brought under the control of several early modern empires generally of Central Asian nomadic origin including the Mughal and Lodhi Dynasties, then Sikh and Hindu rule before conflict forced accession into the modern state of India (Kaul 2014).

2.4 Kashmir and the Inner Asian Mountain Corridor

Recent studies on the prehistory of Eurasian exchange prior to the development of the historic Silk Roads have focussed on the translocation of West and East Asian domesticated crops as archaeologically visible proxies of interaction between West Asia, Europe, South Asia and the Chinese heartland (Stevens et al. 2016, Spengler et al. 2014, Betts et al. 2014, Boivin et al. 2012). Previously thought to be a barrier to exchange, the mountain massif at the heart of Central Asia Inner Asian Mountain Corridor is now understood to be a vector of contact and exchange for seasonally mobile transhumant populations possibly as early as 5000 BP (Frachetti 2012). Notionally, pastoralist groups who spend winters in foothill or lowland areas would have some contact with agricultural villages or urban settlements before migrating to higher pastures in spring/summer months where interaction and exchange would take place with other seasonally mobile groups who would trade onwards with settled populations around their own winter base (Frachetti 2012). Archaeobotanical evidence from pre-historic Central Asian pastoralist settlements campsites implies these groups traded and cultivated millets, wheat and barley as a supplementary food source as well as using them as exotica within funerary contexts (Doumani et al. 2015, Spengler et al. 2014). Evidence for bronze metallurgy also indicates that these groups were engaged in the extraction, processing and smelting of tin and copper resources throughout the IAMC (Frachetti 2012). Recent flow accumulation models of productive pastures across the IAMC also indicate that nodes of historic Silk Road exchange developed around zones of pastoralist land use, rather than agricultural or urban centres (Frachetti et al. 2017).

In addition to detecting exchange through archaeobotanical proxies, considerations have been given to the role of climate change and ecological niches in facilitating or limiting forms of agro-pastoralist crop selection and economic systems (d'Alpoim Guedes 2015, Spengler 2015, d'Alpoim Guedes & Bocinsky 2018). These studies have also led to the abandonment of the notion of ancient pastoralist groups as nomads without agriculture and led to the reconsideration of agro-pastoralism as a flexible economic and social strategy, with shifting pasturing patterns, short season cultivation and resource extraction building up a resilient lifeway for the populations of this mountain region. By selectively cropping within these marginal environments, these groups may have also had a role in inducing phenotypic and genotypic changes in crops such as wheat and barley, allowing shortened photoperiods or growing seasons and their transmission to further higher altitudes and latitudes (Lister et al. 2018, Motuzaite Matuzeviciute et al. 2018, Liu et al. 2017, Spengler 2015).

Based on the presence of the stone harvesters comparable to Chinese Neolithic types at Burzahom and Gufkral, as well as East Asian stone fruits, Stevens et al. (2016) place Kashmir within this network of exchange from around 4000 BP. While the materials drawn upon by Stevens et al. (2016) are poorly reported, subsequent reappraisals of chronology (Betts et al. 2019), and archaeobotanical studies indicating millets also arriving in the valley at or before this time (Spate et al. 2017), seem to indicate the agricultural populations on the floor of the Kashmir Valley were enmeshed in these networks of exchange from the Early Neolithic onwards. Yatoo (2012) has raised the possibility of seasonal mobility of at least part of the population to areas outside the valley during winter, though this has been difficult to test archaeologically. Based on isotopic studies indicating Kashmir was a source of Harappan lead, Law (2008) has speculated that seasonally mobile herding populations may have been involved in resource extraction and trade between Kashmir and the Harappan regions to the south. Ascertaining the presence of a seasonally mobile agro-pastoralist population in Kashmir during the Neolithic and early historic periods may provide some insight into the mechanisms of exchange and interaction between the valley and adjacent regions of South and Central Asia.

2.5 Summary

This review identifies a number of gaps in the study of the past in Kashmir, generally arising from poorly resolved climate studies or mis-reporting of archaeological data. Previous syntheses on past human-environment interaction in the valley have correlated periods of settlement expansion during the Neolithic, Kushan and Dynastic periods as driven by the onset of optimal climate conditions (e.g. Shali 2001, Agrawal 1992). Recent palaeoclimate studies (Babeesh et al. 2019, Lone et al. 2019, Shah 2019) have complicated these interpretations by shifting the timing and impact of climate phases in the valley, while archaeological reappraisals (Betts et al. 2019) have changed our understanding of the economic chronology of the prehistoric periods. These recent studies have complicated previous understanding based on parallelism between the palaeoenvironmental and archaeological record. The remainder of this thesis examines environmental change and shifting social-ecological systems in the Kashmir Valley, with a particular focus on upland pastoralism. The following chapter provides a theoretical and methodological orientation for this approach.

Chapter 3 Theoretical and methodological orientation

3.1 Understanding Human-environment interaction in Kashmir

Long-term human ecology in the Kashmir Valley has been primarily understood through the remains at the archaeological sites at Burzahom and Gufkral as well as through climate data derived from the Kashmir Palaeoclimate Project (Shali 2001). These data tended to correlate expansion of archaeological settlements on the valley floor with warm-humid climate conditions during the Neolithic and Kushan and later historic periods. These periods have been interpreted as times of population growth, leading to Malthusian pressures and eventual societal collapse in intervening climate deteriorations (Agrawal 1992, Lone et al. 1993, Shali 2001). Yatoo (2012) has argued that these analyses are an artefact of excessive focus on the two most extensively excavated archaeological sites and a methodological focus of 20th century archaeologists on finding the largest or oldest settlements. Following a landscape-oriented rather than site-specific focus, Yatoo (2012) undertook extensive and intensive survey across multiple landforms and ecological zones in Baramulla district. Though the sites in this study were only relatively dated, they revealed a long-term process of variation in settlement pattern and differentiated use of ecological niches. These changes were interpreted as a result of the dynamic between climate and environmental change, social organisation and technological developments.

A reappraisal of the chronology of the Neolithic (Betts et al. 2019) as well as a number of new palaeoenvironmental studies (Babeesh et al. 2019, Lone et al. 2019, Shah 2019) has generated the necessity for a review of previous interpretations of climate-driven Malthusian cycles in the Kashmir Valley. The agricultural transition during the Neolithic was previously assumed to capitalise on warm humid conditions associated with the Holocene Climate Optimum, positioning the Kashmir Valley as an ideal site of cultivation (Agrawal 1988) at ca. 5000 BP. The climate records from Anchar (Lone et al. 2019) and Wular (Shah 2019) lakes indicate that while there may have been higher precipitation ca. 5000 BP, the climate was already transitioning to a more arid phase and the onset of fully dry conditions began ca. 4500 BP. This drier phase is also evident in the earliest stages of the Manasbal lake record (Babeesh et al. 2019) prior to 3500 BP.

There has been extensive debate on the presence and nature of the Aceramic Neolithic phase at or around 5000 BP (Bandey 2009), with only a thin deposit at Kanispur relatively dated to earlier than 4700 BP (Pokharia, Mani, et al. 2017). The beginning of the Aceramic Neolithic at Gufkral now appears to date closer to 4700 BP (Betts et al. 2019). At Kanispur there is no evidence for domesticated plant remains (Pokharia, Mani, et al. 2017), however, at Gufkral remains of domesticated wheat, pea, barley and lentil were recovered (Sharma 2013). Though these remains fall in the date range ca. 4700-4400 BP, their position in the stratigraphic sequence is not reported other than that they were recovered “towards the close” (Sharma 2013, p.39) of the period. This re-examination of climate and early settlement chronology would indicate that the development of agriculture in Kashmir took place against a backdrop of aridification, rather than optimal precipitation. Recently published archaeobotanical data now suggests that early cultivators in the Kashmir Valley had a broader base of agricultural resources than previously believed, and these may have allowed for the growth of a resilient food producing economy able to respond to changing precipitation regimes (Pokharia, Mani, et al. 2017, Spate et al. 2017). Elsewhere in South Asia new research indicates that much of the growth of Harappan urbanisation and the post-urban transition took place against a background of protracted aridification, and that social resilience was maintained through diverse adaptations that utilised a wide array of agricultural resources as well as directing productive activities towards suitable ecological niches (Thakur et al. 2019, Giosan et al. 2018, Petrie & Bates 2017, Petrie et al. 2017).

Following Yatoo's (2012) arguments, the failure to detect these diversified systems of landscape use in Kashmir is likely attributed to a methodological focus on the excavation of large agricultural sites adjacent to the Jhelum floodplain, rather than the absence of human settlement and land use in foothill or mountain areas of the valley. An example of this is seen in preliminary evidence tentatively dated to ca. 3000-2000 BP that may indicate the extraction and smelting of iron ore on the hilly areas behind Wular Lake (Yatoo 2015). As large agricultural sites are poorly represented across the valley floor during this period, this may be cautiously interpreted as a change in economic focus towards extractive industry and the long-distance trade of iron. Environmental data from this period indicates an arid event from ca. 2500-2000 BP (Lone et al. 2019, Babeesh et al. 2019) that may have driven populations away from sedentary cultivation to more flexible systems of resource extraction and food production.

These shifting, long-term patterns of human-environment relationships in Kashmir can be considered through the lens of "resilience theory" (Redman 2005). Originally articulated by Holling & Gunderson (2002) as a way for understanding the dynamics of ecosystems, resilience theory aims to go beyond the binary of growth and conservation (or expansion and collapse in the case of human societies) that dominates much of the ecological discussion. The framework conceives of Social-Ecological Systems (SESs) as the complex relationships between organisms and their environment, which are bound up in an adaptive cycle of four phases: growth (r); conservation (K); release (Ω); and reorganisation (α) (Figure 3.1). The first two stages of this adaptive cycle are a period of slow growth and adaptation, where capital (typically biomass and nutrients) is accumulated and a small number of species or groups begin to dominate the ecosystem, while maintaining some diversity in relict patches of the landscape. This process of accumulation and loss of system diversity adds stress to the ecosystem and internal or external forces may induce a release (or collapse) stage. This release energy is then rapidly redirected to the reorganisation phase, in which new adaptations to the changed environment are undertaken.

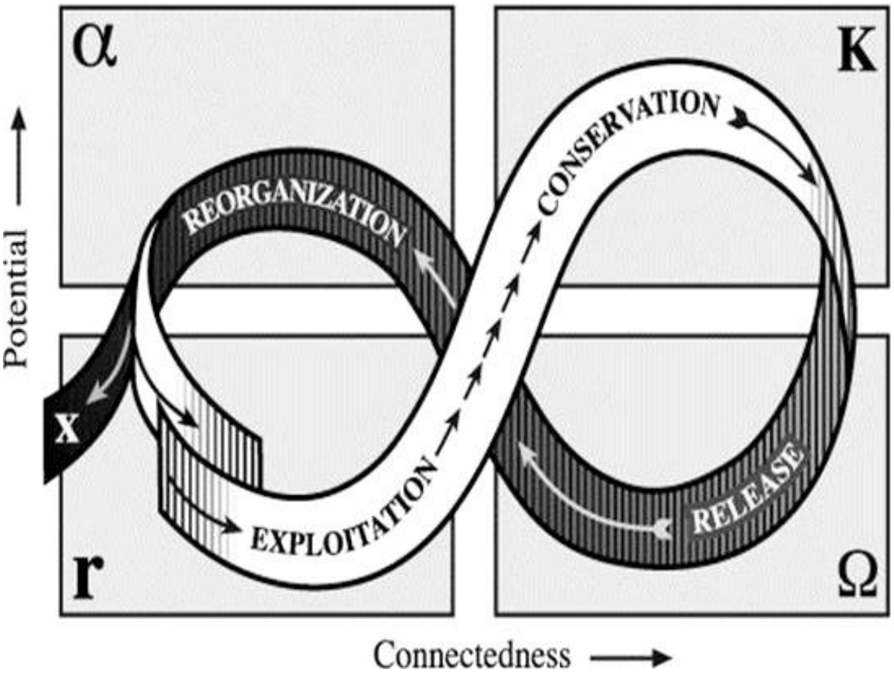

Figure 3.1: Four phases of Holling & Gunderson's (2002) adaptive cycle.

Adaptive cycles were conceived of as a way of negotiating the ways in which change in ecosystems is neither gradual and stable nor entirely chaotic, that spatial attributes of ecosystems are non-uniform and that ecosystems do not contain mechanisms for maintaining homeostasis (Holling & Gunderson 2002). In this approach, resilience is not conceived of as the way in which a system can remain static (or avoid collapse) but the ways in which an SES can absorb, respond and adapt to stress or perturbation, or successfully reorganise when subject to stressors. Adaptive cycles and resilience theory have been applied to archaeology by Redman (2005), arguing that the framework is a useful approach for archaeologists to think beyond Malthusian-type cycles of growth and collapse, and as a means of understanding the relationship between past societies, their environments and the causal mechanisms of social change. Redman cites the example of the social transition between Preclassic and Classic periods of the Hohokam desert farmers in Arizona, where a large body of scholarship assumed that a period of stable water availability was a precursor for wealth accumulation and population growth in the Preclassical period (r & K phases) before higher fluvial variability led to a population collapse and social reorganisation in the Classical period (Ω & α phases). Counterintuitive to these assumptions, a reappraisal of household size, monumental construction and hydrology by Ingram (2004) indicated that higher water variability drove widespread flooding and mineral renewal of agricultural land during the Classic phase, allowing for a larger population and more accumulated material wealth in this period. Redman (2005) argues that approaching these questions through the phases in resilience theory helps to delink causal or deterministic environmental changes from supposed corresponding changes in the archaeological record.

This assumed parallelism between the archaeological and environmental records in Kashmir and the associated assumptions of climate-driven growth and collapse may be complicated through more multifaceted investigations of land use across the valley. Mobile or semi-mobile agro-pastoralism has been previously been raised as one form of adaptation in the valley, primarily based on the interpretation of large subterranean structures at Neolithic sites as seasonal storage pits rather than habitations (Coningham & Sutherland 1997). Conningham & Sutherland (1997) propose a theory for the Kashmir Neolithic in which agricultural settlements were "nuclear" summer habitations, where part of the population engaged in cultivation while others herded animals in the middle and higher altitudes before a wholesale migration out of the valley during winter. Yatoo's (2012) survey data does provide some suggestion as to varying zones of settlement and land use in the valley during the prehistoric and early historic periods. These shifting seasonal settlement patterns and land usage in Kashmir have also been alluded to in the *Rajatarangini* (Stein 1900) though these descriptions stretch into deep mythological time. Preliminary archaeological evidence from a stratified deposit within a conical subterranean pits at the site of Qasim Bagh indicate these were likely storage structures (Spate et al., 2017) rather than winter habitations as they have previously been interpreted (Bandey 2009). This recent evidence raises the question as to the nature of settlement in the Kashmir Valley during winter in the Neolithic and adds weight to Conningham & Sutherland's (1997) hypothesis of a seasonally mobile population.

Seasonally mobile forms of cultivation and herding has been referred to as "multi-resource pastoralism" in ethnographic literature (Salzman 2004). In this system of pastoralism there is a division of labour between herding and other productive industries such as farming, resource extraction such as mining or forestry, and production and trade of secondary goods. This broad productive base allows for an adaptable society with a high degree of agency in the way they are engaged with the pastoralist landscape:

> *"…*few populations limit themselves to one productive activity. Rather, nomadic mobility is likely to be put to work as well in aid of other productive activities, such as cultivation, as among the Baluch, or fishing, as among the Nuer. Nomadic mobility is not infrequently from a location of one productive activity, such as pastoralism, to another, such as arboriculture*."* (Salzman 2004, p.24).

This flexible ecology is well suited to the notion of adaptive cycles in resilience theory, which emphasises "persistence, adaptiveness, variability, and unpredictability" (Holling & Gunderson 2002, p.27) as traits of a viable long-term Social-Environmental System. Again, Salzman:

> *"Nomadism can be used as an opportunistic 'rapid response' to the sudden and temporary availability of irregular and unpredictable resources, such as pasture. The migration pattern in these circumstances is consequently irregular in timing and direction and asymmetrical in pattern."* (Salzman 2004, p.23).

Two comparative ethnographic studies from Inner Asian mountain regions may demonstrate the way in which a wide range of pastoralist strategies extend beyond simple patterns of herding and rather function as a complex and resilient socio-environmental system. In the first of these, Dong et al. (2016) drew on three case studies from the Indian Himalaya, Nepal Himalaya and Qinghai-Tibet Plateau to examine the ways pastoralist populations are entangled with various ecological and economic systems including resource enrichment or degradation, cultivation, industries such as tourism or forestry, as well as engagement with external bodies such as government and non-government organisations.

In Nepal (Dong et al. 2016), pastoralists often worked through collective institutions or committees in order to maintain communally agreed-upon best ecological practices, such as rotational grazing and the herding of particular species of animals to suitable ecological niches. While these activities aimed to sustain pastureland for herding, activities such as cultivation or guiding of tourists allowed for secondary sources of food production and income. These secondary sources reduce economic imperatives on herding and allow for pastoralists to engage in best-practice land management strategies. The case study from the Indian Himalaya also found that seasonally mobile transhumant herding drawing on local knowledge had the best outcomes for managing landscapes, thus reducing degradation. The transhumant groups also engaged in wider institutional networks such as through negotiation with cultivators over land access rights, which often necessitated payment in the form of animal products and intensified other processes of trade, exchange and interaction with the cultivators. Similarly on the Qinghai-Tibet Plateau, Dong et al. (2016) assessed long-term drivers of landscape degradation, finding it to be the result of the dynamic between human impacts and climate change that is not yet fully understood. The study finds pastoralists have developed systems of "adaptive grazing" to cope with both climate change and pasture degradation, including reseeding campsites, more frequent movement and a wider utilisation of vertically differentiated environmental zones. Conservation oriented constraints imposed by external institutions such as government land management programs acted to further degrade ecosystems, as they prevented pastoralists from engaging in their more flexible systems of responsive land use and management:

> *"…policy initiatives aimed at sustainability may lead to overstocking because of insufficient understanding of current social-ecological systems of pastoralism… breaking human-natural systems (social-ecological systems) is greatly associated with rangeland degradation in the QTP and other areas of the developing world."* (Dong et al. 2016, p.219).

The second comparative case study examined pastoralism in the Pamir region of Afghanistan, the Altai and Tien Shan ranges in Xinjiang and the steppes of Inner Mongolia (Kassam et al. 2016). As in the Himalaya and Tibet case studies, these investigations articulated that pastoralists' social ecological systems developed as the result of long-term processes of landscape evolution and accumulated indigenous knowledge. The two studies from China concluded that government policies aimed at landscape preservation and sedentising pastoralist populations had a detrimental effect on both biotic diversity in the landscape as well as the incomes and wellbeing of pastoralist populations. In the Pamirs, the study identified two sets of ecological adaptation, a long-distance migratory herding practiced by Arab Pashtuns, and the higher altitude cultivation system of the Shugni people. In the course of a seasonal migration, the Arab Pashtuns often utilise high altitude pastures where the Shugni also undertake secondary herding away from the agricultural settlement. While both groups emphasise their economic, ecological and cultural differences, they engage in trade and exchange, and have shared institutions for negotiating the allocation of resources. Against the backdrop of conflict and government corruption in Afghanistan, the study authors argue that despite their differences, the ways in which the two agro-pastoralist groups were entangled with one other's mutual wellbeing produced a flexible social-ecological system with beneficial results for both landscape ecology and economic development.

This review of some of the general principles of multi-resource pastoralism as well as specific case studies has highlighted some of the ways in which pastoralist SESs are particularly suitable adaptive cycles for the marginal environments of Inner Asian mountain ranges and fit well with the adaptability and unpredictability privileged in resilience theory. These cycles may comprise initial colonisation of ecotopes during the growth (r) phase, including the modification of landscapes to more suitable grazing lands. These rangelands may be maintained in the conservation (K) phase through the practices described above, including circular grazing, increased mobility, propagation and reseeding of herbaceous plants or selective herd composition. During release (Ω) periods, response to environmental or other perturbations may require negotiation with other pastoralist groups, farmers or governing bodies, as well as the redirection of productive activities, for example to undertake increased cultivation or modify migration patterns. These practices may become institutionalised during the reorganisation reorganisation (α) phase. Over time these adaptive cycles would allow for the embedding of a resilient pastoralist Socio-Ecological System across Inner Asian mountain landscapes.

3.2 Pastoralist landscapes and Niche Construction Theory

In a 1993 essay, the anthropologist Tim Ingold described landscapes as spaces of accumulation of the interaction between physical features and temporally contingent activities (tasks) that are in a continual process of making and re-making one another, "*…the landscape as a whole must likewise be understood as the taskscape in its embodied form*: a pattern of activities 'collapsed' into an array of features" (Ingold 1993, p.162, emphasis Ingold's). As a discipline bridging both the natural sciences and the humanities, Ingold (1993, p.172) argued that archaeologists are well positioned to integrate the understanding of physical space and human activity and arrive at an understanding of landscapes as more than atemporal collections of physical features as well as push historical study to move beyond "dematerialised" cultural approaches.

This understanding of landscapes as a palimpsest of long-term social and natural processes had been applied directly to Inner Asian pastoralist landscapes by Frachetti (2008), defining them as spaces of "…scalar flexibility of both perceived and physical boundaries of interaction and regional exploitation. The physical extent of pastoralist landscapes is dictated partly by environmental conditions such as topography, hydrology, vegetation and climate" (Frachetti 2008, p.22). Making allowances for human agency and the strategic responses to environmental conditions, Frachetti argues that this understanding eschews environmental determinism and may instead be considered as a form of "environmental pragmatism" in which the agency of pastoralist groups is influenced by two primary factors, the balancing of environmental conditions on the one hand with the need to maximise the productivity of herds of animals – the pastoralist's primary economic base – on the other. While the environment does exert some constraint on these pastoralist strategies, the choices made by pastoralists also influence the features of the environment, such as the way in which several wetter years may render high altitude meadows unusable, while increasing biomass at lower altitudes. This would drive pastoralists to graze at lower and middle altitudes, ultimately increasing biotic pressure in these zones while leaving high altitude meadows to become overgrown (Frachetti 2008, p.22). This feedback loop between environmental conditions, pastoralist choices and the co-evolution of the landscape in mountainous Inner Asia has been framed in more direct terms by Spengler (2014), through the lens of Niche Construction Theory (NCT). Ingold (1993, p.172) closes his essay on landscapes by noting he aimed only to direct archaeological questions, not provide methodological expertise on how these may be approached. NCT is a framework that may be particularly suitable to examine the way that pastoralist social-ecological-systems became embedded in, and directed, the evolution of Inner Asian landscapes.

NCT has its origins in evolutionary biology but has since been applied archaeologically (Laland & O'Brien 2010). It aims to explain the co-evolution of organisms and their environment through describing the processes by which an organism:

> "…modifies the feature-factor relationship between itself and its environment by actively changing one or more of the factors in its environment, either by physically perturbing factors at its current location in space and time, or by relocating to a different space-time address, thereby exposing itself to different factors." (Odling-Smee et al. 2003, p.41).

Niche construction activities may be presented as the relationship between two binaries, inceptive/counteractive activities on the one hand and perturbation/relocation on the other (Odling-Smee et al. 2003, p.46). Inceptive niche construction takes place when an organism initiates changes in an environmental niche, whereas counteractive activities occur when organisms try to mitigate the effects of environmental changes within a niche. These activities are undertaken either through processes of perturbation or relocation described in the quote above, thus the four types of niche construction can be construed as: inceptive perturbation; counteractive perturbation; inceptive relocation; counteractive relocation. A summary of these types is given in Table 3.1.

Table 3.1: Four types forms of activity in NCT (modified after Odling-Smee et al. 2003).

	Perturbation	**Relocation**
Inceptive	*Organisms initiate a change in their selective environment by physically modifying their surroundings. e.g., emission of detritus*	*Organisms expose themselves to a novel selective environment by moving to or growing into a new place. e.g., invasion of a new habitat*
Counteractive	*Organisms counteract a prior change in the environment by physically modifying their surroundings. e.g., thermoregulation of nests*	*Organisms respond to a change in the environment by moving to or growing into a more suitable place. e.g., seasonal migration*

We may apply these niche constructive activities to a hypothetical situation that draws on some of the factors in the pastoralist adaptive cycle from the section above. As a result of local government pressure, a seasonal transhumant group shifts from summer grazing at middle altitudes around agricultural settlements to herding in a high steppic desert (inceptive relocation). In this new environment, the poor forage consists of low-growing thorny herbs and leads part of the pastoralist group to again move to a different area and take up cultivation (counteractive relocation). Some of the pastoralists remain in the steppic environment, modifying their herd composition by decreasing the number of sheep and increasing the number of goats that are able to more easily graze this environment (counteractive perturbation). Over time the herders also induce a phenotypic change in the goats, selectively breeding animals with tooth and jaw structures able to browse closer to the ground that in turn impacts the environment through changes in the vegetation spectrum as well as increasing soil erosion (inceptive perturbation). The pastoralists then mitigate this degradation through programs of reseeding grazed areas (counteractive perturbation). Ultimately these processes may also direct the evolution of the pastoralists themselves, where the population remaining at high altitude may be exposed to selective pressures for inhabiting this environment, while the now cultivators may undergo physical changes associated with different forms of labour and diet. These selective pressures have been termed *ecological inheritance* (Odling-Smee et al. 2003, p.42), considered by some as an evolutionary factor almost as important as an organism's genetic inheritance (Zeder 2016). From this hypothetical we can see that NCT allows for a broad exposition of the dynamics between organisms and their environment. When applied to human activity NCT allows us to avoid environmental determinism by allowing for human agency, and also accounts for cultural-historical factors such as the initial institutional pressures that forced the movement of the pastoralists in this example.

As it has its origins in evolutionary biology, the majority of applications of NCT in archaeology have tended to focus on the co-evolution of humans, plants and animals and associated genotypic and phenotypic changes during the transition to agriculture (Laland & O'Brien 2010, Zeder 2016). Elsewhere others have argued that given *Homo sapiens'* capacity for cultural learning and transmission, human niche construction must be considered socio-cultural niche construction, having implications for understanding the timing and nature of the Anthropocene as a global epoch (Ellis 2016). In an effort to model the long-term consequences of human niche construction, Boivin et al. (2016) synthesised multiple proxies available to archaeologists to provide an empirical basis for the examination of the Anthropocene. While this study was critiqued for avoiding discussion of evolutionary processes (Ellis et al. 2016), it is clear its primary aim was to elucidate the types of data that archaeologists are able to draw on in order to contextualise the long-term evolutionary pathways implicit in NCT. These data include archaeobotanical and zooarchaeological remains to examine domestication, pollen and geomorphological data to model landscape modification or DNA studies on the timing and nature of colonisation by domesticates of new environmental niches (Boivin et al. 2016).

Sarah McClure (2015) has undertaken a thorough review of the evolutionary and social-ecological consequences of the spread of pastoralism in Neolithic Europe. The review identified four phases of inceptive perturbation, counteractive perturbation, inceptive relocation and counteractive relocation based upon factors such as water and grazing requirements, landscape degradation, herd composition and integration of pastoralism with other social-ecological systems (Figure 3.2). Crucially, McClure links these niche construction activities back to evolutionary pathways such as the development of lactose tolerance in Northern European populations as a result of dairying. This, in turn, have arisen from the suitability of cattle within this environmental niche, as opposed to the selection of goat- based transhumance in the more mountainous regions of Southern Europe. McClure's study demonstrates the utility of NCT for examining ancient pastoralism as a continuous feedback loop between human agency, selective pressures and environmental conditions. The enrichment and degradation of pastoralist niches has also been examined by applying NCT to on site archaeobotanical records from Anatolia (Marston 2017, Miller 2010) where the diversity and relative representation of various herbaceous seeds have been interpreted as evidence of vegetative health of steppic environments.

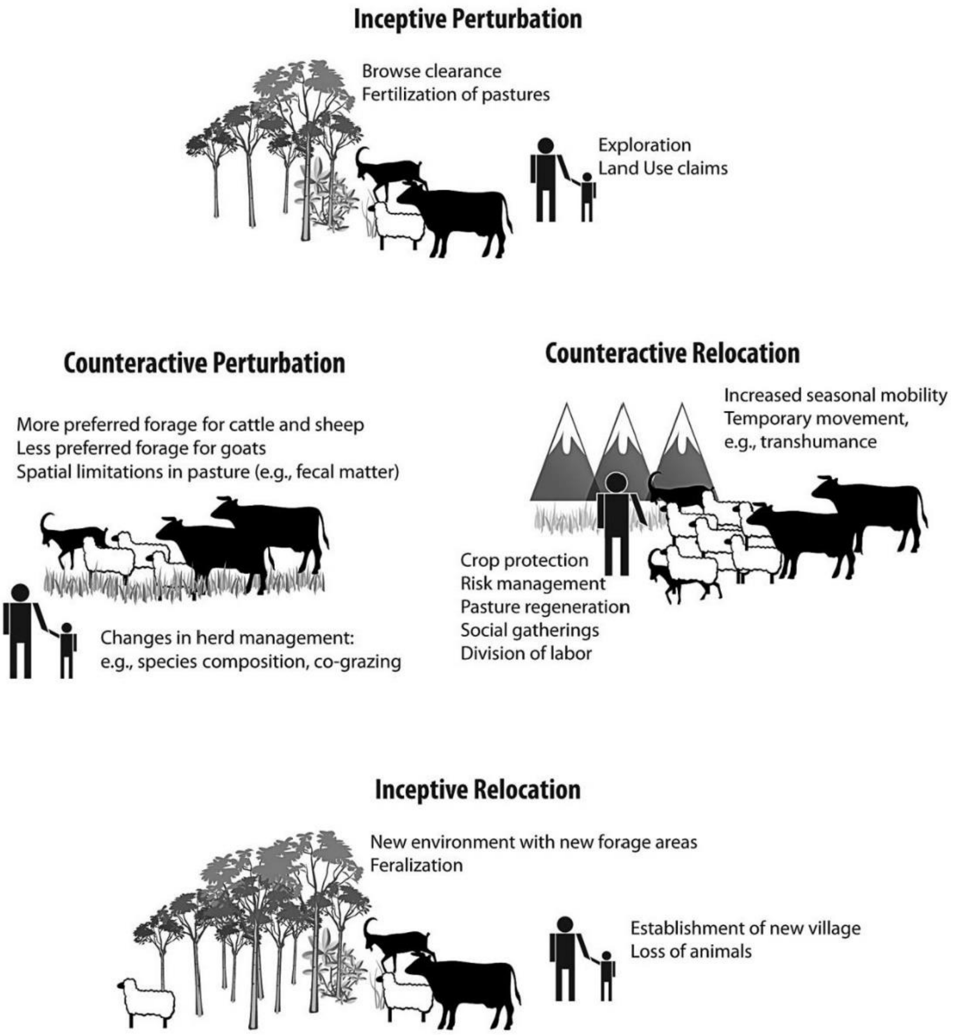

Figure 3.2: Four forms of pastoralist niche constructing activity (adapted from McClure 2015).

Spengler (2014) has argued that NCT is an effective framework for underscoring the agency of Central Asian pastoralists during the Bronze and Iron Ages, demonstrating the ways in which the social and ecological adaptations of these groups went beyond simply occupying suitable grazing niches and instead actively transformed their environments. While Spengler does describe the way that pastoralists colonise rich foraging ecotopes within patchy mountain environments, these are often enriched through propagation of favourable forage plants and the suppression of unpalatable competitors such as grasses and sedges. This niche enrichment may be detected in charred seed remains associated with dung burning in the archaeological record. The taxa include various species of *Chenopodium* and *Polygonum* which are palatable colonisers of disturbed areas and have robust seed coatings that survive digestion. These enriched niches then have the potential to be foci of cultural activity across dispersed networks of pastoralist interaction (Frachetti 2012). In addition to enrichment of these ecotopes, pastoralist niche construction may include more widespread modification of the landscape such as conversion of forest to pasture land through wholesale clearing followed by suppression of sapling regrowth by grazing animals (Spengler 2014).

Supplementary agriculture at sites such as Tasbas, Begash and Tuzusai in Southeast Kazakhstan (Doumani et al. 2015, Spengler et al. 2013, Frachetti, Spengler, et al. 2010) may also be a form of pastoralist niche construction where cultivation informs other cultural or economic choices such as herd structure or trade contacts, whilst also exerting selective pressure on other biota through competition or landscape modification. While the former two sites have archaeobotanical assemblages dominated by arid-tolerant barley and millet that likely had a lower labour investment, Tuzusai on the rich soils of the Talgar alluvial fan is dominated by wheat. While more difficult to grow in this environment, wheat has a higher nutritional return and may suggest an emphasis on agriculture at the site, whereas the inhabitants of Begash and Tasbas may have a more diverse and mobile social-ecological system comprising herding and cultivation dispersed across a wider pastoralist niche. The divergence between these two types of niche activities may also be attributed to technological/chronological change between the Bronze Age (Begash and Tasbas) and the Iron Age (Tuzusai) (Chang 2018).

The entanglement between land formation processes and human land use on the Talgar alluvial fan situates pastoralist niche construction and SESs as a feedback loop between four processes: the Central Asian loess cycle; fluvial processes of the Talgar River; soil formation processes across the alluvial fan; and long-term strategies of Bronze and Iron Age pastoralists and agro-pastoralists (Ullah et al. 2019). The study argues that flexibility of niche constructing activities allowed agro-pastoralist SESs to respond to Holocene environmental change such as variation in fluvial and aeolian processes or degradation of soil or vegetation. Ullah et al. (2019) describe these strategies as being part of a “positive feedback” loop that contributed to ongoing processes of niche enrichment and maintenance that were only disrupted during the Soviet period, raising the possibility of “re-engineering” these social-environmental systems as a way to contribute to future landscape conservation. As has been stated elsewhere, archaeological understandings of niche construction during a deep time Anthropocene may contribute to future frameworks of environmental sustainability (Boivin et al. 2016, Spengler 2014). These archaeological case studies, as well as the ethnographic examples from the section above, build a strong argument that the niche-constructing activities of various forms of pastoralism and agro-pastoralism contribute to resilient social-ecological systems best suited to the environment of the Inner Asian mountain ranges.

3.3 Examining Pastoralist Niche Construction in Kashmir

Unlike some marginal environments of the Inner Asian mountain massif such as the Pamirs, Karakoram or Tibetan Plateau, the Kashmir Valley is a rich ecological niche with a fertile soil landscape and good water availability. Prehistoric and early-historic social-ecological systems in Kashmir may have been comparable to other intermontane or foothill landscapes throughout Central Asia such as the Zerafshan (Spengler & Willcox 2013) and Ferghana (Askarov 1996) valleys, or the Talgar alluvial fan (Ullah et al. 2019, Chang 2018) where mobile herding was typically incorporated into broader systems of flexible agro-pastoralism. Detecting niche-constructing activities may be best approached by dividing the valley into a series of three environmental niches: the valley floor; foothill/mountain zones; and sub-alpine to alpine meadows (Figure 3.3). On the valley floor, present niche-constructing activity may be characterised by large urban settlements and intensive agriculture across the Jhelum River alluvial landscape. As the following study is concerned with examining long-term socio-environmental systems of pastoralism in mountain and high altitude meadows a closer consideration of niche-constructing activities drawing on ethnographic and geographic description is necessary here.

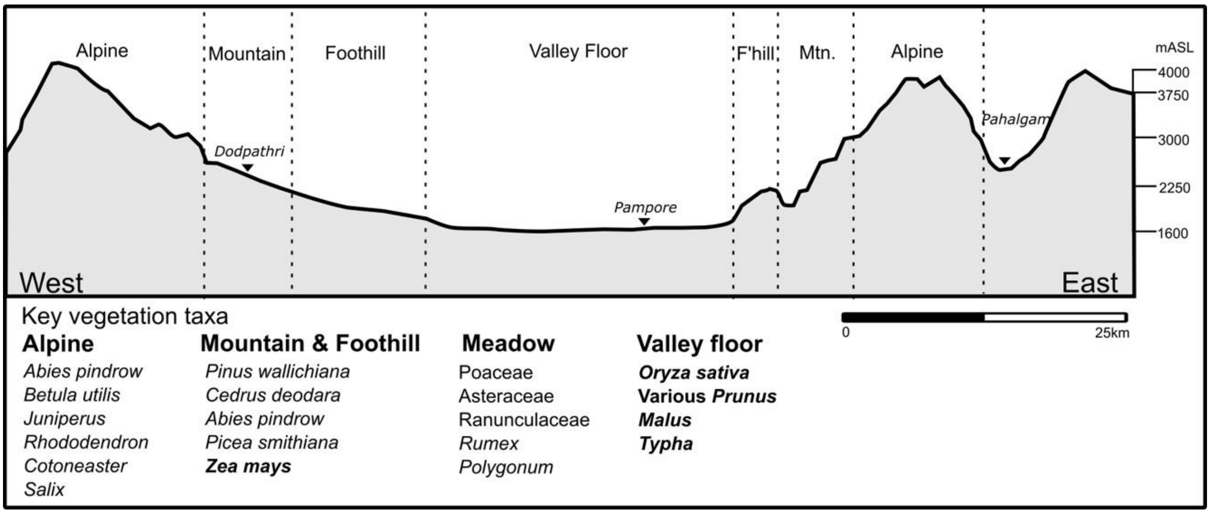

Figure 3.3: Altitudinally differentiated zones of social-ecological niche construction in the Kashmir Valley, west-east transverse section through Budgam and Anantnag Districts. Economically important vegetation types in bold. (Adapted from Spate 2019).

Casimir & Rao (1985) have described the utilisation and modification of various altitudinally differentiated ecological niches in Kashmir and adjacent areas during a seasonal migration cycle of Bakarwal pastoralists. On the Pir Panjal rim of the Kashmir basin, pastoralists clear areas of *Pinus* forest and suppress growth of saplings, opening the wooded areas into new ecological niches:

> "There is good pasture on the northern slopes of the Pir Panjal at an altitude of about 2,500m in the Cedrus-Pinus formation …On the whole, the undergrowth of the woodlands and their marginal zones is characterized by dense stands of *Gallium, Geranium, Trigonella, Astralagus, Potentilla, Euphrasia, Tanacetum, Alchimila*, and the genera *Polygonum, Chenopodium, Portulaca*, and *Cerastium*, all gathered intensively by the Bakrwal and eaten as vegetables. The fields, cut as wide aisles through the woods, serve as pasture." (Casimir & Rao 1985, p.227).

A number of these herbaceous plants utilised by Bakarwal pastoralists are types also identified by Spengler (2014) as indicative of pastoralist niche enrichment in other areas of Central Asia.

While enrichment of niches may be an aspect of positive feedback loops, the impacts of overgrazing and landscape degradation can also result from a poorly managed pastoralist SES. The studies reviewed in Chapter 2 (Mir et al. 2015, Ahmad et al. 2013, Khuroo 2013, Dad & Reshi 2013, Dad & Khan 2010) discussed the impact of grazing on vegetation diversity at sites of varying intensities of grazing. These studies generally found that moderate grazing may enrich niche diversity, while declining diversity and an overabundance of Poaceae as well as high proportions of unpalatable *Urtica*, *Plantago* and Asteraceae types were associated with overgrazing. These studies also found high representation of *Rumex, Polygonum* and *Trifiolium* in heavily grazed meadows, colonising nitrogen-enriched areas of dung accumulation. The relationship between pastoralism and geochemical and sedimentary change has also been studied in meadows on the mountain flanks in

Kashmir (Jaweed et al. 2015). In addition to the nitrogen enrichment, this study found a linear relationship between nitrogen, potassium, phosphorus and sulphur, all increasing on a gradient from lightly to heavily grazed areas. The coarse sand fraction of surface sediments also increased from 4.2±1.7% in lightly grazed areas to 13.7±4.16% at sites of heavy grazing. Figure 3.4 shows the results of varying grazing impacts on the landscape at Tosa Maidan at ca. 3100m ASL on the Pir Panjal flank of the Kashmir Valley.

These pastoralist niche construction activities may generally be conceived of as inceptive perturbation, as they involve pastoralists directly modifying the landscape through processes of colonisation, directed and undirected alteration of the vegetation spectrum and impacting of soil processes. Counteractive perturbation by pastoralist groups in these mountain areas may include changes in herd composition or strategic engagement in supplementary agriculture. While some of these activities may be detected in the archaeological record, such as the accumulation of *Polygonum* or *Chenopodium* or exhaustion of woody forest taxa in records of on-site burning (Spengler 2014) archaeological survey has yet to fully explore the pastoralist landscape on the mountain flanks of the Kashmir Valley where these site types may be discovered. Given the current political instability in the valley, the undertaking of intensive survey in these regions is extremely difficult and recent archaeological works have typically followed strategies of redating and rapid sampling of exposed sites on the valley floor (Betts et al. 2019). In order to better understand the long-term development of pastoralist ecology in the mountain flanks of the Kashmir Valley, ancient pastoralist land use must first be detected. This study aims to identify pastoralist land use through environmental proxies that may be indicative of changes in the vegetation spectrum, burning and clearing of the landscape and impacts on geomorphic processes. These data are drawn from environmental cores acquired through fieldwork on the mountain flanks of the valley. The following section 3.4 provides a review of the ways in which agro-pastoralist land use has been reconstructed from environmental records in adjacent areas of Asia.

Figure 3.4: Impact of caprid grazing at Tosa Maidan: a & b - lightly grazed areas with dung accumulation, growth of Rumex and Trifolium, healthy groundcover; c - Moderate grazing with evidence of trampling, dung accumulation, Rumex and thistle growth; d - Heavily grazed/degraded. Thistles and nettles dominate, surface erosion. (Summer 2018).

3.4 Reconstructing past human-environment interactions in Eurasia

The methodology in this study follows the principal that naturally accumulating sediment archives such as peat bogs and lake basins contain a stored record of long-term environmental change (Chambers 2012). These records may include changes in vegetation evidenced by distributions of plant pollen, fire history derived from charcoal influxes, as well other geomorphological processes seen in changes in sediment properties. As humans are one of the primary transformative agents within their ecological niches (Ellis et al. 2013), data from sediment archives attributed to human activity may include changes in pollen spectra indicating the clearing of forests and transition to cultivation (Gaillard 2007), geochemical and charcoal signatures of mining and smelting (Hall et al. 2016) or eutrophication of lakes as evidence of encroaching urban settlement (Lone et al. 2019). As discussed above, the environmental impacts of pastoralist ecology in Kashmir most often relate to changes in vegetation, either through the impacts of stocking herds of large herbivores in meadows or through the clearing and conversion of closed forests environments to open pasture landscapes. Animal herds may also induce erosional processes that may be detected in sediment archives.

The following review presents studies of pollen and other environmental proxies that are technically illustrative of the ways in which palaeoenvironmental data may be used to reconstruct and examine the long-term dynamics of human-environment interaction. As Kashmir sits at the boundary between a number of South and Central Asian ecological zones comprising multiple biomes, these studies have been loosely grouped geographically as temperate/continental Eurasia (including Central Asia and China) arid high Asia (Tibetan Plateau and the high Himalayas) and sub-tropical South Asia.

3.4.1 Continental Eurasia

China

Li et al. (2009) have reconstructed an environmental record from a loess-palaeosol sequence from the Guandong Basin on the North China Plain with the aim of articulating the beginnings of the human impact in the Yellow River Valley, traditionally considered the heartland of Chinese civilisation. The study aimed to synthesise pollen and micro-charcoal records with archaeological survey data as a means of modelling intensified land use patterns in the region, and to investigate the onset of the Anthropocene in China more generally. Six pollen stages were identified, beginning with arid-steppic conditions indicated by higher levels of *Artemisia* and Amaranthaceae from ca.9500-7700 BP. From 7700BP, charcoal influxes increase, argued to be the initiation of slash and burn type cultivation in the region. The authors correlate pollen Zone 3 (5500-4470 BP) with the onset of the Holocene climate optimum in northern China. During this period increases of Poaceae pollen, as well as a Polygonaceae type identified by scanning electron microscope studies as *Fagopyrum*, are argued to be a marker of cultivation strategies associated with the Yangshao Neolithic culture. *Fagopyrum* pollens are interpreted as evidence of buckwheat cultivation, the primary rainfed crop of the region, while ongoing decrease of *Artemisia* and increasing Poaceae pollens are argued to be an indicator of land clearing and intensification of cereal grasses. The study argues that other climate records indicate increasingly arid conditions following the Holocene optimum would have been favourable to the expansion of *Artemisia* types and thus an anthropogenic explanation is forwarded. Increases in charcoal influx and settlement density data are correlated with these vegetation changes to argue for intensifying land burning and usage until the end of slash and burn agriculture and stabilisation of settlements at around 2700 BP. It should be noted that the interpretation of *Fagopyrum* pollens as evidence for buckwheat cultivation is controversial due to the difficulty of discerning this pollen type beyond the genera level (Hunt et al. 2017). The Guandong Basin is far to the north of the genetic centre of origin of buckwheat in southwest China (Ohnishi 1998) and this pollen record pre-dates any archaeobotanical evidence of cultivation. These circumstances emphasise that certain elements pollen records should be interpreted cautiously and supported by other lines of evidence, particularly when examining past human-environmental interactions.

A study of magnetic stratigraphy, sediment particle size and pollen (Zhang et al. 2018) from the Luoyang Basin in central northern China examines early-mid Holocene climate change as a factor in the transition from hunting and gathering to agriculture, and subsequent human impacts on the environment. Soil magnetism and particle size indicate a stabilisation of the landscape of the basin at around 8300 BP, attributed to a reduction in earlier flood events. Vegetation communities at this time also indicate drier conditions, with broad-leaved tree taxa declining in favour of *Pinus* forests and Amaranthaceae dominating the herbaceous taxa. The formation of a large river terrace during this period allowed for the expansion of cultivation in the basin. From ca. 7500 BP, Amaranthaceae declines in favour of *Artemisia* and other Asteraceae, interpreted as indicating wetter conditions. A rapid increase in *Urtica* pollens is interpreted as evidence for human disturbance of the landscape and the beginning of systematic cultivation, correlated with the rapid increase in Yangshao Neolithic settlement density in the basin.

Central Asia & Eurasian Steppe

Three lake cores adjacent to pastoralist settlements of the Sintashta culture (Stobbe et al. 2016), in the Trans Urals region of southern Russia and northwestern Kazakhstan investigated land usage, economy and environmental impact of Bronze Age pastoralist populations in the Eurasian steppe zone. Archaeobotanical (Rühl et al. 2015) and isotopic (Motuzaite Matuzeviciute et al. 2015) evidence suggests that unlike agro-pastoral groups of southern Kazakhstan, cereal agriculture played no part in the economies of Sintashta pastoral populations. Pollen diagrams produced by Stobbe et al. (2016) indicate a warm humid climate suitable for agriculture, though the authors hypothesise that Sintashta groups rejected this possibility in favour of management of rangeland biomass. Principal component analysis (PCA) revealed *Artemisia* and *Ephedra* to be in an antagonistic relationship with *Pinus* and broad-leaved forest elements (Stobbe et al. 2016, fig.7). Though both these sets of elements are sensitive to anthropogenic disturbances, the forest taxa are indicative of closed, humid conditions, whereas *Artemisia* and *Ephedra* are markers of a drier open environment. The authors also note a negative correlation between *Artemisia* and *Ephedrea*, and taxa associated with grazing, including Poaceae, *Plantago*, and Polygonaceae types, arguing it is therefore possible to separate anthropogenic grazing impacts from climate change. Despite the presence of some ruderal plants, Stobbe et al. conclude there is little impact on the overall vegetation spectra of the sites and that region provided an ideal humid environment suitable for herding of cattle. The authors raise several models through which this environment may be maintained, though note that such a system would limit the settlement of Sintashta groups to the Trans Urals region.

Beer (2007) reconstructed vegetation and fire regimes in a number of forest zones in Kyrgyzstan through comparison between modern pollen rain and five lake and swamp records situated within *Juniperus, Juglans*, *Picea*, and mixed forests. An investigation into the anthropogenic or natural origins of *Juglans* forests indicated that walnut cultivation appears to be introduced to the region around 1000 years ago (Beer, 2007, fig.8). A sharp increase of *Juglans* in this pollen record follows large influxes of charcoal, the introduction of cereal grass pollen and ruderal herbs such as *Rumex*, *Urtica, Plantago* and cannabis types ca. 1200 BP. This record may indicate the earliest intensification of agriculture in the mountain forests of Kyrgyzstan, though archaeological evidence from adjacent regions of south eastern Kazakhstan indicate agro-pastoral activities from around the late 5th millennium BP (Doumani et al. 2015).

Shumilovskikh et al. (2016) have examined landscape evolution and human impact on the Gorgan Plain adjacent to the Alborz Mountains in northeastern Iran, based on a core dating from 6100-800 BP. Shumilovskikh et al. (2016) draw on multi-proxy evidence, including pollen, micro-charcoal, soil chemistry and magnetism, and biological macro-remains. Proxies for agriculture included pollen evidence for ruderal weeds, cultivated trees and cereal grasses while markers for pastoralism included coprophagous fungal spores and beetles, *Plantago* pollens and soil phosphorus content. The largest human impact on the landscape was found to begin around 2700 BP, coincident with a climatic amelioration indicated by expansion of *Artemisia* pollens. The archaeological record shows massive expansion of settlement and irrigation works by the Achaemenid empire following this period. The possibility of localised Neolithic settlement in the immediate vicinity of the lake was linked was indicated by charcoal influx and linked to regional aridification. An increase in pastoralism indicators is particularly marked at around 3500 BP, coincident with a Middle Bronze Age expansion of agro-pastoral activity across much of Central Asia (Frachetti 2012).

3.4.2 Arid High Asia

The anthropogenic conversion of natural landscapes to pastureland has been investigated at several sites across the Himalaya and Tibetan Plateau. Arguing that the current precipitation patterns and relict tree stands in the high Himalaya should give rise to a forest ecotope rather than the present-day dwarf shrub lands, Miehe, Miehe, & Schlütz (2009) challenge the assumption of natural treelessness in this landscape, and rather hypothesise that major deforestation was undertaken by human populations in order to sustain herds of livestock. Using an indicator species approach as described by Gaillard (2007), the study undertook a survey of current land usage and vegetation types, in order to determine what ecological values taxa in the past may have represented. Two cores were taken from Cyperaceae swamps at Shukinath, northern Pakistan (3360m ASL) and Jharkot, central Nepal (3500m ASL). The base of the Shukinath record is dated ca. 5800-2800 BP and exhibits a sharp decline in local *Pinus* pollens. Though it is unclear from the analysis whether this is the result of climate change or human activity, the expansion of open environment *Artemisia* and Poaceae following the forest decline is interpreted to be an anthropogenic suppression of forest regrowth. Despite this, ruderal and indicator taxa such as *Plantago*, *Rumex*, *Polygonum* and *Urtica* are poorly represented throughout the pollen strata (Miehe, Miehe, & Schlütz 2009, fig.6). At Jharkot a similar drastic decrease from *Pinus*/*Juniperus* forest taxa in favour of Poaceae and *Artemisia* is evident at around 5400 BP (Miehe, Miehe, & Schlütz 2009, fig.7). This period also sees the introduction of cereal-type grass pollens and may be a proxy for human presence in the region. At around 500 BP, an expansion of *Rumex* and other grazing indicators at the expense of Poaceae, including cereal pollen-types, is interpreted as an abandonment of cultivation in favour of pastoralist strategies as a response to declining climatic conditions during the Little Ice Age. Though the records from these cores are unable to untangle climate or human factors in the initial forest decline, the authors argue that the ecology of the region is able to support forests and their ongoing suppression is an anthropogenic effect.

A second study by Miehe, Miehe, Kaiser, et al. (2009) also examines the impacts of human presence on the Tibetan Plateau, one of the largest pastoral ecosystems in the world. The case study argues that as a long-term archaeological record is now established on the plateau, assumptions about the natural existence of pastures must be reconsidered in light of ongoing debates regarding the global Anthropocene. Using modern grazing ecology as an analogue for the past, Miehe et al. examine the formation of the current vegetation landscape, aiming to separate climate from human impacts through micro-charcoal, sediment and archaeological data. Influxes of *Plantago* and grazing-related weeds, as well as an increase in pollen at around 8800 BP, are interpreted as the first presence of large herbivores, though the authors note this pre-dates the earliest zooarchaeological evidence for caprids in Tibet or China by more than 5000 years. More problematically, this early date is also several thousand years prior to any archaeological or archaeobotanical evidence for the development of agro-pastoralism on the Tibetan Plateau (d'Alpoim Guedes et al. 2014) and the sediment coring site itself is geographically removed from the earliest known archaeological settlements on the eastern edges of Tibet. More secure pollen indicators for herbivore grazing increase markedly after 2000 BP (Miehe, Miehe, Kaiser, et al. 2009), though the study concludes that there is the possibility for the development of pastoralist ecology on the plateau much earlier, which may be best confirmed through new archaeological data. This difficulties with interpreting the early date for herding activity in this case study again emphasises the importance of utilising multiple, discrete lines of evidence when examining human activity in the palaeoenvironmental record.

Study of a deep water core at Tso Moriri (Leipe et al. 2014) in Ladakh reconstructs climate change through limnological, non-pollen palynomorph (NPP) and pollen data while also trying to detect human impacts through markers in the vegetation record. Pollen spectra from the core suggests that the Tso Moriri record is more reflective of regional climate change than of localised human activity, though a sharp increase in ruderal and grazing associated weeds, and coprophilous fungi are noted after 2700 BP. Leipe et al. (2014) note the expansion of meadow-type vegetation from 4500-2700 BP, which may be tentatively linked to archaeological evidence for prehistoric open sites associated with “Neolithic transhumance” (Ganjoo & Ota 2012). Earlier influxes of grass charcoals from 11kBP-4500 BP are interpreted as evidence for increased monsoon-related lightning strikes in the lower Himalayan regions, with their long distance delivery also resulting from strengthened ISM convection. Changes in algal richness from Tso Moriri after 4500 BP have been interpreted as evidence for the onset of aridification, which Leipe et al. correlate with other studies arguing that increasing aridity was a driver for the urbanisation and agricultural diversification of the Harappan civilisation in the northern regions of the South Asian subcontinent.

3.4.3 South Asian Subcontinent

A growing body of palaeoclimatic records from the northern regions of India and Pakistan (Dixit et al. 2018, Giosan et al. 2018, Petrie et al. 2017, Prasad et al. 2014, Raj et al. 2015, Giosan et al. 2012) have focussed on the so called “climate-culture” relationship wherein shifting relations between the Indian Summer Monsoon and Western Disturbances influenced economic and settlement strategies of past populations as a response to fluctuations in precipitation regimes. Much of this body of study has examined the shifts between the pre-urban, urban and post-urban phases of the Harappan civilisation between ca. 3000-1700 BC as responses to either optimal or deteriorating climate conditions (Madella & Fuller 2006).

Petrie et al. (2017) stress in particular the need for palaeoecological records proximal to archaeological sites being studied and close chronological integration of environmental and archaeological data. The point regarding proximity of palaeo-records to archaeological sites is important, as much of the discussion of sociol-ecological change in northern South Asia draws on Arabian Sea cores for the reconstruction of regional palaeoclimate, particularly examining the precipitation fluctuations in marine records (Giesche et al. 2019, Giosan et al. 2018, Giosan et al. 2012). These studies primarily examine the correlation between weakening ISM and westerly precipitation and changes in Harappan urbanisations, agriculture and settlement patterns. These relationships have been described as a “push-pull” type by Giosan et al. (2012, 2018) who compare settlement and geomorphological data with coastal cores reconstructing winter precipitation patterns through genetic and planktonic proxies. These studies argue that strengthening winter precipitation led to the reorganisation of Harappan settlements from large complex centres to diverse regional/rural settlements, driving populations to areas of higher winter water availability and adapting summer/winter cropping patterns or forms of mobile agro-pastoralism better suited to new ecological conditions.

Drawing on geomorphic, settlement and archaeobotanical data from the Ghaggar-Hakra river system, Petrie et al. (2017) note similar processes of adaptation, though caution against overly simplistic explanations, arguing that diverse Harappan affiliated populations may have already adapted or had the means to adapt to localised environmental niches prior to urbanisation. This study compares archaeological, archaeobotanical and spatial data with terrestrial lake records in Haryana (Dixit et al. 2015, Dixit et al. 2014) to argue that while regional climate change may have weakened summer and winter precipitation patterns, the timing and environmental impacts of these changes were non-uniform. This non-uniformity can be linked to variations in the archaeological record that take into account more localised ecologies.

Localised changes have also been examined among isotopic and palaeobotanical data from Khirsara in Gujarat (Pokharia, Agnihotri, et al. 2017) argued to be reflective of aridity driven selection of certain millets over winter crops. This process becomes more marked after a sharp shift in carbon isotope fractionation, interpreted as evidence of the 4.2K arid event at the site. Also in Gujarat, multi-proxy studies (Raj et al. 2015, Prasad et al. 2014) drawing variously on palynological, phytolith, isotope, magnetic and geochemical data from Gujarat have reconstructed shifting patterns of summer/winter precipitation in the region, indicating an onset of drier conditions at around 5000 BP as a possible driver of urbanisation and systems of agriculture in the region.

3.4.4 Distinguishing climate change from anthropogenic impacts

The reconstruction of vegetation communities using fossil pollen records is confounded by a number of factors including the relative pollen productivity of different plant taxa, the source area of plant pollen for the sampling site and pollen settling velocities, causing some taxa in the environment to be absent from the record and overrepresentation of others (Sugita 1994). Further complexity arises from issues such as the way that anthropogenic landcover change can also be a forcing factor for climate change (Gaillard et al. 2015), thus feedback loops between human activity, environmental variability and climate in pollen records can be very difficult to disentangle. These complications can also occur across proxies, as seen in debates as to whether variability in charcoal influx were a result of climate-driven change in fire regime, or of climate-driven vegetation change where the expansion of pyrophytic or fire tolerant plant communities then drove higher burning intensity in the landscape (McGlone et al. 2012). With specific reference to environmental change in mountain environments, Tinner & Ammann (2005) have stressed the need for independent non-biotic environmental records, as well as the use of multiple biotic proxies in order to avoid circuitous arguments.

The use of multiple biotic proxies is based on the assumption that one or several variables within the data set are indicative of broader climate or environmental changes, while other variables are interpreted as responding to these changes (Birks et al. 2010). Ideally, validation of variation in indicator types can be compared across records from the same region. For the Kashmir Valley, the only robust biotic records may be diatom studies from the Wular (Shah 2019) and Manasbal (Babeesh et al. 2019) lakes, however, these examples as well as the record from Anchar Lake (Lone et al. 2019) also provide a good record of environmental change through non-biotic (sedimentary, geochemical, magnetic) proxies. Additional non-biotic proxies of regional precipitation and water availability are available from oxygen and carbon isotope data from speleothems in Central Asian (Wolff et al. 2017) and Himalayan (Kathayat et al. 2017, Kotlia et al. 2015) caves. Boreal spring precipitation has also been reconstructed across the Western Himalaya for the past millennium through tree ring data (Yadava et al. 2016). Comparison between these records and palaeoenvironmental data in this study may help to understand the biotic responses to environmental change around the study sites.

As this study is ultimately oriented towards answering *archaeological questions* using environmental records, a more qualitative interpretation of the data may be suitable. Ideally, this approach would draw on several sampling sites across the landscape, where changes in variables indicative of human activity may be verified against one another (Edwards et al. 2015). The case studies above as well as the prior review of grazing impacts have identified a number of plant taxa, changes in sediment properties and fungal spores that may be indicative of pastoralist land use in Kashmir. While some of these may be sensitive to climate or other environmental changes, co-variation of multiple indicators would likely be indicative of anthropogenic impacts rather than climate factors.

In the studies above, this approach appears most effective when sites were selected specifically to answer questions about localised human impact in the landscape, as in the Chinese (Zhang et al. 2018) and Eurasian steppe (Stobbe et al. 2016) cases. These may be contrasted with the records from the northern subcontinent, where a higher number of multi-proxy regional climate records has allowed for more systematic environmental reconstruction. When compared with an expanded archaeological record comprising a large number of urban and rural sites this has generally directed research questions towards the role of climate change in broader historical processes. The approach taken in this study is that the pastoralist landscapes on the mountain flanks of the Kashmir Valley are a composite of cultural and natural features, comprising a number of niches of more concentrated agro-pastoralist activity. Coring of suitable deposits within these niches has the potential to reconstruct their environmental history and examine these spaces in the landscape to be in some way *archaeological sites* themselves. The following chapter outlines field-sampling protocols and provides a description of the sites in the study.

Chapter 4 Fieldwork sites and methods

4.1 Overview of field program

This chapter describes the methods undertaken to select and sample sites for palaeoecological reconstructions of upland pastoralist land use in Kashmir. Fieldwork took place over two seasons, April-May 2017 and May-June 2018, once spring snow melts had cleared access to higher mountain pastures. Three districts in the Kashmir Valley were selected: Budgam to the west of the capital Srinagar, encompassing a number of high pastures on the Pir Panjal flank; Baramulla in the northwest of the valley; and Anantnag to the southeast of Srinagar, also containing a number of middle and high altitude pastures on the Himalayan flank (Figure 4.1). All fieldwork was carried out in collaboration with Dr. Mumtaz Yatoo from the Centre for Central Asian Studies at the University of Kashmir, Srinagar.

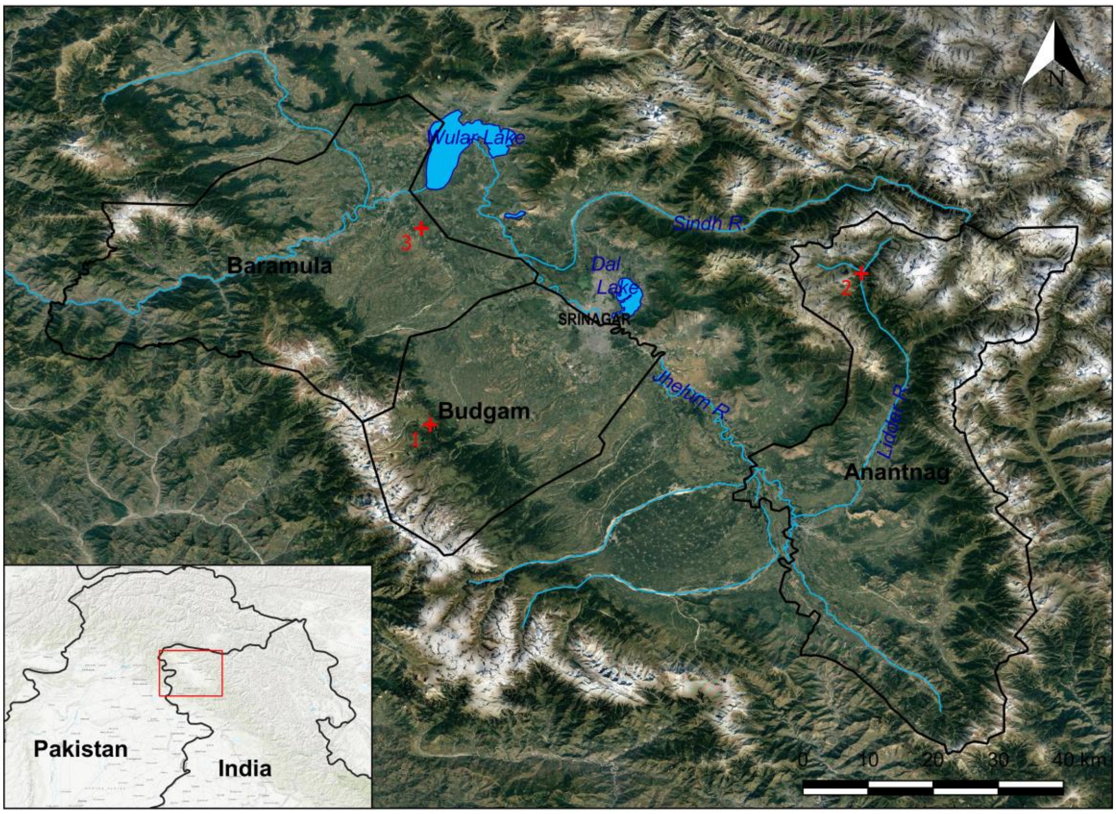

Figure 4.1: Districts of Kashmir where fieldwork was undertaken and localised study areas. 1. Pastures around Doodpathri; 2. Hygam Lake; 3. Pastures around Aru Valley/Pahalgam. (Basemap source: Google Satellite Tiles plugin for QGIS)

Pollen core samples from forest hollows are often suitable for providing stand-scale vegetation histories, whereas small- to medium sized lakes and mires have pollen catchments that generally represent regional scale vegetation communities, covering up to several hundred square kilometres (Seppä 2007). Distinguishing between cultural and non-cultural pollen sampling, Pearsall (2015) states that sampling from either archaeological contexts, or lake or swamp margins, are generally most suitable for examining human-induced changes to pollen spectra, while medium-sized lakes (~5000m^2) are best suited for regional environmental signatures (Sugita 2007a, Faegri et al. 2007).

As emphasised in the previous chapter, this study considers pastoralist landscapes to be mosaics of natural and cultural features where multiple sites of human activity take place. Within this landscape, niches enriched or otherwise impacted by grazing or other pastoralist activities may be considered individual “sites”. By sampling of suitable sediment deposits with relatively small catchment size adjacent to or within these foci of activity, the study aimed to reconstruct both natural and human-induced processes local to the sites. These could then be compared with more regional records of past environmental change.

Obtaining regional records was the primary aim of the 2017 fieldwork which targeted Hygam Lake in Baramulla District, and Nilnag lake in Budgam District. The equipment chosen for this work was an improvised percussion coring device that was made in Srinagar, comprising a heavy steel slide hammer and a steel clamp with striking platform, manufactured to suit locally available plumbing pipe (Figure 4.2). This equipment was used to drive a ø75mm sharpened PVC pipe fitted with a rubber piston into lake sediments and retrieve cores without sediment slipping. During the course of this fieldwork, opportunistic sampling of non-lake sediments was also undertaken at Pari Has and Kunzarji-Sar using this equipment.

Figure 4.2: a) Striking platform; b) slide hammer used in percussion coring.

Fieldwork in 2018 aimed to more systematically sample mires from pasture zones at various altitudes on the east and west flanks of the Kashmir Valley. For this purpose, a D-section peat corer manufactured by Dormer Australia was selected as the most suitable sampling equipment (chamber ø50mm; chamber length 500mm). Samples were taken in 50cm intervals, across 2 parallel holes less than 1m apart with a minimum 10cm overlap. An example of this is given in Table 4.1. Following recovery, samples were placed into split PVC plumbing tubes, with preliminary sedimentary descriptions logged and photographed in-field before being wrapped in heavy duty plastic for transportation. Drawbacks of this method include the inability to drive the sampler through heavily compacted sediments.

Sample #	Depth range (cm)
1.1	0-50
2.1	40-90
1.2	80-130
2.2	120-170
1.3	160-210
2.3	200-250

Table 4.1: Example of sampling intervals using D-section method.

Sites in the mountain areas were selected based on a combination of elements, including the reported presence of suitable deposits (e.g. in Agrawal 1992), current and historical utilisation of these areas by pastoralist groups (Casimir & Rao 1985) or the potential to re-test and build upon past preliminary environmental studies (e.g. Singh 1963). Fieldwork was also influenced by other logistical factors such as the physical and political accessibility of pastures, particularly on the Pir Panjal flank close to the military Line Of Control. The majority of sampling sites in mountain pastures were located through extensive walking survey, following topography indicating the likelihood of accumulation of suitable deposits. Features in the archaeological or cultural landscape indicating long-term settlement or human ecology in these areas helped to narrow down survey zones and any archaeological features were also recorded as part of the survey. Several other sampling sites were directly targeted based upon the advice of local Kashmiri or Gujjar pastoralists who described long-standing swamps or mires located in or close to grazing meadows. The sites are described on a district by district basis and full spatial information is provided at the end of the chapter in Table 4.2, Table 4.3 and Figure 4.20.

4.2 Budgam District

Budgam lies to the west of Srinagar, encompassing an area of 1291km^2 on the Pir Panjal flank (Rashid et al. 2011). The district contains a varied topography, from the Jhelum alluvial zone to high peaks. A large number of relict flat top karewas are in the district, though as yet there has been no systematic archaeological survey of these features. A number of large, well-known meadows in alpine and sub-alpine zones including Doodhpathri, Yusmarg and Tosa Maidan have been traditional areas of grazing utilisation during pastoralist seasonal migrations, and more recently have been promoted as tourist attractions. Below the tree line, these meadows are interspersed through conifer forests. From a number of these meadows, it is possible to pass through the Pir Panjal and into Poonch and other areas to the west. At some larger pastures such as Yusmarg, Gujjar pastoralists build semi-permanent villages as a base for herding to higher altitudes, while part of the community engages in cultivation of maize and other crops as well as guiding and trekking in the tourism industry. Also within the mountainous areas of the district, agricultural villages are present up to an altitude of around 2300m ASL. Kashmiri farmers in these villages generally engage in a mixture of horticulture, cultivation of summer vegetables and cereal, as well as transhumant herding to higher pastures throughout the district. During the course of fieldwork in 2018, a large Kushan site was located on a Karewa behind one of these villages, Ashrat Nard (lat. 33.876481/lon. 74.641099 Decimal Degrees; ca.2265m ASL) with evidence of substantial architectural remains (Figure 4.3).

Figure 4.3: Kushan structural remains at Ashrat Nard.

The program of environmental coring in Budgam aimed to sample a number of deposits near or in these meadows, at various altitudes. Most of the sites sampled are along a roughly north-south linear transect running between Tosa Maidan and Nilnag lake (Figure 4.4), though due to the extensive nature of field survey there was some deviation. Survey along the transect was extensive and discontinuous, with targeting of sections that were logistically accessible and likely to have deposits suitable for sampling.

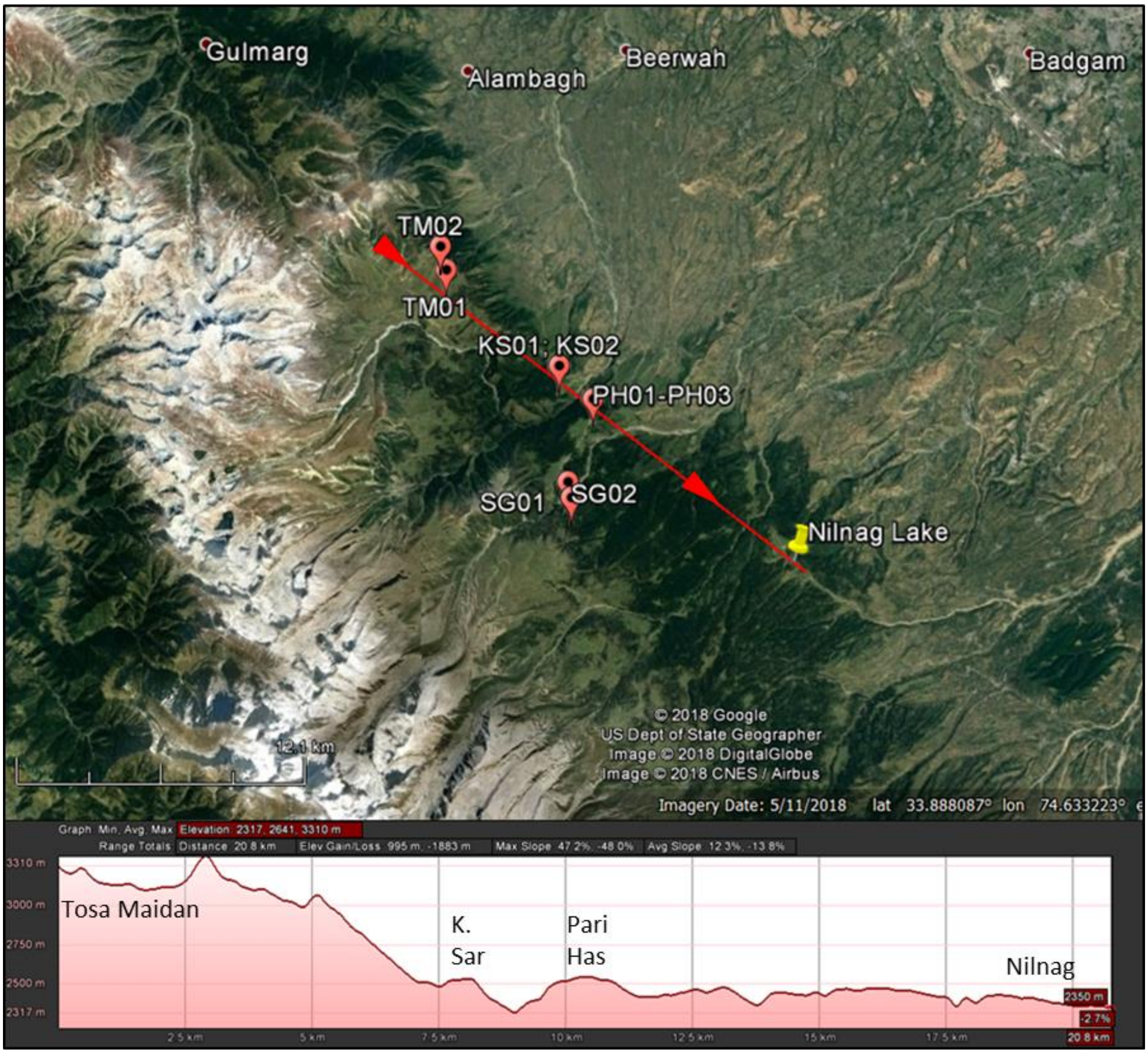

Figure 4.4: Survey transect (in red), location of core samples and slope profile of transect, Budgam District (modified from Google Earth Pro).

4.2.1 Pari Has

Pari Has is a peat mire located in a basin in the Doodhpathri area, situated at around 2600m ASL. Sediment accumulation at the site takes place through downslope in-wash from a series of slopes and terraces to the west and south. A series of low undulating rises have impounded drainage, leading to the development of swampy conditions though some outwash takes place through a gentle stream flowing to the northeast of the swamp (Figure 4.5) The sharpest slope to the west rises to a modern road and an expansive meadow area known as Danger Pora, currently under heavy grazing as well as recreational usage. The area is typically inaccessible in winter, however, there are small, semi-permanent settlements throughout the Doodhpathri area where pastoralists reside during summer as a base for herding as well as secondary economic activities such as small scale forestry.

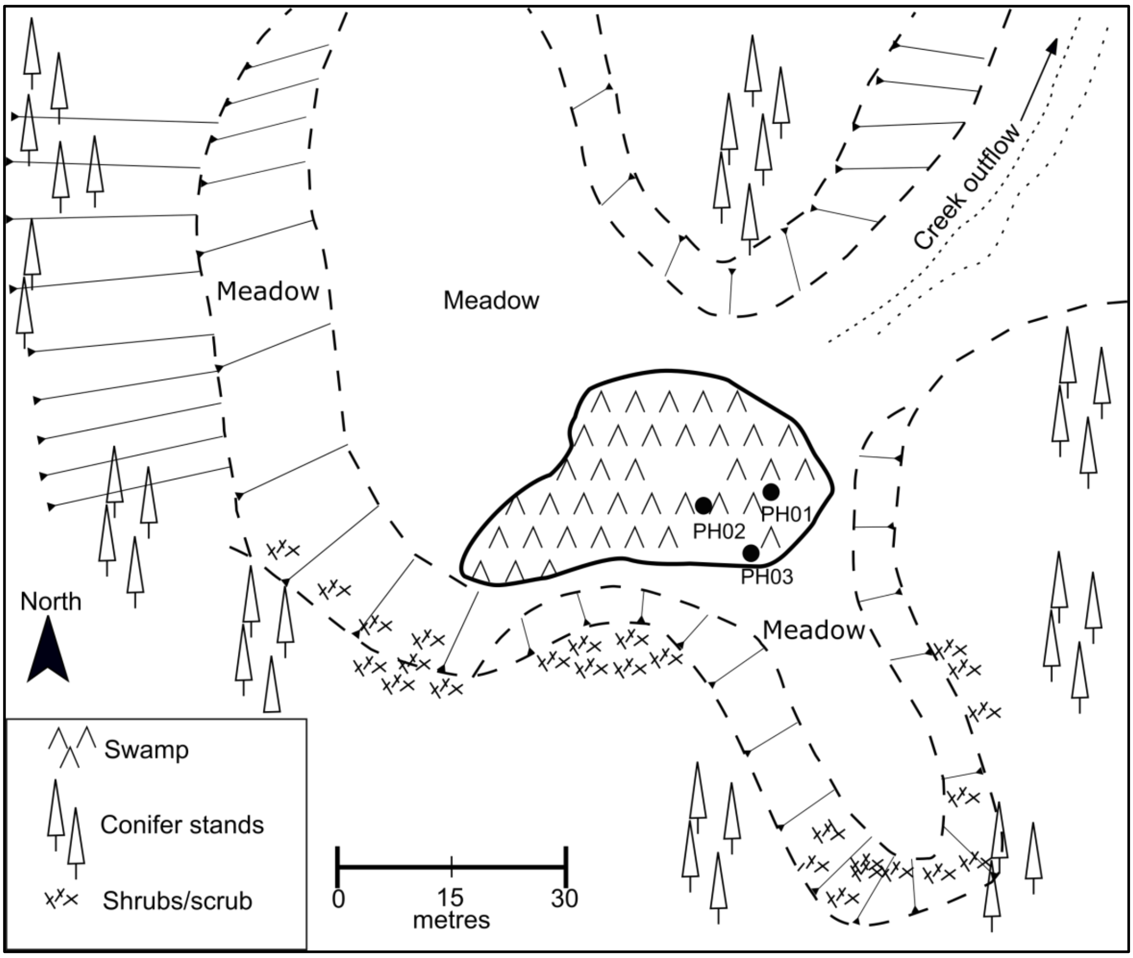

Figure 4.5: Sketch of topography, coring locations and physical features at Pari Has.

The southern and western slopes are currently wooded with dispersed *Abies* stands, with clearings colonised by *Viburnum* and *Sambucus* shrubs (Figure 4.6a). Herbaceous ground cover comprises grasses, sedges, *Trifolium* and *Potentilla* mats, along with other meadow vegetation including various Asteraceae and Polygonaceae types. These meadow areas were subject to moderate to heavy grazing at the time of fieldwork with the exclusion of a fenced area to the east, allowing for a comparison between grazed and ungrazed areas. Vegetation in areas heavily disturbed by humans, animals or tree roots include thistle, nettle, agrimony and *Plantago* (Figure 4.6c).

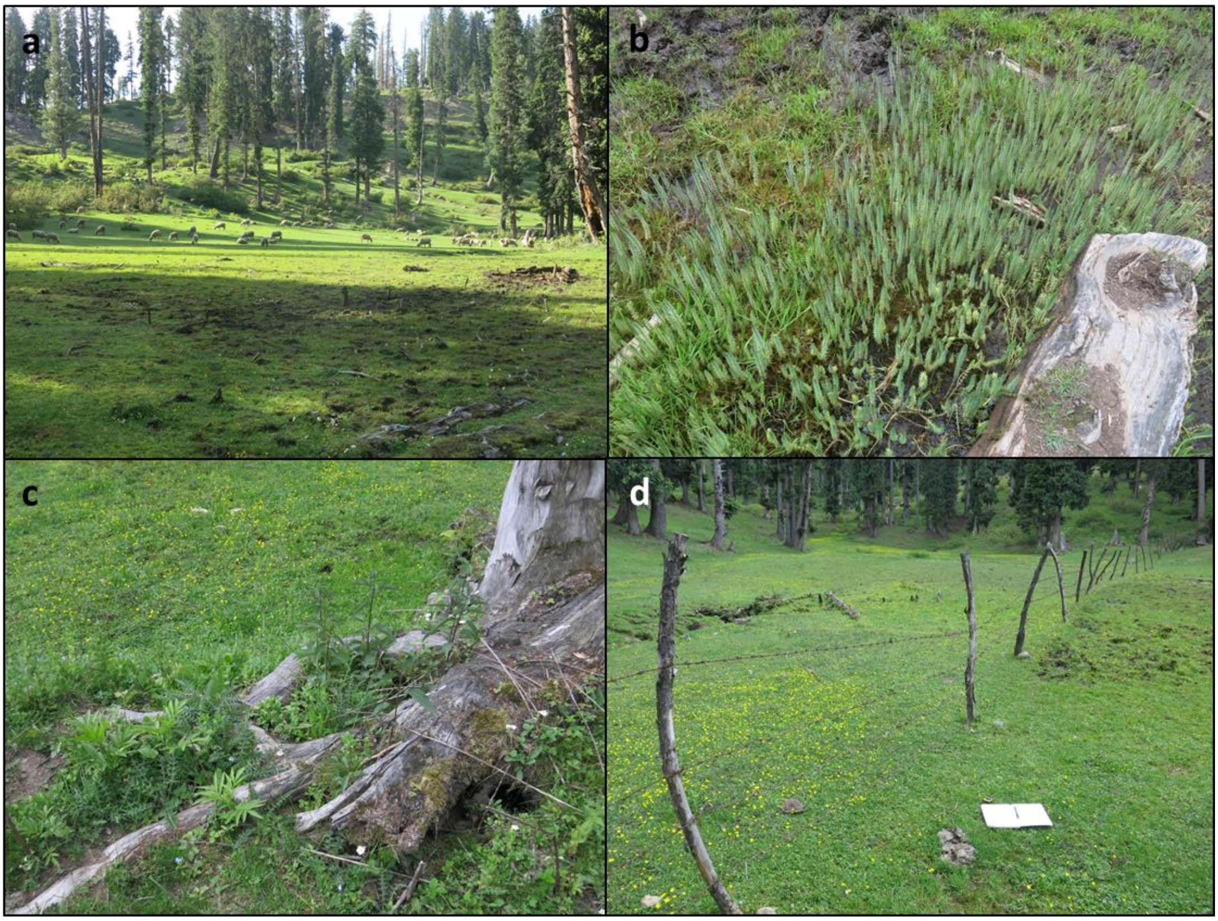

Figure 4.6: Pari Has site and surrounds: a) swamp (foreground) - view to west of Abies stands and associated shrubs; b) Myriophyllum aquatics at centre of swamp, summer high water stand 2018; c) assorted weeds; d) ungrazed (left) and grazed (right) meadow areas.

The profile of the adjacent slopes appears to be typical Karewa soils and the presence of large morainic boulders at slightly lower elevations 1-2 kilometres to the south and north of the site indicate sedimentation in the basin as likely occurring since the last glacial retreat in Kashmir. This topography influenced the selection of the site as the basin appeared to be a slow forming post-glacial accumulation with little high-energy outwash and thus suitable for reconstruction of Holocene land use.

Two cores, PH01 and PH02, were sampled at the site in April 2017 by slightly adapting the percussion coring method. These samples were each driven to a depth of 2 metres, though due to compression of the organic rich sediments, the overall length of samples retrieved was 1.2 metres. Based on preliminary results indicating an age of basal depth of PH01 at around 2100 BP, the site was targeted for deeper sampling with the D-section peat corer in May 2018, closer to the margin of the swamp. A succession of peat-clay-peat-clay beddings were noted, and sampling was undertaken to a depth of 3.55m, where a compact grey-blue clay was resistant to further coring.

4.2.2 Tosa Maidan

Tosa Maidan is a large sub-alpine meadow at around 3100m ASL, within a glacially ground basin. Preliminary works on post-glacial vegetation successions were undertaken by Gurdip Singh (1963), with a poorly resolved sequence beginning around 18000 (Singh & Agrawal 1976). The basin is ringed by high Pir Panjal peaks to the west, with lower rising slopes to the north and south. The northeastern side of Tosa Maidan rises steeply before falling away more sharply towards the Kashmir Valley basin (Figure 4.7a&b). The Sokhnag river flows into the basin from peaks to the south before turning and flowing east, with several streams across the meadow draining into the river. The slopes surrounding the basin are covered in *Abies-Cedrus* stands that are currently extensively logged towards the east. Some areas of sub-alpine *Juniperus* scrub were also observed. Open area land cover is typical meadow vegetation, including various Poaceae, Asteraceae and Polygonaceae types (Figure 4.7c) subject to moderate grazing when the area was visited in the summer of 2018. Between 1964 and 2014, Tosa Maidan was used as a military encampment and artillery training zone, and numerous shell craters were still visible across the meadow and adjacent slopes. Despite this, locals advised that the area has long been an important summer pasture and it was also reportedly used by the Mughals during seasonal movements between summer and winter palaces in Srinagar and Poonch (Singh 1963).

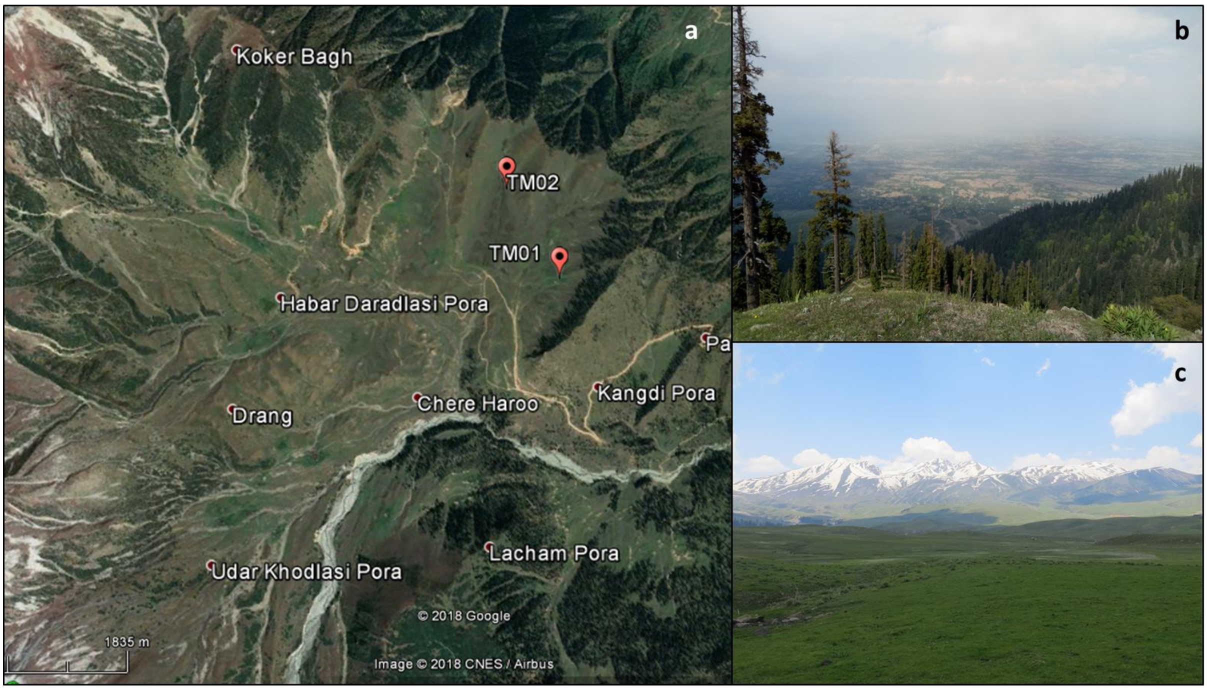

Figure 4.7: Tosa Maidan: a) basin and coring sites; b) view of Kashmir Valley to northeast; c) meadow expanse, west from TM01. (Image a from Google Earth Pro.)

Singh (1963) sampled three cores from mires, “B”, “W” and “T”, of which the mire-T sample was the deepest at 4.15 metres at mid-slope on the basin margins where outwash of sediments would be minimised. Bedding of this sample consisted of 2m of peat, followed by around 2m of mud and clay before reaching a gravel bed. Based on this description one fieldwork task in 2018 was to attempt to relocate and resample mire-T, in order to resolve issues relating to chronology and methodology (see discussion in section 2.2). Due to the poor quality of Singh’s maps, the specific site was unable to be located despite extensive walking survey of the general area indicated and advice from local herders. As a result, two new sites were selected for sampling.

Site TM01 is a marshy area on the southern flank of the basin, on a terrace below fir-covered slopes. Sediments appear to accumulate gently, in-washed from the slopes above and slowly outflowing to the floor of the basin to the southwest (Figure 4.8) . D-section coring was undertaken, reaching a depth of 130cm, where a compact clastic bedding was impassable. In-field recording noted a succession of peat and humified mud layers before reaching a lower clay bedding. By comparing with lithology described by Singh (1963) as well as the AMS dates from mire-T (Singh & Agrawal 1976), it was assumed that the TM01 sample covered a reasonably long Holocene sequence.

Figure 4.8: Coring at TM01, view to northeast.

A second site, TM02, was sampled about 1km to the north of TM01. This site was selected based on its position on a marshy terrace adjacent to a medium-sized stream. The sampling area was situated in a gully assumed to be formed by fluvial action, which may allow for older sediments to be reached below the current marshy accumulation. A depth of 90cm was reached, with marshy topsoil to around 15cm, followed by a 20cm thick grey clay bedding. The lowest layer consisted of a yellow grey clay, and coring was halted based on increasing resistance and the presence of gravels at around 80cm.

4.2.3 Shali Ganga

A second pair of cores for the Doodhpathri area were sampled on the south bank of the Shali Ganga river, around 4km south of Pari Has. The first site SG01 was selected on a terrace above the river flood plain, at around 2800 mASL, where several marshy deposits gently drained into the main river body. The terrace was situated within an eroded basin around 30m deep, with a stratified loess-palaeosol sequence visible in a section to the east. A test core SG01 was taken to a depth of 90cm, on a builtup marshy terrace on the eastern side of the basin. Poorly sorted, medium to large angular gravels from a depth of around 40cm and a sandy clay soil matrix indicated that the basin was likely formed by high-energy downwash into the Shali Ganga, rather than slow accumulation following glacial retreat. This appeared to be confirmed through observation of mobile and poorly sorted gravels and coarse sand-size sediments in streams at the western edge of the basin.

Based on advice of local herders a number of pastures situated within the forested areas at the top of the ridge contained swampy areas or *daldal*, which may have been suitable for coring. Subsequent survey following creek lines and vegetation features allowed for the location of a builtup swampy area within a grazed meadow, 700m to the south of the SG01 coring site at 2870m ASL. The site is situated in a gently undulating meadow, ringed by hill slopes with *Abies-Pinus* stands, opening out to *Viburnum* scrub then herbaceous meadow vegetation (Figure 4.9a&b). The coring site is encircled by several hummocks and appeared to be a shallow infilled basin. The area is drained gently by a small outwash flowing to the west, before turning sharply to the north.

Figure 4.9: SG02: a)hummocks around mire; b)sampling site; c)blue-grey unoxidised clay at lowest sample depths.

The site was designated SG02 and coring was undertaken following the above method. A total of only three subsections were retrieved to a depth of 1.15m. A heavily compacted blue gleysol type clay (Figure 4.9c) beginning at a depth of around 1m impeded any further coring. The general sediment bedding observed was humified mud deposit to around 20cm, followed by an organic-rich brown-grey clay, with darkness and compaction increasing with depth to around 1m, where a sharp boundary with the blue clay was observed. Due to oxidisation of the samples following their extraction, the blue colour of this bedding plane had already been lost on exposed surfaces prior to transportation of samples to Australia.

4.2.4 Kunzarji-Sar

This site was located in 2017 during an extensive survey trek beginning at the village of Arizal and heading through various farming, forest and grazing areas in the direction of Tosa Maidan. In the process of the survey, local herders provided information about the position of a small lake situated in a basin above several expansive terraces used for moderate to intensive grazing. After locating the site, it was evident that recent landslips had led to a breach in the hummocks that had previously impounded drainage of the lake, leading to an outflow of water and sediment. Shepherds in the area stated that this had taken place in the last two to three years, however, a later review of historic satellite imagery in Google Earth to 2001 shows little evidence for a major water body.

The site is located at 2500 m ASL, in a basin about 20m below a ridgeline forested with mixed coniferous stands (Figure 4.10). Below the site are three open grazing areas, on a series of descending terraces at 20-30m intervals. Though the lake had mostly drained, an area of shallow standing water at the southwestern side of the basin was still present. Topography of the site seemed to indicate that the lake was fairly shallow, with a small area of 1.5km^2, however the *-Sar* suffix seems to indicate a water body of some local significance.

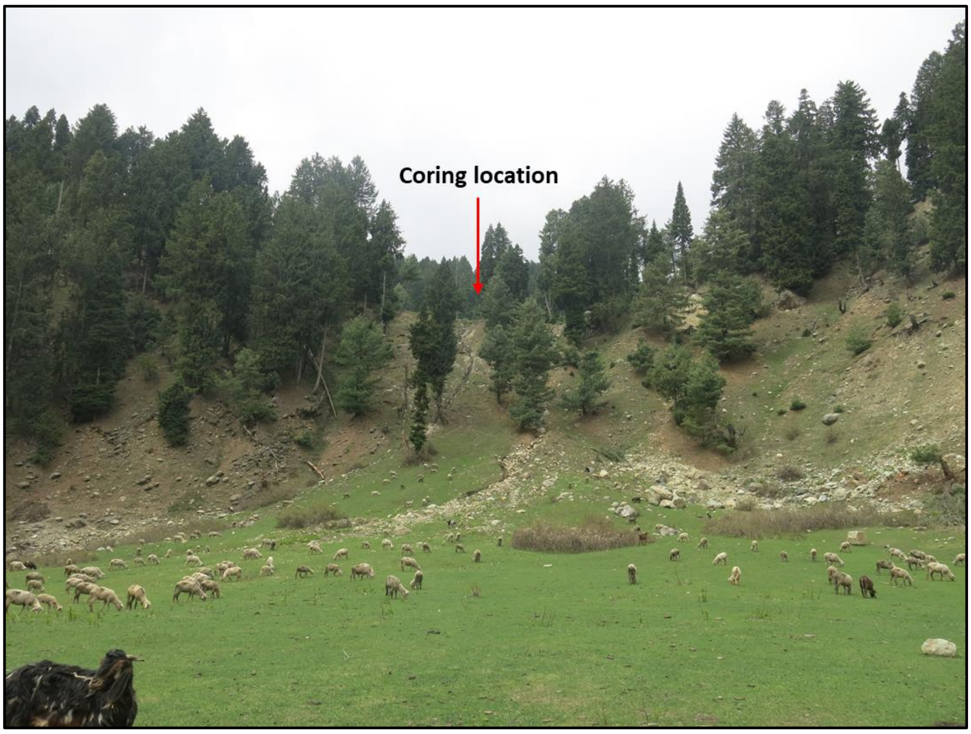

Figure 4.10: Meadow below Kunzarji-Sar, view towards "lake" basin.

As equipment taken on this survey was intended for lake sampling rather than swamp deposits, the western side of the basin was selected for coring using the percussion coring technique. Top sediments at the sampling area were recently in-washed, unconsolidated Karewa soils, and working platforms quickly sank below the surface (Figure 4.11a). Core KS01 was sunk to a depth of 1.9m, and issues with severe compression were immediately apparent. Sampled sediments were extruded, revealing a viscous black organic deposit (Figure 4.11b), compressed to only 40cm thick. Core KS02 was then sunk closer to the water margins, to a depth of 1.4m. Again compression was an issue, though less pronounced, with the total length of sample being 50cm.

Figure 4.11 a) Coring at Kunsarji-Sar; b) extruded sample from KS01.

Though KS02 was transported to the University of Sydney, better study potential at the site may be attained through other methods, such as more suitable coring equipment, to sample the former lake margins.

4.2.5 Nilnag

Located several kilometres from Yusmarg, a large summer pasture with semi-permanent Gujjar nomad settlements, Nilnag is a lake around 12ha in surface area. Believed to be of pre-glacial age (Zutshi et al., 1980), the lake has a summer high stand, filled primarily by snow melt and precipitation only. At 2400m ASL the lake is situated between areas of natural *Pinus-Abies* forest, upland cultivation and pasture zones. Because of this position, Nilnag was a targeted site which may have provided a record of wide-scale ecological change along the Pir Panjal flank and adjacent foothill zones. Historic satellite images in Google Earth indicated the construction of a dam at the south eastern end of the lake in recent years (Figure 4.12), there appeared to be little other impact to the lake. In April 2017 a site visit to Nilnag indicated that works taking place there were much more extensive, with concrete retaining walls built at lake margins. One local advised us that in 2013-2014 the entire lake was drained in the process of dam construction to allow heavy vehicles to drive across much of the lake bed. In these areas, lacustrine sediments were dug out and levelling fills were dumped into the basin to allow for a stable working base. As there was little chance of sampling any undisturbed sediments, work at the site was abandoned.

Figure 4.12: Nilnag Lake satellite image 2014. Dam construction at south east corner (Google Earth Pro)

4.3 Anantnag District

Anantnag is a large district in the southeast of the Kashmir Valley, encompassing cities and agricultural areas on the valley floor as well as Himalayan foothill, upland and massif zones (Figure 4.1). Anantnag contains one of the highest number of culturally and economically significant areas in Kashmir, including several sacred springs from which Jhelum sources flow, major passes to both Ladakh and Kishtwar, and historic urban centres at Anantnag and Bijbehara. Early historic and medieval sites include the Karkota period Martand Sun Temple and the Mughal garden at the Achinag spring. The Pahalgam area in the Lidder Valley is a significant hill station and pasture area, as well as the base for the annual pilgrimage to the Amarnath Cave, a sacred Hindu site. The Amarnath Yatra route historically linked southern Kashmir to areas of the Punjab, as well as passing up to high alpine zones around Sonmarg and on to Ladakh.

The eastern side of the Kashmir Valley has fewer suitable Quaternary age deposits where pastures could form (Agrawal, 1999; Dar et al., 2014). This arises from the fact that the Greater Himalaya has a much sharper topography than the Pir Panjal and that the uplift of Karewa sediments did not generally take place on the eastern flank. Most pastures on this side of the valley are located in side valleys, cut through by rivers or glaciers flowing down from the Himalayan. This higher energy depositional environment limited the number of areas suitable for environmental coring. Fieldwork in 2018 was undertaken in the Lidder Valley (Figure 4.13), formed by the major Jhelum tributary and containing a number of larger pastures zones including the Pahalgam area.

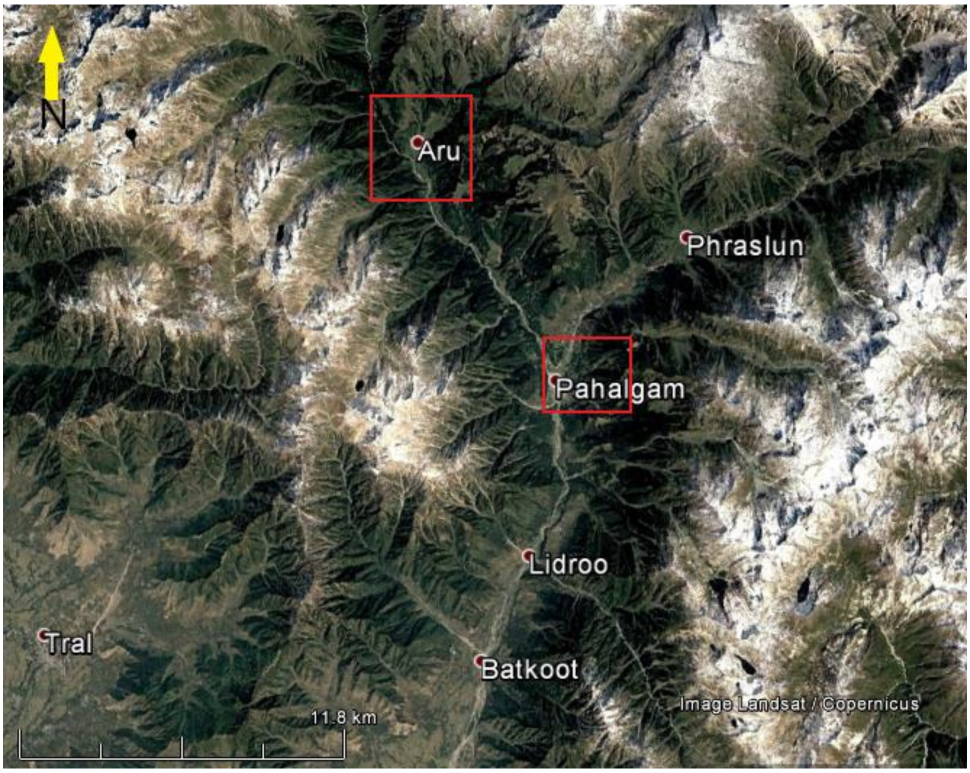

Figure 4.13: Lidder Valley, Anantnag District. Red boxes indicate survey areas (modified from Google Earth Pro)

4.3.1 Gash Angan

The Aru Valley is a narrow branch of the Lidder Valley, forking north westwards at Pahalgam town and opening up to a village and series of pastures after about 10km, sitting between 2500-2700m ASL. Walking survey was undertaken northwards from Aru village in order to locate a suitable site for coring. This survey recorded the remains of a rock-cut Buddhist shrine, large stone slabs with ground out cupules and diagnostic Kushan pottery fragments, evidence for the development of a cultural landscape beginning at least 2000 years ago (Figure 4.14c).

Gash Angan is an open meadow, 2km northwest of Aru Village at 2750m ASL (Figure 4.14 a&b). The meadow is seasonally utilised by both Kashmiri and Gujjar herders in the summer months. Surrounding forest vegetation consists of mixed conifers, with *Viburnum* shrubs on open slopes. Meadow vegetation is typically dominated by Poaceae, Asteraceae, *Rumex* and *Trifolium*.

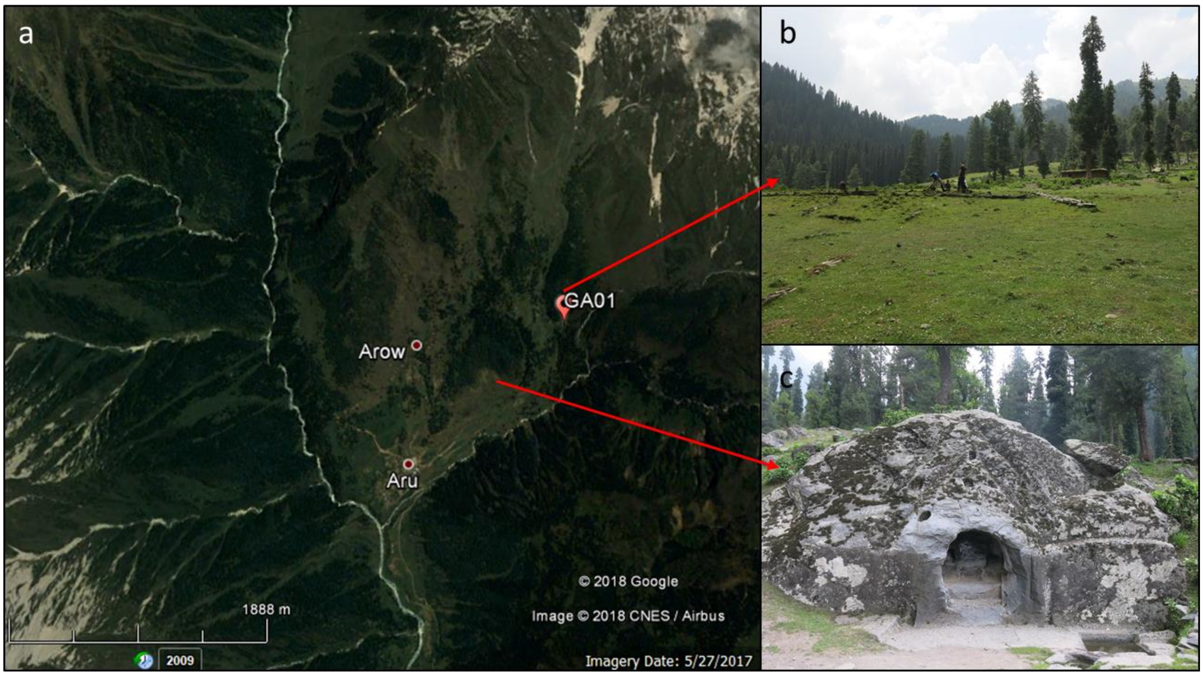

Figure 4.14: Aru Valley survey: a) position of Gash Angan in relation to Aru; b) GA01 coring site (foreground); c) Buddhist carving below Gash Angan. Red arrows indicate photo locations. (Image a from Google Earth Pro).

Because of the steep topography of the area a number of fast-flowing streams drain the meadow, joining the western branch of the Lidder above Aru. Soil deposits across the meadow are shallow and unsuitable for testing. One interfluvial terrace between two streams was selected due its apparent thickness above the water courses and the presence of a peat-like formation. Shovel pitting indicated the top of the deposit was heavily disturbed by large tree roots, and the top 20cm was dug off. Core GA01 was sampled to a depth of 110cm. Below the humified layer were a succession of clay and gravel beds, with angular gravels 10-20mm in size (Figure 4.15). Coring was abandoned due to torsioning of the sample chamber requiring repairs. As the sedimentary sequence indicated the terrace likely formed in a high-energy environment, the site was not returned to.

Figure 4.15: Gravels and loose sediment in core GA01.

4.3.2 Baisaran

Baisaran is an open meadow area on the flanks of the Pahalgam valley, around 2km southeast of Pahalgam town and situated at around 2400m ASL (Figure 4.16). A large part of the area is now fenced off as a tourist park, though the adjacent areas are still used for grazing and settlement by Gujjar nomads (Figure 4.17) As with other parts of the Lidder Valley, the area is part of a cultural landscape associated with the Amarnath Yatra. A large boulder south of the tourist zone is also held to be the tomb of a Sufi Muslim saint (Figure 4.17). Locating a site suitable for testing was difficult, due to shallow soil depths and gravel-sand-clay composition of much of the landscape. A number of marshy accumulations on slowly descending or undulating hillocks within the fenced-off tourist zone were targeted as they appeared to have formed through a more gradual deposition than other fluvial or interfluvial deposits in the area. Forest vegetation around the site are a mix of *Pinus-Cedrus-Abies* stands. Due to fencing around the tourist park preventing grazing, thick growths of Poaceae, Asteraceae and *Trifolium* dominated, while sedges also present at the sampling site. Areas of heavy grazing beyond the fence were colonised by *Rumex* and unpalatable grasses.

Figure 4.16 Position of Baisaran in relation to Pahalgam town.

Figure 4.17: Settlement features around Baisaran. Top: Gujjar houses; Bottom: Sufi tomb

Figure 4.18: BS01 coring site in foreground.

Core BS01 was sampled on a marshy sedge matted area (Figure 4.18), a mid-slope site with little evidence for outwash of sediments. Core samples were taken to a depth of 90cm and a stony bedding was reached at around 95cm. No humus formation was evident, and sediments consisted of silty clay, with high amounts of charcoal. A thin bed of sandy angular concretions was observed at around 30cm and small rounded gravels, increasing in concentration began at around 75cm.

4.4 Baramulla District

Baramulla is located in the northwest of the Kashmir valley, containing a number of significant geographic features including Wular and Hygam lakes, as well as the Jhelum gorge where the river links Kashmir to areas to the west (Figure 4.1). Extensive settlement survey has been undertaken by Yatoo (2012) providing preliminary data on long term and topographically diverse settlement in the district. The oldest dated Neolithic deposit in Kashmir is at Kanispura, on a Karewa terrace towards the west of the district (Pokharia, Mani, et al. 2017).

4.4.1 Hygam Lake

Situated on the Jhelum floodplain at around 1560m ASL, Hygam is currently a protected lake and wetland area around 50 ha in size. Locals report that the lake is typically dry in winter, before filling during the summer through overflow from the Jhelum as well as from nearby Wular Lake. A number of artificial channels also direct input from Wular to Hygam. When the area was visited in 2017, water depth towards the centre of the lake was observed to be up to 4m.

Hygam lies in close proximity to a number of Neolithic, Kushan and Early Historic sites, including Qasim Bagh (Spate et al. 2017) and ruins of the Karkota period capital at Parihaspore. Palynological testing has previously been undertaken by Vishnu-Mittre & Sharma (1966), with a 6m long core sampled at swampy areas at the lake margins. This record lacked any form of absolute dating and was interpreted as being of Neolithic age based on the presence of cereal pollens at the base of the sample. Subsequent phases were dated by comparing floral succession with Singh's (1963) Tosa Maidan record.

Two cores were sampled in April 2017, using percussion coring techniques. Marginal areas around the lake were dense with managed beds of *Typha*, used locally for the production of matting, as well as stands of poplar and willow. Rice is also cultivated in paddy fields at reclaimed margins. Rows and "passages" cleared through *Typha* beds allow for the movement of small water craft, and coring sites were selected in an open area cleared of reeds and vegetation around 300m from the lake edge (Figure 4.19). Coring was undertaken from a platform built between two small timber boats known locally as *shikara*.

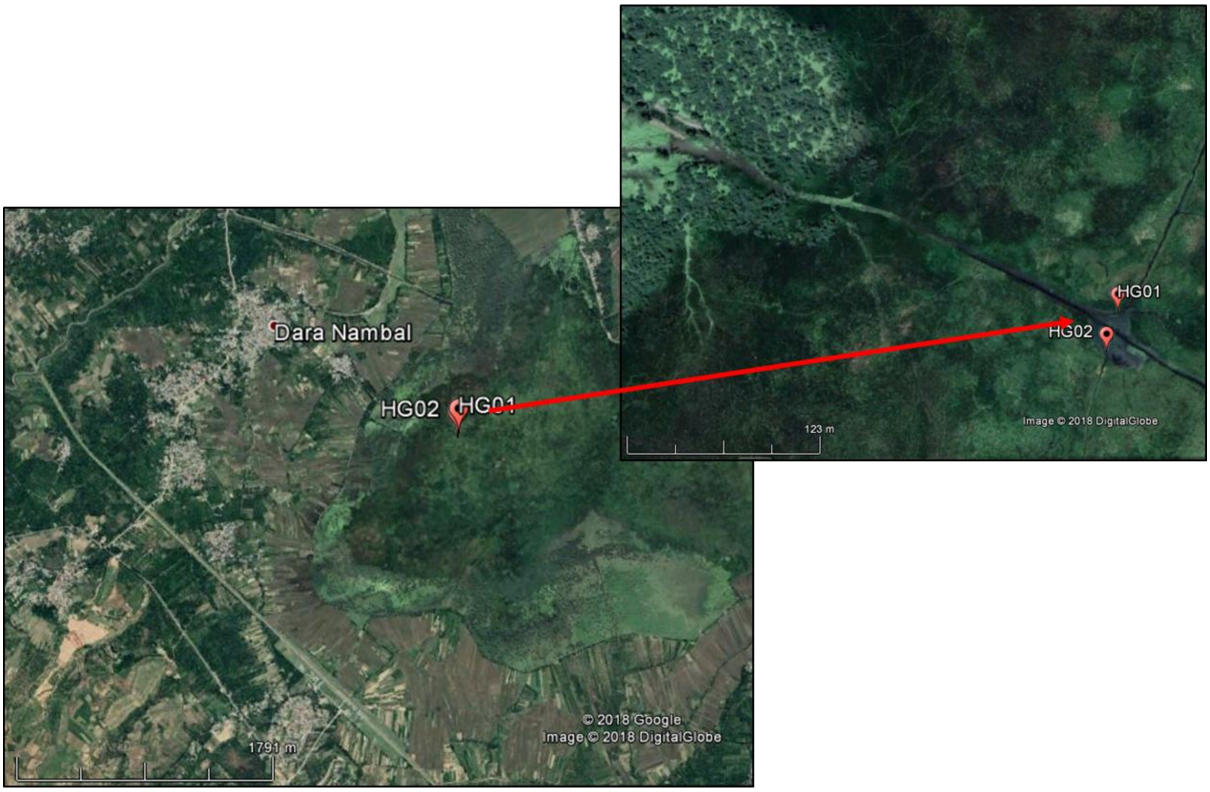

Figure 4.19: Coring locations of HG01 & HG02 at Hygam Lake.

At an area with water depth around 2m, core HG01 was sunk to a depth of 2m. After retrieval of the sample, due to either slippage or compression, the total length of the sample retrieved was 90cm. Core HG02 was sunk in an area 30m south of HG01, where water was 2.5m deep. The sample tube was driven to a depth of 2.5m, which resulted in a sample 1.35m long once compression had taken place.

The rationale for sampling at Hygam was to obtain a regionally representative sample with elements of local valley floor vegetation from the lake margins, as well as some valley-wide representation, distributed by the Jhelum discharge and Wular lake overflow into Hygam. In particular, representation of arboreal taxa in the record may provide a baseline comparison for fluctuations in forest vegetation at higher altitude and provide context as to whether these may be anthropogenically induced, or were the result of other environmental changes.

4.5 Summary

The fieldwork over two seasons succeeded in retrieving at least one sample from mountain pastures on both the Pir Panjal and Himalayan flanks of the Kashmir Valley, as well as one valley floor sample at Hygam (Figure 4.20). Though there was a large amount of geographic and topographic variation in field areas, the sites from Budgam contained the largest altitudinal spread, as well as the deepest core and deposits with the best likely potential for the study of ancient pastoralist activity. Of the 13 cores sampled during 2017 and 2018, eight were transported to the University of Sydney for laboratory study: PH01; PH03; HG02; KS02; TM01; TM02; SG02; and BS01. Due to Australian quarantine laws these samples were Gamma irradiated at 50kGy at Steritech, Wetherill Park, Sydney. Samples were stored at <4°c in the School of Geosciences cool room at the University of Sydney. The remaining cores were stored at the University of Kashmir, with the exception of KS01, extruded and discarded in field. Details for all 2017 cores are recorded in Table 4.2, and details for 2018 cores are recorded in Table 4.3.

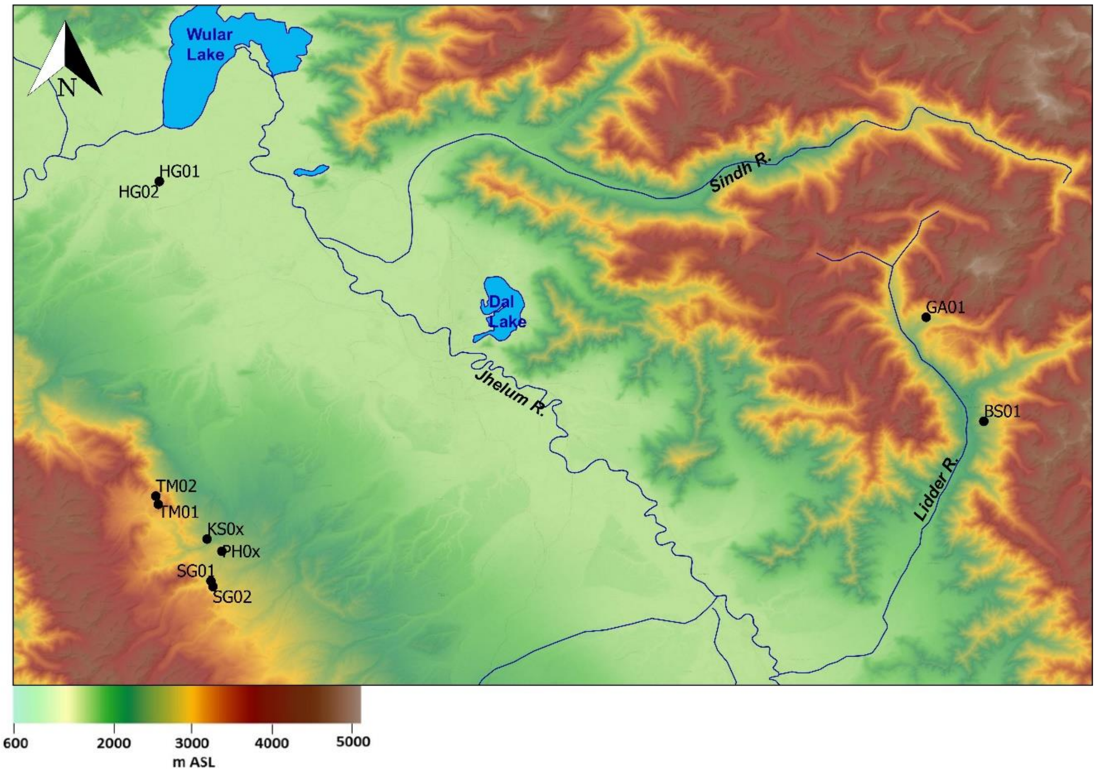

Figure 4.20: Elevation model and map of all sampled sites across Kashmir Valley (DEM raster source: National Remote Sensing Centre/Indian Space Research Organisation).

Table 4.2:2017 fieldwork cores (percussion sampled)

Site/Core	Coordinates (lat./long. decimal degrees, WGS84)	Altitude (m ASL)	Depth below surface(m)	Compressed sample length (m)	Notes
Pari Has					
PH01	33.874815/ 74.581565	2600	2	1.2	-
PH02	33.874805/ 74.581551	2600	1.8	1	Reserved at University of Kashmir
Hygam					
HG01	34.240004/ 74.519860	1580	2	0.9	Water depth 2m; Reserved at University of Kashmir
HG02	34.239782/ 74.519851	1580	2.5	1.35	Water depth 2.4m
Kunzarji-Sar					
KS01	33.886883/ 74.566879	2550	1.9	0.6	Sample extruded onsite
KS02	33.886874/ 74.566827	2550	1.7	0.5	-

Table 4.3: 2018 fieldwork cores (D-section sampled).

Site/core	Coordinates (lat./long. decimal degrees, WGS84)	Altitude (m ASL)	Depth (m)	Notes
Pari Has				
PH03	33.874805/ 74.581588	2600	3.55	9 sample sections (PH03 1.1 – PH03 1.5)
Tosa Maidan				
TM01	33.921172/ 74.518802	3150	1.3	3 sample sections (TM01 1.1 – TM01 1.2)
TM02	33.929292/ 74.516394	3100	0.9	2 sample sections (TM02 1.2 & TM02 2.1)
Shali Ganga				
SG01	33.845456/ 74.570739	2800	0.9	Samples rejected in field
SG02	33.839948/ 74.572713	2880	1.15	3 sample sections (SG02 1.1 – SG02 1.2)
Gash Angan				
GA01	34.105818/ 75.276648	2700	0.9	Samples rejected in field
Baisaran				
BS01	34.003094/ 75.333530	2450	0.9	2 sample sections (BS01 1.1 & BS01 2.1)

Chapter 5 Laboratory methods, quantification and interpretive framework

5.1 Introduction

This chapter presents the methods used to generate, analyse and interpret environmental proxy data from the sampled sediment cores described in Chapter 4. The methods are presented in the order that they are followed in the laboratory, beginning with non- or minimally destructive techniques such as the initial logging process, AMS dating and age-depth modelling and magnetic susceptibility. While AMS dating requires the destructive testing of small samples, this was undertaken early on in the analysis of the sediment cores in order to establish base chronologies to help direct the sampling resolution of later analysis methods. These included more destructive forms of sediment particle size measurement as well as the extraction of charcoal and palynomorphs from the samples. Each of these data types may be indicative of a range of environmental changes around the sampling sites, for example pollen data may be evidence of the transition from a closed forest vegetation to a more open meadow landscape, while fluctuations in annual influxes of charcoals may imply changes regional or local fires signatures related to extensive or intensive burning of the landscape. As individual proxies, it may be difficult to interpret changes in these variables as being the result of local, regional or extra-regional anthropogenic or natural processes. Because of this, co-variation of these proxies allows for more robust interpretation. In this study, these are explored through Principal Components Analysis, a statistical method outlined in Section 5.7. The chapter concludes with summary in Section 5.8 that outlines the ways in which proxies described here may be interpreted as evidence for environmental and ecological change in the Kashmir Valley.

5.2 Initial core logging and subsampling

As two types of sampling technique were employed in the field, there was some variation in the initial logging of cores in the laboratory. Cores sampled using the percussion coring technique (PH01, HG02, KS02) were split longitudinally, first using jig-mounted Geotek vibratory cutters to cut through the PVC tube only, then spatulas to split the sediment parallel to the assumed bedding plane and perpendicular to the tube length. Sediments were then carefully scraped and cleaned for logging and photography. One half of the split sample was wrapped and stored at <4°C as an archival core, while the second was processed as the “working” sample.

Cores sampled using the D-section corer (PH03, TM01, TM02, SG02, BS01) were already transported in split PVC shells and no splitting in the lab was required. As oxidisation of the sediment surface had taken place post-sample extraction, small areas were scraped for colour description. In order to minimise contamination and sample disturbance, photographs were taken without the entire surface being scraped back. Part of the logging process for D-section samples aimed to observe sedimentary changes that would help to accurately re-join subsamples and correct the total sample depth if necessary.

Following photography, samples were described and logged following protocols adapted from Schnurrenberger et al., (2003). This approach aims to homogenise descriptors, allowing for global comparison of sediments, and uses simplified language, making records accessible to non-specialists.

The classificatory scheme used follows: 1. Colour; 2. Bedding; 3. Major modifiers (texture, moisture, fabric, etc.; 4. Primary component; 5. Secondary components. Colour was recorded using a Munsell colour book (Color 1975). Microscopic components in classes 3-5 were observed through the production of smear slides. Small amounts of sediment were scraped from bedding planes using capillary tubes and mounted in Naphrax. Microscopic clastic, biogenic and chemical components were observed at varying magnifications and recorded on separate smear slide sheets. Logging conventions from Schnurrenberger et al., (2003) can be found in Appendix A -Sediment Classification.

Prior to any further subsampling, magnetic properties of the cores were recorded (see section 5.4.1 below) as this is a non-destructive technique best suited to intact samples. Following this, working cores were cut into 1cm thick slices (approximately 9.8cm^3 for ø50mm D-section samples, 22cm^3 for ø75mm percussion cored samples). Further 1cm^3 subsamples for pollen, particle size and charcoal analysis were taken using a modified 5cc plastic syringe.

5.3 Dating and chronological modelling

Chronologies were built using AMS dates returned from organic components within the sampled cores. Samples for dating were extracted during dissection of cores, with short lifespan single items such as twigs the preferred materials, though charcoals or other woody fragments were also dated. If no suitable materials could be found, bulk samples from humified or otherwise organic-rich sediments were sent for dating. All materials were dated at the DirectAMS facility in Seattle, WA, USA. Though acid-base-acid pretreatments are standard for all AMS dating facilities, in peat mire-like conditions the leaching of mobile humic acids may lead to anomalously older or younger dates (Shore et al. 1995, Väliranta et al. 2014). In order to mobilise and remove all humic acid from the date targets, sediments and non-carbonised organic remains were treated a with 10% potassium hydroxide (KOH) solution at 80°C, in a volume suitable for the sample size. Sediment samples were subject to multiple treatments where the sample was centrifuged and KOH decanted until supernatants ran clear. All samples were dried overnight at 60°C. Initially samples from the base of cores were sent for dating in order to triage or exclude any young samples that may fall outside the scope of this study. Calibration was undertaken in Calib 7.01 (Stuvier et al. 2019) with the Intcal13 calibration curve (Reimer et al. 2013). No offsets or reservoir values are known for the Western Himalayan region.

For changes in environmental proxies from sediment cores to be interpreted in historically meaningful ways, robust relations between sample depths and ages must be modelled. While linear interpolation may be suitable for shorter cores, or cores with a large number of dates available, Blaauw & Christen's (2011) Bacon system uses Bayesian statistics to construct chronologies based on users' supplied inputs. These prior constraints may include assumptions about changing accumulations rates or hiatuses in deposition, or the number of iterations of the model's Markov chain sampling algorithm to run. Priors calculated by the model include the initial mean accumulation rates modelled from top and bottom assumed ages of the core. The model was run using the Bacon package (Blaauw & Christen 2011) in R (R Core Development Team 2013).

5.4 Sediment magnetic and physical properties

5.4.1 Magnetic susceptibility

Magnetic measurements provide a non-destructive method for rapidly producing large quantitative data sets that may relate to a number of climate or human-induced processes, including weathering and erosion, transportation and deposition, or biogenesis (Oldfield 2013, Liu et al. 2012). Evidence for these processes is based upon the diamagnetic, paramagnetic, and ferri- or ferromagnetic properties of various iron oxides including hematite, magnetite and greigite (Evans & Heller 2003). In addition, soil magnetic properties may be used to correlate stratigraphic horizons dispersed across a geographic region (Agrawal 1992).

In a Himalayan context, Rawat, Gupta, Srivastava, et al. (2015) have applied magnetic studies to a 13,000 year old peat deposit at Lahaul, Himachal Pradesh, arguing enhanced magnetic phases may be evidence for intensified aeolian or fluvial deposition and thus proxies for intensification of wind activity or precipitation associated with the Indian Summer Monsoon. Phadtare (2000) has also argued for enhanced magnetic susceptibility of peat beds as a marker for intensified ISM precipitation at Dokriani Glacier in Uttarakhand.

Magnetic susceptibility is measured through the application of uniform magnetic field H to a sample, acquiring a temporary magnetisation of M. A dimensionless value of volume magnetic susceptibility (K) may be expressed as the relation $\mathrm{K} = \frac{M}{H}$ (Evans & Heller 2003, sec.2.1). Mass magnetic susceptibility (χ) of a sample may be calculated by dividing K by sample density (ρ). However, for the purposes of this study, dimensionless magnetic enhancements are suitable as general indicators of sedimentary processes and conditions.

Magnetic measurements of all cores were taken in the laboratory, using a Bartington MS3 meter with the MS2E surface scanning attachment, run through the Bartsoft software package. Samples were measured at 1cm intervals along each core, and three 2-second readings were taken at each interval. Automatic drift correction was applied and a blank 2-second air measurement was taken before and after each sample reading. The mean and standard deviation of each sample set was calculated in order to mitigate any measurement errors. Measurements were plotted stratigraphically using C2 v1.7.7 software (Juggins 2007).

5.4.2 Sediment particle size

Sediment particle size analysis provides key data for examining changes in the parent material and depositional processes of sediments, by measuring the proportion of sand, silt and clay particles in a sample. These data may be indicative of past human impact on the landscape, such as increased soil mobilisation and erosion as a result of forest clearing and agriculture. Examples include increased deposition of sand in a lake record at Mahendraparvata, Cambodia, being linked to agricultural intensification and settlement expansion between the 9th and 11th centuries AD (Penny et al. 2014). Geoarchaeological coring in hillslope colluvium and on a floodplain at Neubulans, France also yielded evidence for two phases of agricultural expansion and contraction between the 1st and 8th centuries AD, indicated by intensified erosion and pedogenic modification (Vannière et al. 2003).

As hillslopes are often unsuitable for ploughing and cultivation without substantial terracing, human modification of these landscape often takes the form of conversion to pastures (Goldberg & Macphail 2006). Goldberg and Machphail (2006 , p.77) point out that the base of hillslope deposits often contain poorly sorted, mixed colluvial and alluvial sediments, and that these depositional processes may be further influenced by human activity relating to pastoralism. As many of the mid-altitude meadows in Kashmir where samples were extracted are comprised of undulating hilly zones of Holocene age (Agrawal, 1992), change in soil particle size may be a useful indicator of human impact on this landscape.

Following logging and dissection of cores, 1cm^3 subsamples were taken at varying intervals determined by factors including accumulation rates, stratigraphic changes or other proxy data. Samples were placed in 50ml centrifuge tubes and organic matter was removed through oxidisation with hydrogen peroxide (H_2O_2; 30% w:v). Samples were heated in a hot water bath to 70°C for a minimum of two hours, before being removed and left overnight. In samples where organic matter was still clearly observed, supernatant was decanted and the process repeated, often multiple times for samples from humified beds.

Samples were then deflocculated in 30ml of a sodium hexametaphosphate ($(NaPO_3)_6$) solution (5% w:v) and mechanically agitated for a minimum of two hours. Particle size distribution was measured by laser diffraction using a Malvern Mastersizer 2000 with Hydro dispersion attachment. Samples were poured into the water bath through a 2mm sieve to remove any gravels , then ultrasonically dispersed for 20 seconds prior to measurement. Gravels above 2mm were recorded as absolute counts per cm^{-3}.

Output data were analysed using the Gradistat v8 macro for Microsoft Excel (Blott & Pye 2001). This package provides textural descriptions based on geometric measures of Folk & Ward's (1957) graphical descriptions, as well as statistical data on sediment sorting (σ_G) and skewness (Sk_G), kurtosis (K_G) of the distributions using method of moments. These data, as well as sand-silt-clay fractions, were then plotted stratigraphically using the C2 software package. Textural class output enriched the more qualitative sediment descriptions produced during initial the initial core logging process. Sediment size, σ_G, Sk_G, and K_G values are listed in Appendix A -Sediment Classification.

5.5 Charcoal studies

The deposition of small macro- and microscopic charcoals or black carbon into terrestrial sediment archives may be an indicator of natural and anthropogenic fire regimes, at varying and overlapping spatial scales (Clark 1988, Clark et al. 1998, Ohlson & Tryterud 2000). Clark (1988) notes that pollen slide microcharcoals behave like other dust particles, and even the largest fragments (5-20µm, representing 90% of pollen slide charcoal) of this class lift upwards of 100m in low wind velocity and are potentially deposited tens to hundreds of kilometres away. Unlike larger dust particles, Clark found charcoals above 100µm were also readily lifted and deposited, particularly when forest density was thinned by burning. Based on these findings, charcoals in this study were classed into local (> 250µm), local-regional 125-250µm, and extra-regional <125µm sizes.

Lab extraction protocol

Extraction of charcoals followed a protocol adapted from Stevenson & Haberle (2005). This process overlaps with the first step of pollen extraction, with 1cc of sediment being dispersed in 15ml of $(NaPO_3)_6$. This sample was then separated through 250µm and 125µm nesting sieves, with the <125µm fraction being retained for pollen and micro-charcoal study. Though carbon sizes below 100µm may be representative of regional fires, due to the large size of some *Abies* pollens in Kashmir, 125µm was selected as a more suitable sieve size.

The 125-250µm and >250µm fractions were retained in sample jars, where they were oxidised in dilute (5%) H_2O_2 in order to bleach all non-carbonised materials. Samples were then washed again in DI water and stored in jars until counting.

Counting and statistical analysis

For counting, >125µm and >250µm fractions were transferred to a petri dish and counted using a dissecting microscope over a 1cm^2 grid. As macro charcoal counts were fairly low across all samples, all charcoal fragments were counted. Microcharcoal (<125µm) counts were recorded in the process of pollen counting. Microcharcoal concentrations were estimated using a known quantity of *Lycopodium* marker spores added to the sample:

$$\textbf{Concentration (cm}^{-3}\textbf{)} = \frac{\text{charcoal count}}{\textit{Lycopodium}\text{ count}} \times \frac{\textit{Lycopodium}\text{ added}}{\text{sample volume}}$$

Mooney & Tinner (2011) recommend a minimum number of 200 objects (either pollen slide charcoals or *Lycopodium* spores) to be counted for properly modelled charcoal influxes. However, at some sample depths charcoal concentrations were minimal and counts were abandoned after 25 *Lycopodium* spores were counted and a rapid lower magnification scan clearly indicated there was no charcoal in the sample.

Modelled annual influx rates were calculated by multiplying the concentration or absolute counts of charcoal per cm^3 by the accumulation rate in cm/year from the age depth model. Periods of above or below average influx were then calculated by subtracting the mean of all influx rates from the influx rate at each sample depth. This approach was taken to control stochastic variation and identify periods of intensified burning in the landscape.

5.6 Pollen and non-pollen palynomorphs

Reconstruction of past environments using pollen data follows the principal that stratigraphically accumulated morphologically identifiable pollen types may be indicative of past vegetation communities around a sampling site (Seppä 2007). Changes in vegetation communities may support interpretations of past global climate change, human activity or localised environmental change, depending on the spatial scale of the site catchment. Often preserved with pollen spores in sediment archives are non-pollen palynomorphs (NPPs) including fungal spores, parasite eggs, invertebrate remains and algae (van Geel, 2002). The integration of NPPs with traditional pollen studies has the ability to enhance the interpretive strength of the pollen data. In addition to pollen studies, the approach in this thesis maintains a particular focus on coprophagous fungal spores as NPPs that may be indicative of the presence of herbivores in the palaeoenvironmental record.

5.6.1 Fossil pollens

Lab extraction protocol

Extraction of pollen from sediments follows standard procedure adapted from Faegri et al. (2007) and Bennett & Willis (2001). As emphasised by Bennett & Willis, pollen extraction is a goal focussed procedure rather than a process with strict adherence to method, and therefore variations were sometimes made in regard to duration or repetition of steps based on particular characteristics of samples such as organic or silicate concentrations.

Sediments were subsampled into 1cm^3 volumes using a 5cc syringe with the nozzle removed, at intervals approximating 100-year temporal increments, and where possible at evenly divisible depths, to allow for evenly increased resolution where required. These samples were then placed into 50ml plastic centrifuge tubes, along with 15ml of $(NaPO_3)_6$ dispersant (5% w:V), and one *Lycopodium* spore tablet (Lund University batch #1031; total spores 20,848 ± 691) was added as an exotic marker. Samples were then mechanically agitated for a minimum of 2 hours, and sieved through a series of 250µm and 125µm nested meshes. These coarse fractions were retained for charcoal analysis (section 5.5 above). The sieved solution was centrifuged at 3000rpm for 3 minutes and supernatant decanted.

Humic colloids were removed through the addition of 10ml of 10% potassium hydroxide (KOH) solution. Samples were vortex shaken and placed in a hot water bath for 30 minutes. Samples were then centrifuged and supernatant decanted. Samples were then shaken with DI water, and again centrifuged and decanted.

Digestion of silicates then took place using a hydrofluoric acid (HF) solution (40% w:v). Approximately 12ml of HF solution was balanced to the 15ml sample tube mark and samples were vortex mixed and placed in a hot water bath for at least two hours. Samples with high siliclastic content were left to react for longer. Samples were spun down and HF supernatant decanted. Following HF treatment, samples were washed once with 10% HCl to remove carbonates and break up remnant silica clumping, then twice washed with DI water. In samples with high remnant mineral content this step was repeated.

Any remaining non-sporopolleniferous organic matter was removed through acetolysis. First samples were dehydrated through washing with 10ml glacial acetic acid. A 9:1 solution of acetic anhydride ($(CH_3CO)_2O$) and concentrated sulfuric acid (H_2SO_4) was prepared, of which 10ml was added to each sample and vortexed. All samples were then placed in a hot water bath preheated to 100°C. As acetolysis can dehydrate and damage pollen microfossils, samples were placed in the bath for no longer than 5 minutes. Samples were then centrifuged, decanted and washed once with glacial acetic acid, and once with DI water.

Samples were then transferred to 1.5ml test tubes, and mixed with 0.5-1ml of glycerol and a drop of ethanol for mounting and archival storage. This mixture was then thoroughly agitated and 50µL was transferred to a glass slide on a hotplate, and sealed under a coverslip using paraffin wax.

Identification and counting

Previous pollen studies by Singh (1963), Vishnu-Mittre & Sharma (1966) and Dodia 1983, provided a background for the expected Holocene pollen spectrum suitable for this study. Keys from Rekha Dodia's PhD thesis (1983) also provided a general guide to pollen morphology from Kashmir, though generally to the family level only.

A reference collection of photographic and classificatory features was compiled, based on relevant literature, including P.K. Nair's works on Quaternary pollens from Kashmir (Nair 1961) and the western Himalaya (Nair 1965). Online pollen databases of temperate Northern Hemisphere taxa such as PalDat (www.paldat.org) and the Global Pollen Project (www.globalpollenproject.org; Martin & Harvey 2017), and Farooq Jan's (2015) PhD thesis on pollen from the Swat Valley, Pakistan, were useful resources for photographic material for regional as well as temperate Eurasian taxa more broadly. Himalayan reference material at the Birbal Sahni Institute of Palaeosciences in Lucknow was also consulted during visits in 2017 and 2018. Morphological studies of Polygonaceae pollens from China (Zhang & Zhou 1998) and *Rumex* and *Polygonum* genera from Pakistan (Yasmin et al. 2010a&b) allowed for the identification of grazing associated plant pollen from Kashmir. Other literature included several family specific studies from the Pollen Flora of Pakistan (Perveen 1999, Perveen & Qaiser 1999, Perveen & Qaiser 2006a, Perveen & Qaiser 2006b, Perveen & Qaiser 2006c, Perveen & Qaiser 2007, Perveen & Qaiser 2014, Perveen et al. 2004).

Slides were scanned in horizontal transects using an Olympus CX40 microscope at 400x magnification and all palynomorphs were recorded. Where possible, pollens were identified to species level, though often it was only possible to identify genus or family groups. A study of moss polsters across the Kashmir Valley has found that certain conifer pollens, particularly *Pinus* are over represented, contributing more than 75% of pollen counts at open area sites on the valley floor where pine stands are absent (Vishnu-Mittre & Robert 1971). Due to this, fluctuation in the arboreal pollen curve may not be truly representative of forest composition or vegetation around sampling sites. As a result, this study focusses on the relative proportions and presence/absence of non-arboreal pollens that may be indicative of grazing pressures around the study sites and a target minimum count of 150 non-arboreal pollens was aimed for each slide. At sample depths where pollen counts were low, a minimum of two slides were counted except in rare cases were more than 200 *Lycopodium* spores were counted on a single slide and the sample was sterile of other pollen. If after these two slides the target minimum number of samples was close, counting continued on a third slide. If it was apparent that pollen concentrations were extremely low then these counts were recorded and new samples were taken from proximal depths. Unknown types were photographed and described following conventions in Punt et al. (2007), and attempts were made to identify them from the above listed keys. All identified pollen types and their major identifying or morphological characteristics are presented in Table 5.1. Photographs of pollens are presented in Figure 5.1.

Classification and Statistical Analysis

Following counting, pollen were classified into broad major categories such as trees, shrubs, grasses, herbs etc. In some cases, especially when pollens were identified to family level only (e.g. Rosaceae) multiple classifications may be applicable. As large family grouping may also encompass a number of these categories, a site-specific attribution of both primary and secondary classification was informed by field observations of the local plant ecology around the sites, as well as previously published studies on plant communities in Kashmir (Rao 1961, Dhar & Kachro 1983, Khuroo et al. 2011, Khuroo 2013, Dad & Reshi 2013, Mir et al. 2015). Classifications for pollen types are listed in Table 5.1.

Pollen spectra were plotted stratigraphically using Tilia version 2.0.41 (Grimm 2015). Pollen counts were plotted as relative abundances, the most common method for presenting palynological data, despite distortions that may be introduced through overrepresentations of some variables or high numbers of “zero” values for others (Traverse, 2007). Relative abundances were favoured, as methods such as modelled pollen influx or concentration rates that may be a more “absolute” representation of past environments often require more complex transformations, and also risk introducing errors from chronological models (Birks, 2007). To mitigate distortions caused by overrepresentation, Cyperaceae pollens were excluded from percentage calculations, as is common practice when sedge plant material comprises a large percentage of the sediment matrix (Beer 2007). Pollen zones representing major environmental changes were grouped using stratigraphically constrained cluster analysis based on square root transformation of absolute pollen counts. These zones were plotted based on cluster dendrograms produced using the CONISS function in Tilia (Grimm 1987, Grimm 2015).

Indicator type approach

Indicator species studies are based upon the assumption that modern plants and those represented in past pollen diagrams share the same ecologies such as light, soil and moisture requirements, climate constraints and responses to factors such as other plant, animal or human activity (Gaillard 2007). Drawing on Iverson’s early studies of prehistoric land cover modification and use, Behre (1981) produced a set of pollen indicator species relating to past human activity in Europe, including farming, grazed forest understories, natural and artificial meadows and fallow fields.

Following this principal, a number of indicator taxa relating to pastoralist activity were identified in modern studies of grazing impacts on modern Kashmir meadows (Mir et al. 2015, Ahmad et al. 2013, Dad & Khan 2010). These studies examined vegetation community composition in ungrazed and moderately to heavily grazed areas, and incorporated a number of altitudinally and topographically differentiated sites. From these studies a number of pollen types that may be indicative of various intensities of grazing activity and landscape modification by herders were identified, including various Asteraceae, Poaceae, *Polygonum* and *Rumex*, and *Trifolium*. Additionally, these studies recorded a number of species susceptible to overgrazing for which lower pollen representation may be indicative of increased grazing pressure. Indicator values for other taxa were derived from literature on the flora of Kashmir (Rao 1961, Dhar & Kachro 1983, Khuroo et al. 2011, Khuroo 2013, Dad & Reshi 2013, Mir et al. 2015), or through observation of plant ecology in the field. All indicator values are listed in Table 5.1. Summed percentages of these indicator types could then be plotted in addition to singular pollen variables as a way of summarising total variation between taxa groups such as natural forest, meadows, or types relating to agriculture or pastoralism.

Following the available literature (Rao 1961, Dhar & Kachro 1983, Khuroo et al. 2011, Khuroo 2013, Dad & Reshi 2013, Mir et al. 2015), the secondary indicator values for pollen types can be characterised as follows:

Anthropogenic: Taxa associated with human activity such as agricultural grasses and weeds, plants associated with human settlement, or other anthropogenic disturbance of landscape. Includes cereal-type Poaceae, or disturbed area colonisers such as Cannabaceae, Amaranthaceae or *Plantago*,

Boreal: Tree types associated with cold-dry conditions, generally relating to higher altitudes in the Kashmir Valley, including *Betula*, *Corlyus* and *Alnus*.

Grazing: Herbaceous or meadow vegetation associated with nitrogen-enriched, disturbed or degraded environments that may indicate the presence of large numbers of herbivores. Primary types include *Rumex, Trifolium, Plantago, Polygonum*, Caryophyllaceae and Poaceae types.

Marsh: Generally herbaceous taxa growing on the margins of swampy or marshy areas, including *Typha, Persicaria, Polygonum* cf. *plebium*-type. Higher representation may be indicative of wetter environmental conditions or poorer drainage.

Meadow: Herbaceous taxa associated with open meadow type environments. Their higher representation may in some cases indicate human-induced changes relating to deforestation and pastoralism though this should be supported through other proxy evidence. Typically includes various Poaceae, Asteraceae, Polygonaceae and Caryophyllaceae types.

Open area: Non-herbaceous shrubs associated with cleared areas at margins of meadows or forests, generally *Viburnum* and *Sambucus*.

Temperate: Tree types ecologically associated with warm-humid conditions in the Kashmir Valley or Western Himalaya, including *Quercus, Juglans* and *Carpinus*.

5.6.2 Dung fungi

The accumulation of coprophagous fungal spores in environmental archives has been interpreted as a proxy for the presence of, or change in the herd structure of, large herbivores. In a critical review of dung fungi studies, Baker et al. (2013) raise several issues, including the identification of fungal spores as being coprophagous, statistical methods, and the lack of validation studies in areas where coprophagous fungi are used as an indicator of zoogenic environmental change. The review finds that *Sporormiella* and *Sordaria* are the most reliable fungal indicators, though identify several other types that may also be suitable proxies. The review finds an almost total absence of validation and palaeoecological studies outside of Europe, North America or Australia, and no studies in Asia outside of Russian Siberia. Since this publication, Shumilovskikh et al. (2016) interpreted *Podospora*, *Sporormiella*, *Sordiaria* and *Saccobolus* fungal types as evidence for ancient pastoralism in Northeastern Iran, though no other environmental or validation studies have been published relating to Central Asia. A recent unpublished study on fungal spores from modern yak dung from the Uttarakhand in the Central Himalayas also found *Podospora*, *Sporormiella* and *Sordiaria* acospores to be the dominant spore types for samples taken during summer (Basumatary et al. 2020)

As preliminary validation of the types of coprophilous fungi present in Kashmir, sheep and goat dung samples were collected at Pari Has and Tosa Maidan. Dung samples were dispersed and humic acids removed in 10% KOH. Cellulose and other organic materials were removed following the acetolysis procedure. Samples were mounted on a test slide, and as few silicate or carbonate particles were observed, treatment with HCl and HF was avoided. Slides were scanned for fungal spores as well as pollens as additional indicators of dominant plant types present in summer grazing biomes. These results have not been included in the following chapter but were entered in Appendix B – Supplementary data. Identification was based on keys, descriptions and illustrated/photographic examples in van Geel et al. (2003), van Geel & Aptroot (2006), (2017), Doveri & Sarrocco (2013), as well as those from the above mentioned Uttarakhand study. These three fungal types are considered to be mostly to fully coprophagous and are considered reliable indictors of the presence of herbivore dung (van Asperen et al. 2019). Identification criteria are given in Table 5.2 and photographs in Figure 5.2.

5.7 Principal Components Analysis

Principal Components Analysis (PCA) is an exploratory and unconstrained multivariate statistical technique to summarise large datasets into linear plots that aim to explain as much of the variance within the dataset as possible (Smith 2015). This is achieved through the decomposition of variables and observations into simplified orthogonal variables known as *principal components* (Abdi & Williams 2010). Each of these components represent a percentage of correlation or covariance within the dataset, and the relationship between the variables and the principal components is described as a *loading*. While multiple principal components are computed in the analysis, the first component (PC1) contains the highest proportion of variation within the data, decreasing with each subsequent component. Often the first two components will contain a significant majority of the variation of the dataset. Principal components may then be mapped as axes, with linear biplots of variables (in this case pollen and other environmental data) illustrating variance within the dataset, and point plots of observations (i.e. sample depths) showing the relation between that sample and the principal components.

For this analysis, variables were produced through compiling absolute counts of pollen taxa into their classificatory groupings such as trees, shrubs, ferns, grazing etc., with the exception of some significant types such as Poaceae and *Artemisia* that were included as singular variables. Other variables included charcoal and coprophagous fungi concentrations. Standardisation of variables so that each variable deviated around a zero mean allowed for the comparison of data derived from different scales (e.g. comparison of absolute pollen counts against microcharcoal concentration). This was undertaken through calculating the mean and standard deviation for each variable. The mean was then subtracted from the observed variables and the result divided by the standard deviation, e.g.:

$$Conifers(standardised) = \frac{Conifer(count) - \mu}{\sigma}$$

PCA was calculated and plotted in PAST v3.17 (Hammer et al. 2001). Statistically significant components were detected through a “broken stick” and scree plot of all components in PAST. These components were plotted against one another and interpretive values for these axes were made based on the loading of variables for that component. For example, a component with a high positive loading of grasses, anthropogenic weeds and charcoal influx may represent human activity, whereas a component with high positive loadings of marshy taxa and ferns and negative loadings of dry favouring plants, such as conifers and *Artemisia*, may be interpreted to represent aridity and humidity in the environment. Stratigraphic zones from the CONISS clustering were applied to the plotted observations.

Table 5.1: Pollen types with morphology, classificaton and secondary indicators.

Family	Genus/ Species/ Other descriptor	Class/type	Polar shape	Equatorial shape	Size µm (Polar/ Equatorial; or diameter)	Aperture	Surface (LM)	Main classification	Secondary indicator type(s)	Reference	Image #
Adoxaceae	*Viburnum* sp.	Tricoplorate	Circular	Prolate	P:25-30 E:20-30	Colpus long, wide; pore indistinct	Reticulate; Exine 5-7µm thick	Shrub	Open area	Perveen & Qaiser, 2007 Nair, 1961	1
Adoxaceae	*Sambucus* sp.	Tricolporate	Circular	Prolate-subprolate	P:20-30 E:20-25	Endoaperture lalongate	Reticulate; Exine 1-2µm thick	Shrub	Open area	Nair, 1965	2 (E) 3 (P)
Amaranthaceae	Undiff.	Pantoporate	Circular	Spheroidal	Spheroidal ø 10-30 µm	Pores circular	Typically granulate	Herb/shrub	Anthro.	Nair, 1965	4
Asteraceae	*Artemisia* sp.	Tricolporate	Circular	Spheroidal-subspheroidal	Spheroidal ø 15-20 µm	Endoaperture lalongate	Granulate to faintly echinate	Shrub	Open area	Nair, 1965	5
Asteraceae	Echinate type	Tricolporate	Circular to triangular	Usually prolate-spheroidal to oblate-spheroidal	P:12-25 E: 15-28	Colpi 10-15 µm long with costae, endoaperture slightly lalongate	Echinate, spines 1-5µm long. Tectum between spines perforate to psilate	Herbs	Meadow; Grazing	Perveen, 1999	6
Asteraceae	Fenestrate type	Lophate	Circular to hexagonal	Generally spheroidal	Spheroidal ø 20-40 µm	Generally tricoplorate; occasionally porate; poral lacunae	Echinolophate	Herbs	Meadow; Grazing	Perveen, 1999	7
Apiaceae	Undiff.	Tricolporate	Triangular to sub-circular	Prolate; “bone” shaped	P: 20-40 E: 10-15	Colpi with costae; colpus length typically equal to equatorial ø	Rugulate	Herbs	Meadow; Anthro.	Perveen & Qaiser. 2006a	8
Balsaminaceae	*Impatiens* sp.	4-colpate	Elliptical	Sub-rectangular	P:30-40 E:15-20	4 narrow colpi situated at “corners” in equatorial view up to 10 µm in length	Reticulate, exine thin ~1µm	Herbs	Anthro.	Dodia, 1985 Nair, 1965	9

Family	**Genus/ Species/ Other descriptor**	**Class/type**	**Polar shape**	**Equatorial shape**	**Size µm (Polar/ Equatorial; or diameter)**	**Aperture**	**Surface (LM)**	**Main classification**	**Secondary indicator type(s)**	**Reference**	**Image #**
Betulaceae	*Alnus* sp.	4-porate	Circular	Oblate	P:15-28 E:25-40	4 (rarely 3 or 5) pores, distributed evenly around equator aspidate, apsis ø~6µm	Scabrate to granulate, 1.5-2.5µm thick	Trees	Boreal	Nair, 1961; Perveen & Qaisar, 1999	10
Betulaceae	*Betula* sp.	Triporate	Circular	Oblate	P:20-25 E:25-30	3 (rarely 4) pores distributed evenly around equator, aspidate, apsis ø~7µm	Psilate to granulate, exine 1-2 µm thick	Trees	Boreal	Nair, 1961 Perveen & Qaisar, 1999	11
Betulaceae	*Carpinus* sp.	Triporate	Circular	Oblate	P:25-30 E:30-35	3 (rarely 4) pores distributed evenly around equator, aspidate	Psilate	Trees	Temperate	Dodia, 1985 Nair, 1961	12
Betulaceae	*Corylus* sp.	Triporate	Sub-triangular	Oblate	P:20-25 E:25-30	3 pores distributed evenly around equator, apsis not as developed as other Betulaceae	Psilate	Trees	Boreal	Dodia, 1985 Nair, 1961	13
Brassicaceae	Undiff.	Tricolpate	Circular	Prolate to prolate-spheroidal	P:15-25 E:12-20	Colpus long, sunken, acute ends at polar apex	Generally reticulate	Herbs	Meadow; Anthro.	Perveen et al. 2004	14

Family	Genus/ Species/ Other descriptor	Class/type	Polar shape	Equatorial shape	Size µm (Polar/ Equatorial; or diameter)	Aperture	Surface (LM)	Main classification	Secondary indicator type(s)	Reference	Image #
Cannabacae	Cannabis type	Triporate	Circular	Spheroiodal	Spheroidal ø 20-30µm	3 (rarely 2 or 4) pores ø 2-3µm. Circular shape with rim between annulus and porus.	Psilate. Nexine and sexine not distinct under LM	Herbs	Anthro.	Punt & Malotaux, 1984	-
Caryophyllaceae	Undiff.	Pantoporate	Circular	Spheroidal	Spheroidal ø 25-40µm	Pores generally evenly distributed over surface, pores ø 3-6µm	Reticulate, exine ~2.5µm thick	Herbs	Meadow; Grazing	Perveen & Qaisar, 2006b Nair, 1965	15
Cupressaceae	*Juniperus*	Inaperturate	Circular	Spheroidal	Spheroidal ø 25-40µm	Inaperturate, fissure sometimes opened across pollen	Granulate to psilate	Conifers/shrubs	-	Khan et al., 2017	16
Cyperaceae	Undiff.	Inaperturate	Irregular	Irregular	Typically >25 µm	Inaperturate, occasional small fissures	Granulate to psilate	Herbs	Marsh; Cyperaceae	Dodia, 1985	17
Ephedraceae	*Ephedra* sp.	Polyplicate	Circular	Prolate	P:25-40 E:15-25	Pseudosulcus between plicae	4-12 plicae, triangular in equatorial view, psilate	Shrubs	-	Khan et al., 2017 Bollinder et al,. 2015	18
Fabaceae	Fabaoidae type	Tricolporate	Generally triangular to lobate	Spheroidal to prolate	P:20-35 E:15-25	Pores circular, often with operculum, ø 3-5µm, colpi long and narrow	Reticulate to finely reticulate, psilate towards colpi forming distinct margins	Herbs	Meadow; Grazing	Nair, 1965	19
Fagaceae	*Quercus* sp.	Tricolporate	Circular to sub-triangular	Spheroidal to sub-prolate	P:20-25 E:18-22	Colpi 2-3µm wide, indistinct endoaperture	Granulate/ scabrate	Trees	Temperate	Nakagawa et al., 1986 Nair, 1961	20

Family	Genus/ Species/ Other descriptor	Class/type	Polar shape	Equatorial shape	Size µm (Polar/ Equatorial; or diameter)	Aperture	Surface (LM)	Main classification	Secondary indicator type(s)	Reference	Image #
Haloragaceae	*Myriophyllum* sp.	4-porate	Circular	Spheroidal	Spheroidal ø 20-30µm	4 (rarely 3 or 5) pores evenly distributed around equator, pronounced aspis with ø up to 9µm	Granulate	Aquatic	Marsh	Nair, 1965 Dodia, 1985	21
Juglandaceae	*Juglans* sp.	Pantoporate	Circular	Spheroidal to spheroidal-oblate	Spheroidal ø 40-55µm	Circular pores ø1.5-3.5µm distributed across one hemisphere only	Faintly granulate to psilate.	Trees	Temperate Anthro. (generally historic to modern periods only)	Dodia, 1985 Nair, 1961	22
Liliaceae	Undiff.	Sulcate	Elliptical	Prolate. Dry grains boat shaped.	P:40-60 E:30-40	Sulcus, up to 40 µm in length, 12 µm at widest point. Often infolded on dried grains.	Reticulate	Herbs	Open area; meadow	Dodia, 1985 Nair, 1965	-
Pinaceae	*Abies pindrow*	Vessiculate-bisaccate	Elliptical	Bisaccate	Polar view Total length: 110-180 Corpus ~100x75 Sacci ~70x50	Inaperturate, occasional fissure as base of corpus	Reticulate – reticulations of sacci larger and hetero-brochate on sacci, smaller on corpus. Exine ~7µm thick	Conifers	-	Khan et al., 2017 Dodia, 1985 Nair, 1961	23
Pinaceae	*Cedrus deodara*.	Vessiculate-bisaccate	Elliptical	Bisaccate – corpus often spherical	Polar view Total length: 75-95 Corpus ~55x45 Sacci ~ 45x40	Inaperturate, occasional fissure as base of corpus	Granulate w/reticulation on sacci. Exine ~ 3µm, proportionally thinner than other Pinaceae	Conifers	-	Tiwari et al., 2012 Khan et al., 2017 Dodia, 1985 Nair, 1961	24

Family	Genus/ Species/ Other descriptor	Class/type	Polar shape	Equatorial shape	Size µm (Polar/ Equatorial; or diameter)	Aperture	Surface (LM)	Main classification	Secondary indicator type(s)	Reference	Image #
Pinaceae	*Picea smithiana*.	Vessiculate-bisaccate	Elliptical	Bisaccate – sacci hemispherical with no pronounced constriction at corpus join.	Polar view Total length: 95-145 Corpus ~75x65 Sacci ~ 70x60	Inaperturate	Finely regulate on corpus to reticulate on sacci. Corpus exine ~3-4µm, reticulations on sacci ~5µm	Conifer	-	Khan et al., 2017 Dodia, 1985 Nair, 1961	25
Pinaceae	*Pinus* sp.	Vessiculate-bisaccate	Elliptical	Bisaccate – corpus generally prolate	Polar view Total length: 60-90 Corpus ~50x30 Sacci ~ 40x35	Inaperturate, occasional fissure as base of corpus	Rugulate/ vermiculate corrugations on corpus, reticulation on sacci. Corpus exine 2.5-3.5 3µm	Conifer	-	Khan et al., 2017 Dodia, 1985 Nair, 1961	26
Plantaginaceae	*Plantago* sp.	Pantoporate	Circular	Spheroidal	Spheroidal ø 15-30µm	6-14 circular pores unevenly distributed across surface. Circular, ø~3 µm.	Granulate	Herbs	Grazing; Anthro.	Dodia, 1985 Nair, 1961	27 28
Poaceae	Undiff.	Monoporate	Circular	Spherodal	Spheroidal ø generally >15µm	Distinct circular pore with annulus	Psilate	Grasses	-	Nair, 1965	29
Poaceae	Cereal type	Monoporate	Circular	Spherodal	Spheroidal ø >40µm	Distinct circular pore ø3 with annulus ø~10µm	Psilate	Grasses	Anthro.	Behre 2006	30 31
Polygonaceae	*Persicaria* sp.	Pantoporate	Circular	Spheroidal	Spheroidal ø 45-60µm	Circular apertures enclosed by muri	Reticulate with large muri. Lumina 3-6µm across. Total exine thickness ~6 µm	Herbs	Marsh	Zhang & Zhou, 1998	32

Family	Genus/ Species/ Other descriptor	Class/type	Polar shape	Equatorial shape	Size µm (Polar/ Equatorial; or diameter)	Aperture	Surface (LM)	Main classification	Secondary indicator type(s)	Reference	Image #
Polygonaceae	*Polygonum* cf. *aviculare*	Tricolporate	Circular	Prolate to sub-prolate	P:25-30 E:20-25	Colpi length 13-15 µm, pore circular	Granulate or indistinct, Exine thicknes ~1.25µm	Herbs	Meadow;	Yasmin et al., 2010b Zhang & Zhou, 1998	33
Polygonaceae	*Polygonum* cf. *plebium*	Tricolporate	Circular to sub-triangular	Prolate	P:20-24 E:12-17	Colpi length 9-10 µm	Finely reticularte	Herbs	Marsh	Yasmin et al., 2010b Zhang & Zhou, 1998	34
Polygonaceae	*Rumex* sp.	Tricolporate (occasionally 4-colporate)	Circular	Spheroidal to spheroidal-prolate	Ø20-30	Non-lacunate; colpi length 9-10 µm	Granulate	Herbs	Grazing	Yasmin et al., 2010a Zhang & Zhou,1998	35 36
Polygonaceae	Undiff.	Tricolporate or pantoporate & not identifiable to above genera or species	Circular	Prolate to spheroidal	Ø20-30	Colpi length 10-15 µm,	Granulate to reticulate	Herbs	-	Nair, 1961, Nair, 1965 Zhang & Zhou,1998	37
Ranunculaceae	Undiff.	Tricolpate; occasionally pantoporate (*Thalictrum* type)	Circular	Spheroidal to sub-prolate	P:18-24 E:15-20 Ø20-30	Colpi length 12-18 µm	Scabrate	Herbs	Shrubs	Perveen & Qaiser, 2006; Nair, 1965	38 39
Rosaceae	Undiff.	Tricolporate	Circular to triangular	Oblate to subprolate	P:15-25 E:15-25	Colpi lengh 10-20 µm; Endoaperture circular	Striate to striato-reticulate	Open area; Herbs	-	Perveen & Qaiser, 2014 Nair, 1965	40 41
Rubiaceae	*Galium* sp.	6-8 colporate	Circular, "flower" shaped	Spheroidal	ø20-30		Psilate	Herbs	Grazing	Nair, 1965	-
Salicaceae	*Salix* sp.	Tricoplate	Circular	Spheroidal	Ø10-15	Colpi lengh 8-10 µm	Reticulate	Trees/shrubs	Boreal	Nair, 1965	42
Sapindaceae	*Acer* sp.	Tricolporate	Circular	Spheroidal	ø25-30	Colpi length 20-22 µm	Finely striate to striato-reticualte	Trees	-	Lama et al., 2015	-
Typhaceae	*Typha* sp.	Tetrad	Tetrad	Tetrad	Ø20-40	Inaperturate	Reticulate	Marsh	-	Dodia, 1985	43

Family	Genus/ Species/ Other descriptor	Class/type	Polar shape	Equatorial shape	Size µm (Polar/ Equatorial; or diameter)	Aperture	Surface (LM)	Main classification	Secondary indicator type(s)	Reference	Image #
Urticaceae	*Urtica* sp.	Triporate	Circular	Spheroidal	Ø10-20	Pores small, circular, slightly protruding	Psilate, exine thickens slightly around pores	Herbs	Grazing	Punt & Malotaux, 1984	44
	Monolete		Sub-circular	"Bean" shaped		Indistinct	Psilate	Ferns	-	Dodia, 1985 Nair, 1965	45
	Trilete		Lobate to triangular	Elliptical		3 laesura spanning majority of polar surface	Psilate	Ferns	-	Dodia, 1985 Nair, 1965	46

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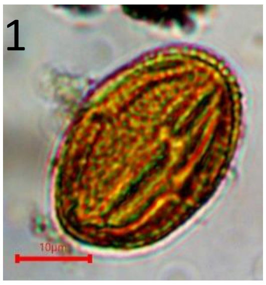

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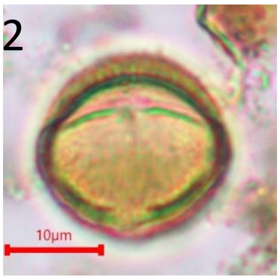

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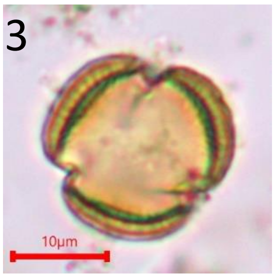

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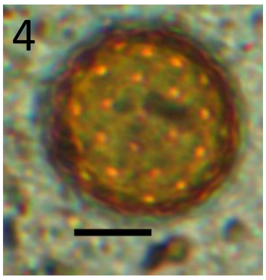

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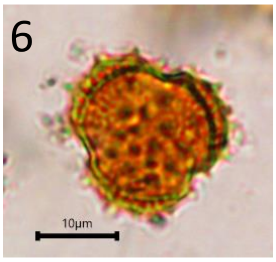

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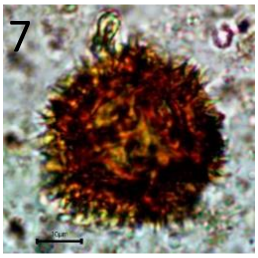

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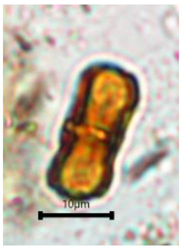

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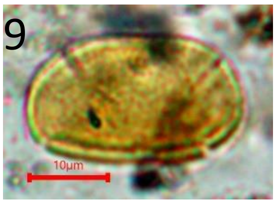

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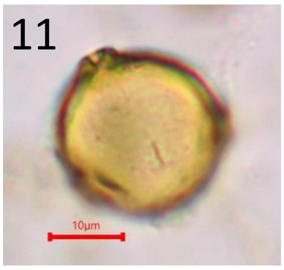

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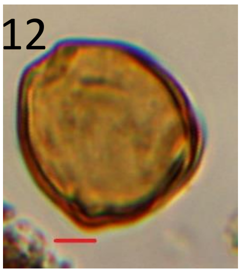

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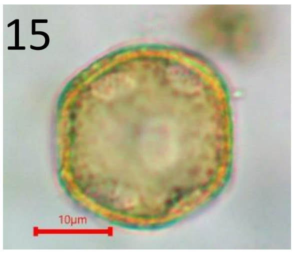

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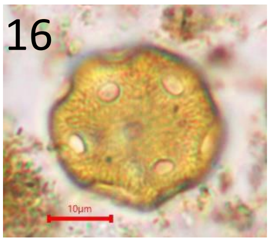

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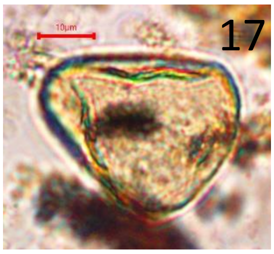

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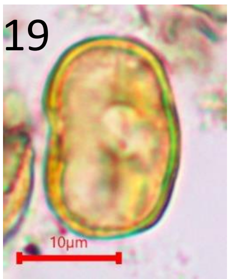

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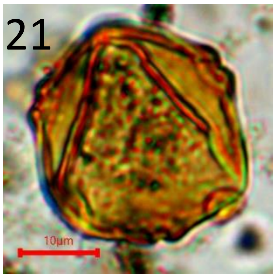

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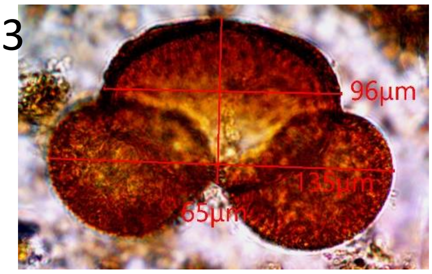

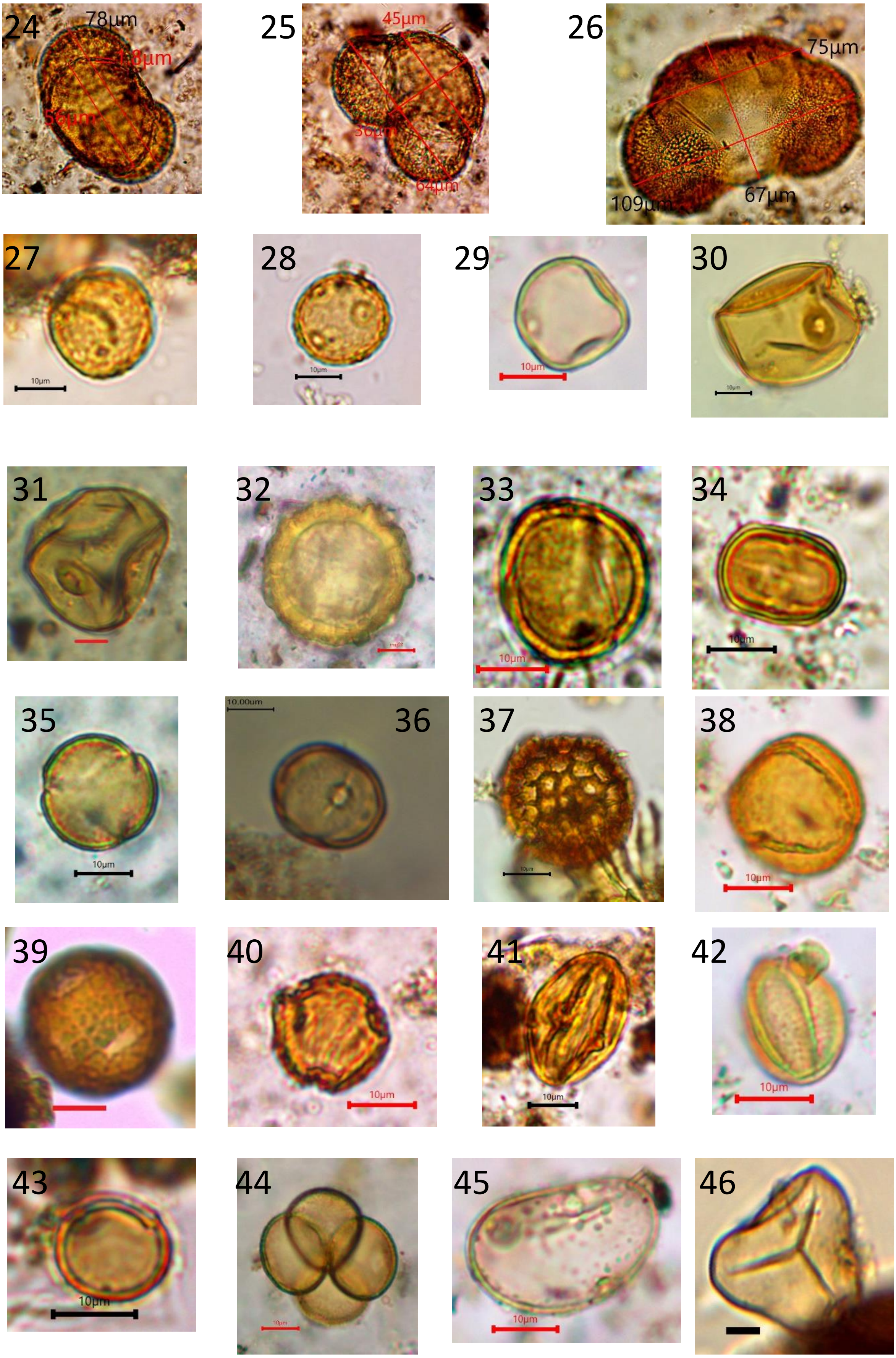

Figure 5.1: Photographic references for pollen types in Table 5.1.

Table 5.2: Identification features and references for coprophagous fungal spores.

Type	Description	References
***Podospora*-type**	Ellipsoid to ovoid with truncated or blunted base. Spore length 20-50µm, width 15-25µm. Single pore in sub-apical (occasionally apical) position. Pore ø 1-2.5 µm with thickened annulus.	Schlütz & Shumilovskikh 2017, van Geel et al. 2003
***Sordaria*-type**	Ellipsoidal often with slightly flattened base. Spore length 15-30µm, width 10-15µm. Single pore in apical position, ø<1.5µm.	van Geel et al. 2003 van Geel & Aptroot 2006
***Sporormiella*-type**	4- to poly-celled acospores, generally fragmented into single cells. Two cell types – sub-conical terminal cells and cylindrical central cells. All cells have a distinct germ slit along entire cell length. Individual cell length 15-20µm, width 10-15µm.	Doveri & Sarrocco 2013 van Geel et al. 2003

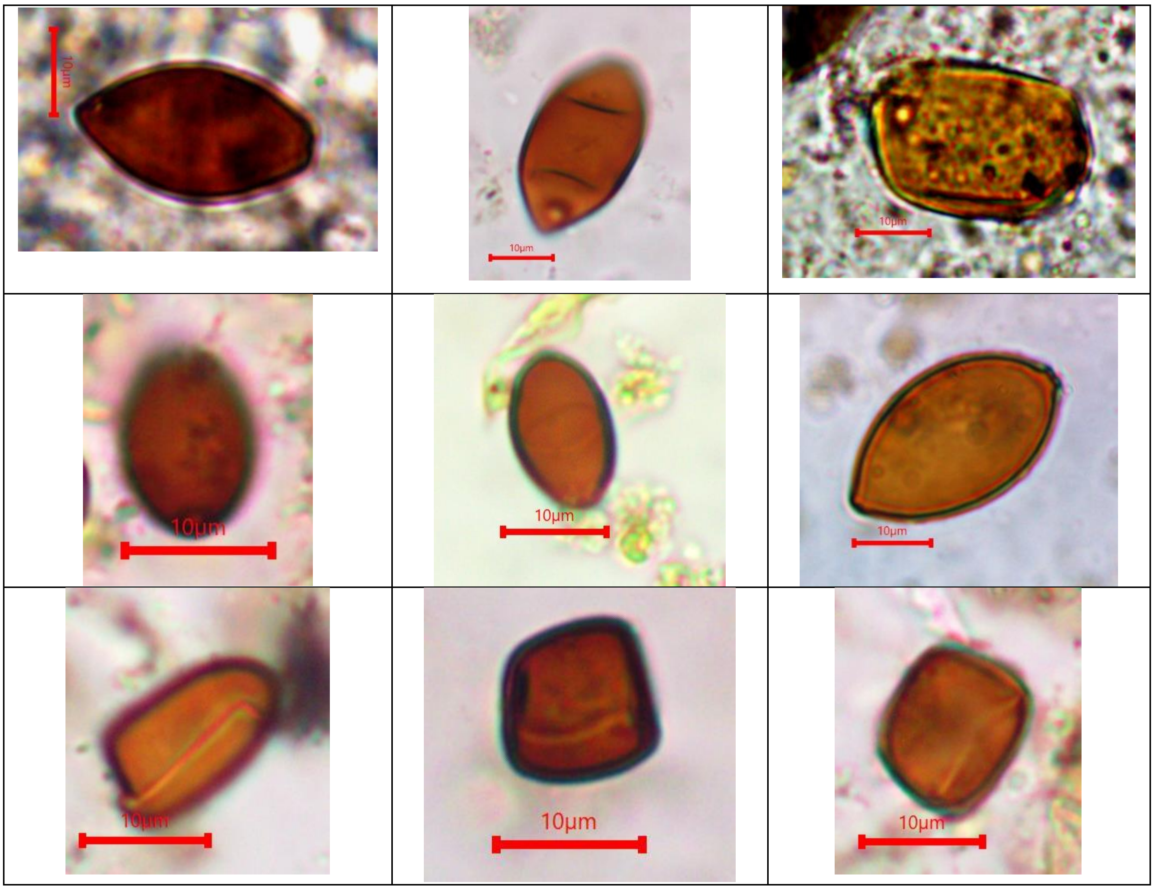

Figure 5.2: Photographic references for fungal spores. Top row - Podospora; Middle row - Sordaria; Bottom row - Sporormiella.

5.8 Interpreting proxy indicators of pastoralist activity in the palaeoenvironmental record

From the descriptions in Sections 2.1.4 and 3.3 we may understand some of the impacts of pastoralism on the landscape and vegetation composition specific to the Kashmir Valley. A more generalised review of indicators of past human activity in Section 3.4 as well as the above methodological backgrounds. Drawing out markers from these studies, we can now articulate a number of variables detectable in the palaeoenvironmental record that may help us to reconstruct past pastoralist land use in the Kashmir Valley, presented in Table 5.3.

Table 5.3: Potential proxy-indicators of agro-pastoralist land use around study sites.

Proxy	**Type**	**Description**	**Reference**
Poaceae	Pollen	Increased grass and lower herbaceous diversity has statistical relationship with grazing intensity	Dad & Khan 2010 Dad & Reshi 2015 Mir et al. 2015 Ahmad et al. 2013
Poaceae – cereal type	Pollen	Cultivation associated with agro-pastoralism	-
Rumex, Caryophyllaceae, *Trifolium*-types	Pollen	Plant types associated with niche enrichment of grazed areas. Forage herbs for human and animal consumption. *Rumex* often absent from ungrazed/undisturbed areas	Casimir & Rao 1985 Dad & Khan 2015 Spengler 2014
Asteraceae, *Plantago*, *Urtica, Sambucus*	Pollen	Ruderal and unpalatable plants associated with degraded landscapes and over grazing.	Dad & Khan 2010 Dad & Reshi 2015 Mir et al. 2015 Ahmad et al. 2013
Artemisia	Pollen	Open landscape shrub, highly sensitive to grazing pressures. Declining values related to presence of herbivores.	Dad &Khan 2010 Vishnu-Mittre 1966
Podospora, Sordaria, Sporormiella	Fungal spores	Coprophagous spores associated with herbivore dung.	van Geel & Aptroot 2006 van Asperen et al. 2019
Mean particle size, sorting values	Sediment	Larger, more poorly sorted sediment may relate to herbivore or human induced erosion.	Jaweed et al. 2015
Macro-charcoal	Charcoal	May be evidence of localised anthropogenic burning – forest clearing or campsites.	-

While each of the proxies presented in Table 5.3 can be each alone be interpreted as evidence for pastoralism, their variability within their respective records may be due to a number of other factors including climate change or other human-induced or natural processes. The co-variation of a number of proxies, particularly a combination of biotic (pollen, fungal spores) and abiotic (sediment, charcoal) types may allow for a stronger interpretation that these variations were a result of pastoralist activity. By treating each of these proxies as independent variables, PCA is an effective way to measure co-variation within the entire dataset and aid the interpretation of the data. It must be stressed that in this study PCA is an exploratory method for summarising the main characteristics of the data set. Variation of principal components loadings cannot be taken *a priori* evidence of pastoralist activity or other environmental variation and interpretation must ultimately be based on examination of the underlying data the PCA is based on. The following Chapter 6 presents the results of the lab methods described in this chapter, applied to each of the cores from the field sampling in Chapter 4.

Chapter 6 Results

6.1 Introduction

This chapter presents the results of the analytical methods described in Chapter 5 as applied to the cores sampled in the 2017 and 2018 field seasons. No interpretation or comparison of the data is attempted until the following Chapter 7, with the exception of some preliminary examination of the loading of components within the PCA results as is necessary for the presentation of these data. As the site of Pari Has was resampled in 2018, the data from core PH01 has been superseded by PH03. Dates and pollen data from PH01 have been included in Appendix C – Preliminary PH01 data (superseded), however, these data were in a preliminary stage before parameters for identification and classification of all pollen types had been established. Due to high levels of compression and problems in the sampling process, KS02 was not analysed thus the core has not been described in this chapter.

6.2 PH03

6.2.1 Logging

Core PH03 is 350cm long and comprises six stratigraphic units (Figure 6.1). Unit 6 (0-102cm depth in core) is a very thick-bedded, very dark brown (10YR 2/2) humified organic mud with many rootlets, grass and *Carex* fragments, and *Carex* seed coats throughout the matrix. This unit is soft and deformable with high moisture content, terminating with a diffuse 1cm lower boundary. Unit 5 (102-135cm) is a thick-bedded very dark greyish brown (10YR 4/2) clastic mud with a minor organic component comprising very fine rootlets and leaf fragments . An indistinct 5cm lower boundary (very dark greyish brown; 10YR 3/2) spans 130-135cm.

Unit 4 (135-283cm) is a very thick, very dark brown-black (10YR 2/1) humified mud/peat bed. The primary component of this unit is organic material comparable to Unit 6, with occasional twig (ø2-4mm, 10-20mm length) or wood fragments (largest size 10x30mm), increasing in concentration towards the base of the unit. This unit is moist, soft and deformable. Between 270 and 283cm are a set of interbedded very thin (1-3cm), very dark grey (2.5Y 3/1) clastic and very dark brown-black peat (10YR 2/1) beds. These sets formed an indistinct boundary with Unit 3 at 283cm.Unit 3 (283-313cm) is a medium-bedded dark greyish brown (2.5Y3/2) mud with secondary component of rootlets and leaf fragments that increase as depth increases, forming a diffuse boundary with Unit 2 at 313cm. Unit 2(313-317cm) is a thin, very dark brown-black (10YR 2/1) humified mud similar in composition to Unit 4, with a sharp lower boundary at 317cm. Unit 1 (317-350cm), is a thick-bedded dark grey (2.5YR 4/2) clastic mud. There are minimal visible organic fragments, which decrease as depth increases. Concentrations of oxidising iron fragments increase with depth.

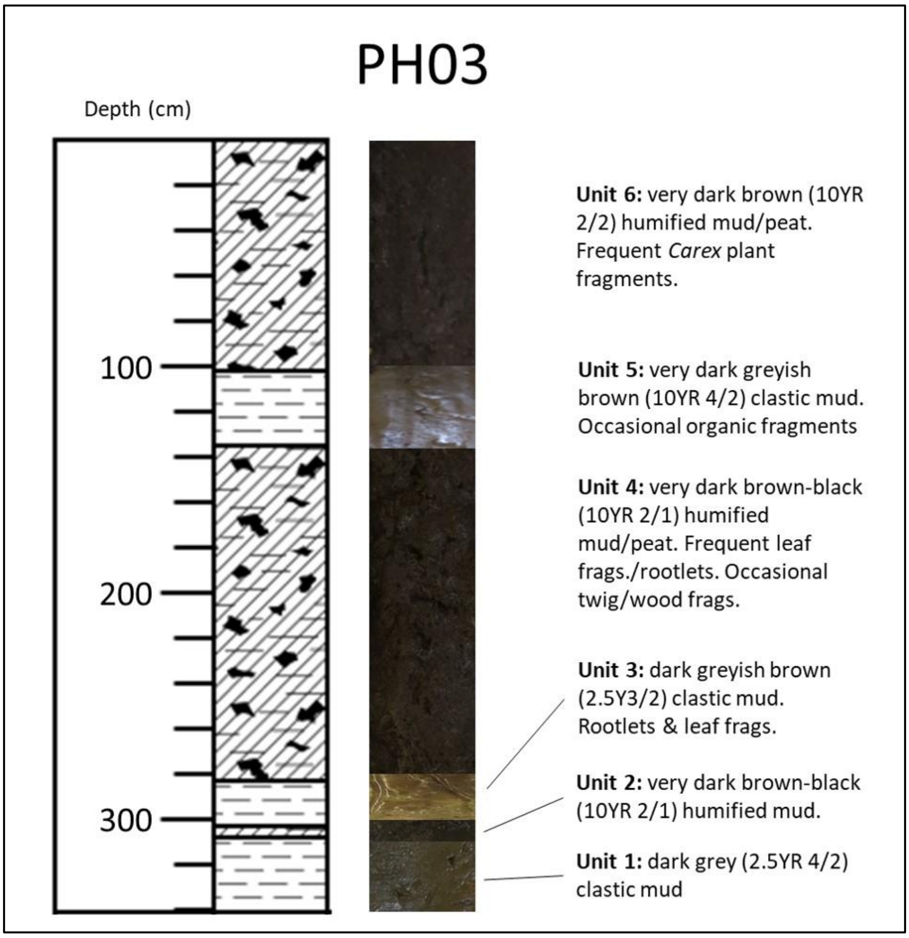

Figure 6.1: Stratigraphic plot and photographic log, core PH03.

6.2.2 Chronology

Four radiocarbon ages from the lower sections of PH03 were returned from plant materials or bulk sediment samples (Table 6.1). Two additional radiocarbon ages were acquired on bulk organic samples from core PH01 at stratigraphic changes common to both cores, and are thus transposed here to core PH03. All samples were dated at DirectAMS (Seattle, USA). Initial 2-sigma range calibrations were made using the Intcal13 curve in Calib 7.1 (Reimer et al., 2013). While the dates were generally in sequence, there were small inversions between dates PH03_2.4_295 & PH03_1.5_332, and PH03_1.3_178 & PH03_2.3_245. The twig sample PH03_2.3_245 was vertical within the sediment matrix and may have been moved down by bioturbation or sampling processes.

Age depth modelling using the Bacon package (Blaauw & Christen, 2011) in R (R Core Team, 2013) assumed a prior average accumulation rate of 10 years/cm based on the oldest date distribution and length of the core (set by d.max=350). Running the model in thirty-nine 9cm thick sections (setting thick=20) allowed for all calibrated age distributions to fall within the model's 95% confidence range (329 years). The maximum uncertainty was 707 years at 117cm depth. All other settings were left as default. Modelled accumulation rates as cm per year were derived from mean values in the model, using the accrate.depth function in Bacon, and plotted using accrate.depth.ghost (Figure 6.2)

Table 6.1: Summary data of AMS dates from core PH03 and transposed dates from PH01. Calibrated in Calib 7.1

Sample no.	Lab code	Material	Depth (cm)	^{14}C age BP	2σ range (cal. BP)	% of probability distribution
PH01-A1	D-AMS 023859	Sediment/peat	95	832 ± 26	692 - 786	100
PH01-C1	D-AMS 023860	Sediment/peat	135	1948 ± 49	1740 - 1756 1780 - 2001	1.2 98.8
PH03_1.3_178	D-AMS 032549	Twig	178	2102 ± 29	1998 - 2145	100
PH03_2.3_245	D-AMS 031342	Twig	245	2079 ± 27	1953 - 1957 1987 - 2130	0.5 99.5
PH03_2.4_295	D-AMS 032553	Sediment	295	2564 ± 24	2539 - 2564 2573 - 2585 2617 - 2632 2699 - 2753	4.8 1.4 3.7 90.1
PH03_1.5_332	D-AMS 031343	Twig	332	2424 ± 30	2352 - 2512 2527 - 2537 2589 - 2616 2633 - 2697	75.7 0.9 5.5 17.9

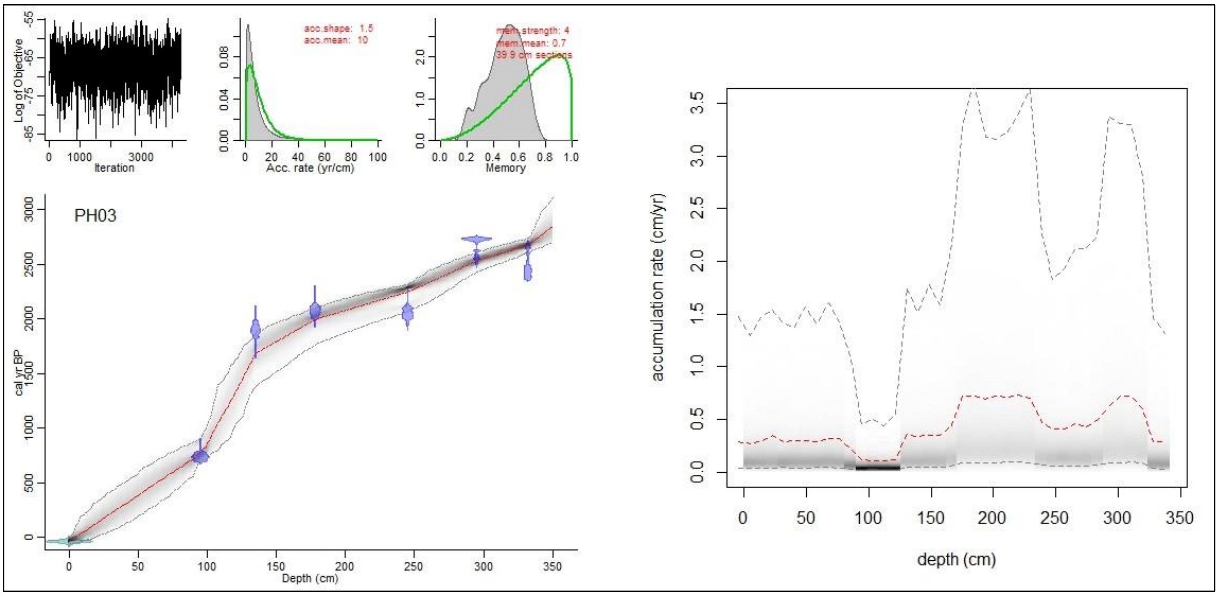

Figure 6.2: Left -Bacon age depth model for core PH03. Calibrated dates indicated by blue distributions. Weighted mean age indicated by dotted red line, 95% confidence range indicated by dashed grey line and grey-black shaded area. Right - modelled mean accumulation rate.

6.2.3 Sediment particle size and magnetic susceptibility

Sediment particle size was variable throughout PH03 (Figure 6.3), though four distinct sections can be clearly correlated with the stratigraphic units described during the initial logging. The largest variations relate to two minima in mean particle size at 100-130cm and 280-350cm. These minima are > 90% clay, with between 8 and 10% silt-sized clasts. Sand makes up no more than 4% of these minima and is generally in the range of 1-2%.

Between 130-280cm, there is higher variability in mean particle size, with a modal peak of 40µm at 180cm with several smaller peaks at around 270, 220 and 160cm. Sand and silt average 17% and

37% of sediment composition between these depths. From 0-100cm sand comprises a mean of 21% and silt 51%, with a mean particle size of 11.5µm. One notable observation is the rapid fluctuation of all values at the boundaries between stratigraphic Units 3 and 4, and Units 5 and 6, as well as their absence at the transition between Units 4 and 5.

All samples were poorly sorted (σ_G 2.00-4.00) or very poorly sorted (σ_G 4.00-16.00). Mean and SD σ_G values for the entire core were 5.5±2.6, and rising to 7.4±1.5 between 0-100cm, and 7.1±2.5 between 130-280cm. There is a very strong positive correlation between increased sand composition and higher sorting values (Pearson's r= 0.913), and a very strong negative correlation between clay and sorting values (r= −0.871). Sand (r= 0.841) and clay (r= −0.73) have strong positive and negative correlations with mean particle size, whereas silt has a moderate linear relationship with the mean particle size (r= 0.58). Sorting values are strongly negatively correlated with skewness (r= −0.745) and kurtosis (r= −0.709). Skewness and kurtosis are strongly positively correlated (r= 0.794).

Magnetic susceptibility (Figure 6.3) Κ values were highly variable but were lower between 0-100cm (range = −0.17-1.6; mean = 0.59 ± 0.39x10^{-1}SI) and 130-280cm (range = −0.72-3.1; mean = 0.94 ± 1.57x10^{-1}SI). Mean Κ value between 100-130cm is 5.9±2.12x10^{-1}SI (range = 1.6-8x10^{-1}SI). Below 280cm (range = 0.9-25.4x10^{-1}SI), magnetic susceptibility rises sharply, averaging 7.98±3.44x10^{-1} SI between 280-315cm and 21.2±4.08x10^{-1}SI between 315-350cm.

6.2.4 Charcoal

Macrocharcoal counts were generally low for both size classes, being seldom higher than 10 particles/cm^{-3} (Figure 6.4). Counts were frequently 0, especially for the >250µm size class. Calculated microcharcoal concentrations averaged 37940 particles/cm^{-3}. Transformation of these counts into modelled annual influx using the modelled accumulation rates (see Section 6.2.2) produced two distinct peaks between 170-150cm and 350-340cm, as well as a smaller peak between 300-280cm, comparable across all charcoal size classes. Mean modelled influx rates were 2.02 particles/cm^2/year for 125-250µm charcoals, 0.77 particles/cm^2/year for >250µm and 13501 particles/cm^2/year for microcharcoal. Influx rates between the 125-250µm and >250µm size classes were strongly correlated (r=0.806), and moderately to weakly correlated with microcharcoal influx rates (r=0.486 and 0.283 respectively). When plotted as deviations around the long-term mean, the three peaks in the modelled influx rate all remain above average (Figure 6.4).

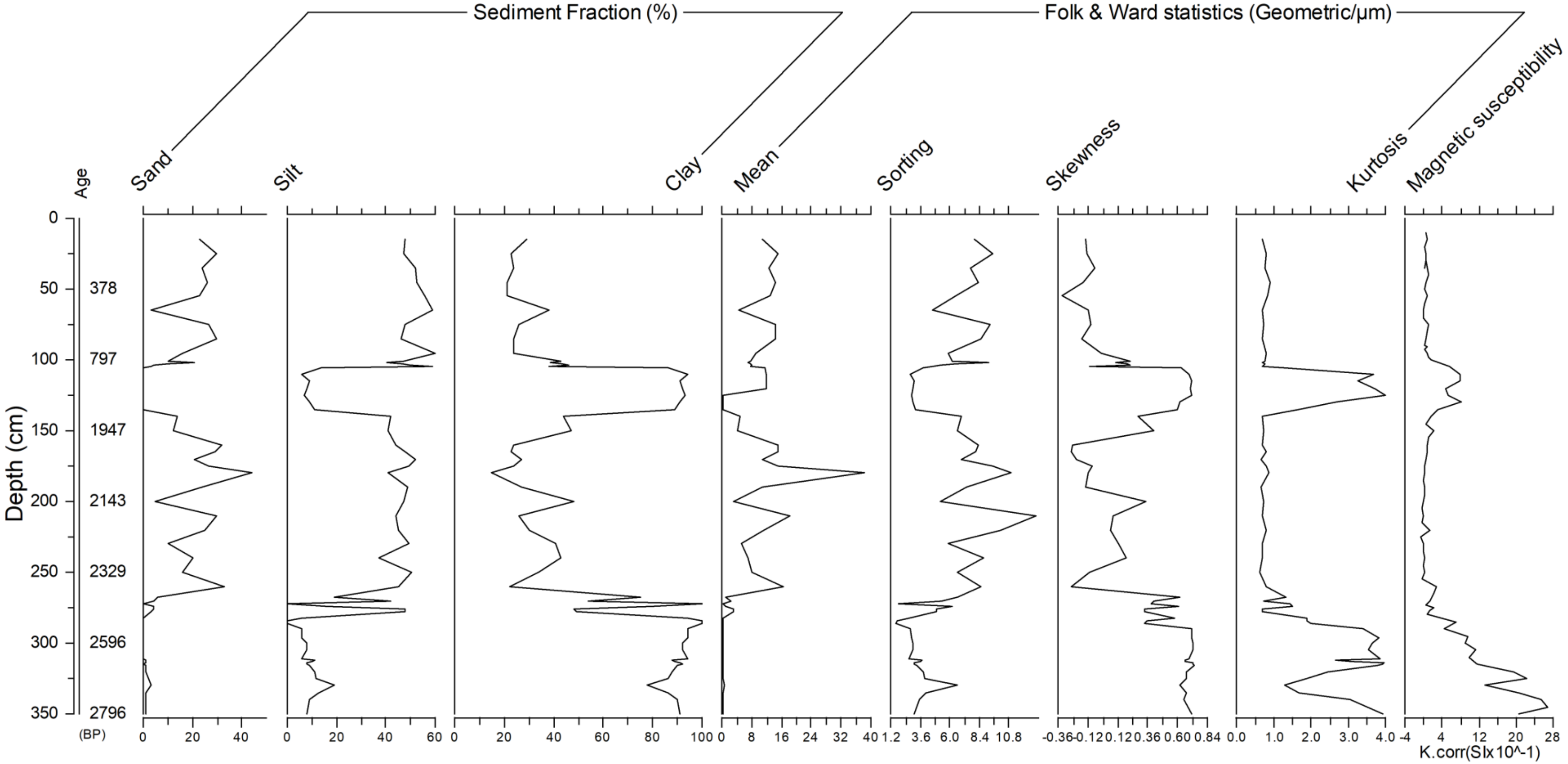

Figure 6.3: Sediment particle size, statistical and magnetic susceptibility data for core PH03.

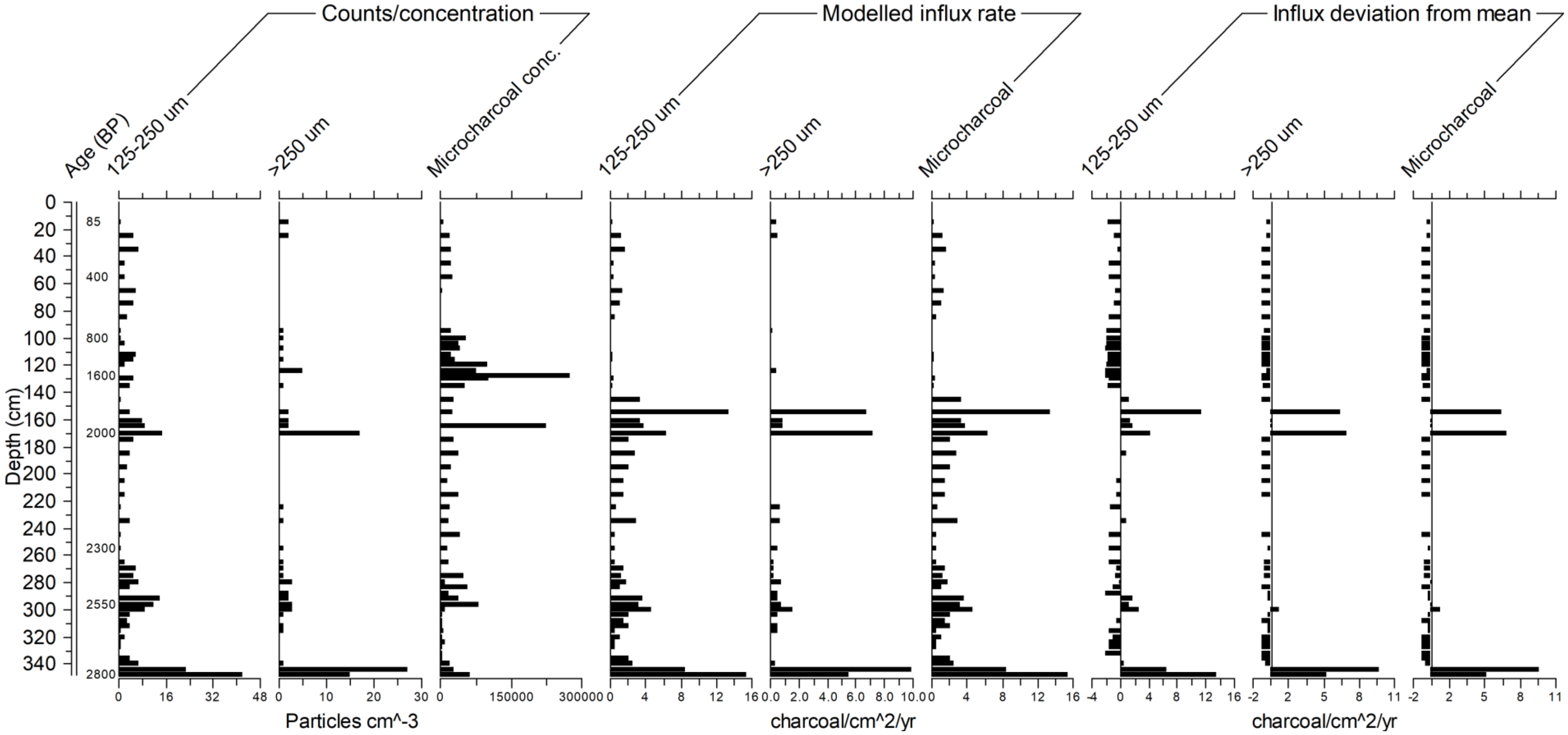

Figure 6.4: Charcoal counts/concentrations, modelled influx and long term variation for core PH03.

6.2.5 Pollen and fungal spores

A total of 51 pollen slide samples were counted between 15-350cm (Figure 6.5, Figure 6.6, Figure 6.7) Total pollen counts ranged from 893−3 (mean 377±252) (Figure 6.7). Lower pollen counts were generally associated with the clay stratigraphic units. Higher counts and concentrations were generally found in the faster accumulating peat units, primarily driven by large numbers of coniferous pollen, requiring high overall counts in order to reach the minimum target of 150 non-arboreal types. The average total pollen count per sample was 376 and a total of 47 taxa were identified. A total of 19,207 identified pollen grains and spores were counted. A total of 261 unidentified pollen grains were distributed in small numbers throughout the dataset (representing 0.15% of the total assemblage) and were excluded when calculating relative abundances. Cyperaceae was also excluded from this calculation and presented as absolute counts only (Figure 6.7, see justification in chapter section 5.6). CONISS analysis based on total sum of squares following a square root transformation of absolute abundances identified five major pollen zones, with Zone 3 divisible into two subzones. Concentrations (spores/cm^3) of coprophagous fungal spores (*Sporormiella, Sordaria* and *Podospora*) were also calculated (Figure 6.7).

Pollen Zone 1 (350-295cm, ca. 2800-2600 BP)

This zone has very low overall total pollen counts. All samples below 320cm had < 20 pollen grains and fern spores counted, after a minimum count of 100 *Lycopodium* spores had been reached and the minimum number of slide transects had been scanned (see methods section 5.6). Between 300-320cm, counts ranged between 50-202 pollens, with an average of 24% (range 17-26%) of this total comprised of Cyperaceae. Other marshy and aquatic taxa, *Myriophyllum* and *Persicaria,* are well represented at between 10-40% of the total assemblage, and monolete and trilete fern spores make up 20-40% and 5-10% of the assemblage between 300-320cm respectively. *Pinus* and *Abies* are the only arboreal taxa present, between 10-40%. Poaceae ranges between 2-4% above 320cm. Undifferentiated Polygonaceae (2-3.5%), Asteraceae (1-7%), Ranunculaceae (0.5-5%) and Amaranthaceae (0.5-3%) are the only herbaceous taxa presented above 1%. *Artemisia* is also present at around 5% in the upper 15cm of this zone. There is a single spike in *Sporormiella* concentration 1834 spores/cm^3 present at 296cm.

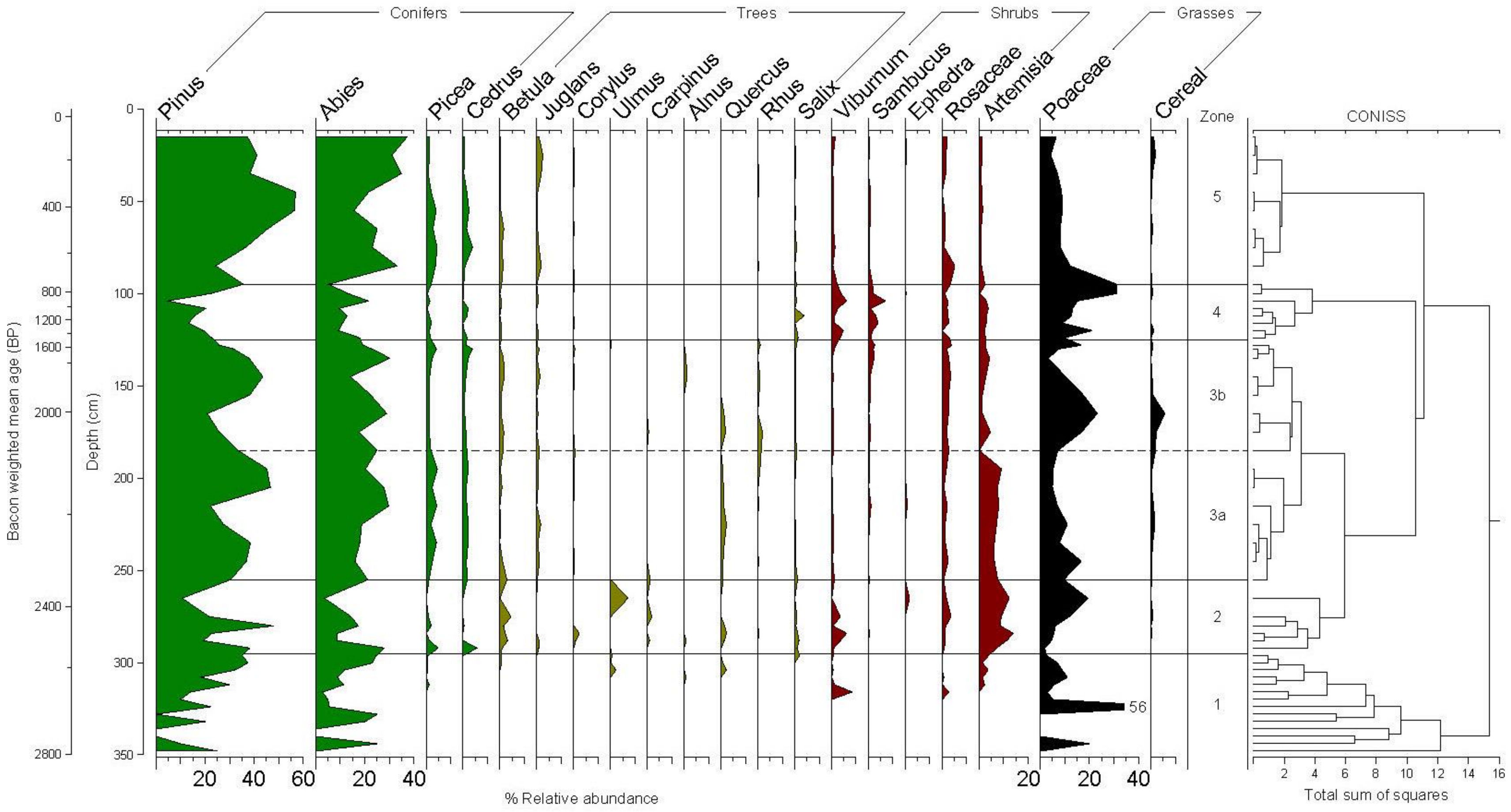

Figure 6.5: Arboreal, shrub and grass pollen relative abundances and cluster analysis for core PH03.

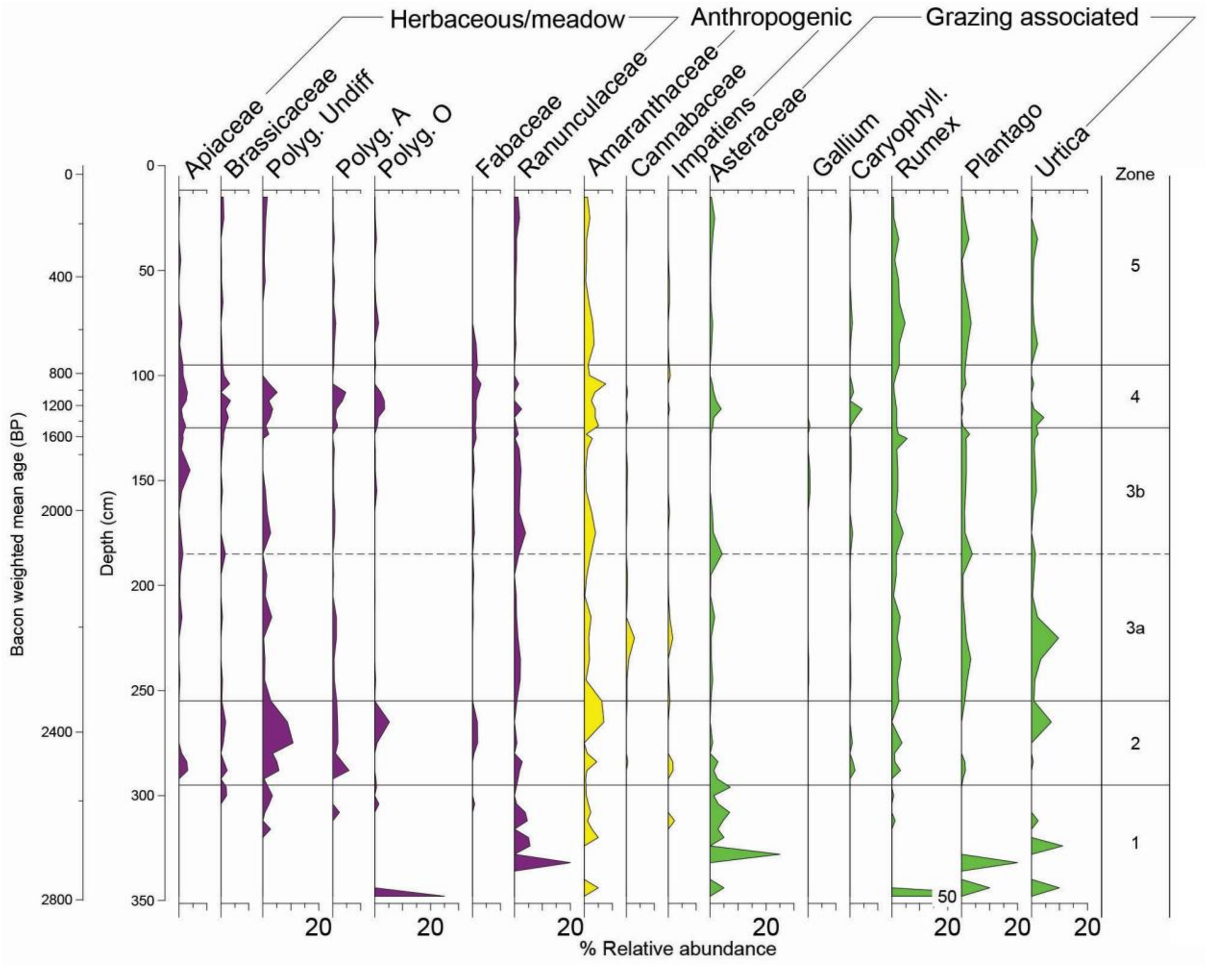

Figure 6.6:Non-arboreal pollen relative abundances for core PH03.

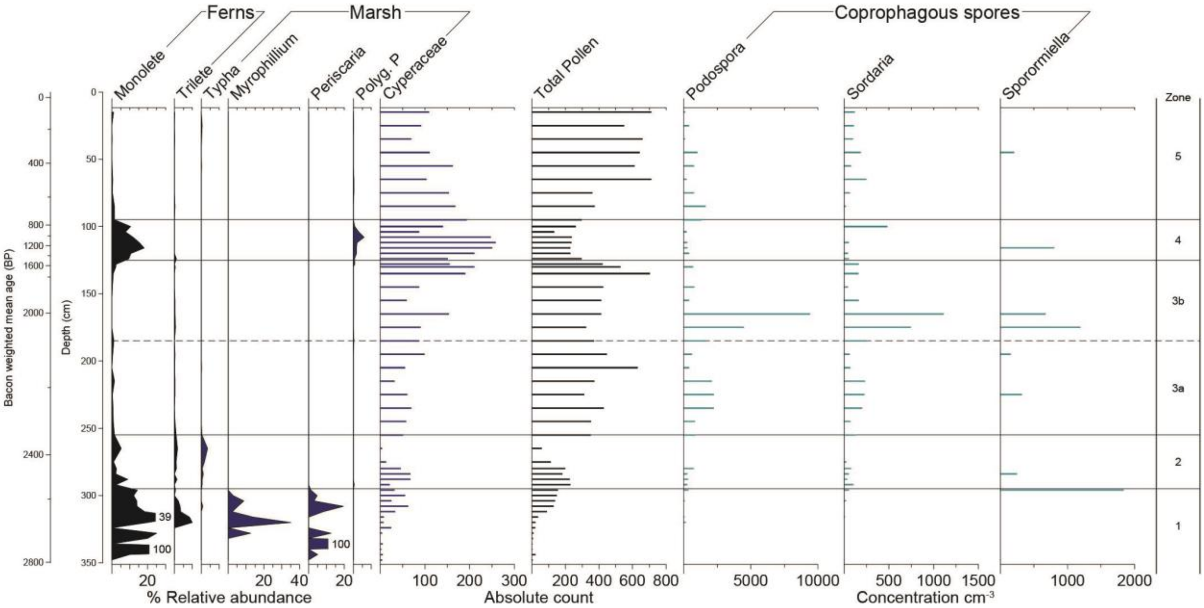

Figure 6.7: Ferns, marshy taxa, relative abundances, total pollen counts and fungal spore concentration for core PH03.

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Pollen Zone 2 (295-255cm, ca. 2600-2300BP)

Total pollen counts in this zone were again low, averaging 231 ± 102 per sample. Major changes in this zone include the sharp increase of *Artemisia* to between 10% and 20% throughout, while other open area colonisers *Viburnum* and Rosaceae also rise to a maximum of 6% and 4%. Arboreal taxa include *Pinus* and *Abies* between 10-20%, whilst broad leafed pioneer taxa such as *Betula*, *Carpinus*, *Corylus* and *Ulmus* are first represented in proportions between 2-7%. *Quercus* and *Salix* are both present at 1-2%. Poaceae rises from 5-10% between the beginning and end of this period, and cereal comprises 1% of the assemblage at 275cm. Monolete and trilete ferns decline to around 5% and 1% respectively. Marshy taxa are absent, with the exception of low representations of *Typha* (0.5-3%). Of the herbaceous taxa, the highest proportions include Polygonaceae (including *Rumex* and *Polygonum* types), Amaranthaceae and *Urtica*, all represented between 1-7%. Coprophagous fungal spores are represented in low concentrations (mean *Podospora* 256/cm^2; *Sordaria* 464/cm^2; *Sporormiella* 254/cm^2).

Pollen Zone 3 (255-125cm, ca. 2300-1500BP)

Zone 3a (255-185cm, ca. 2300-2100BP)

Overall average pollen counts increase to an average of 470 ±96 in this subzone, driven by an increase in conifers, with *Pinus* and *Abies* reaching maximum proportions of 47% and 28% respectively. *Corylus, Carpinus* and *Ulmus* broad leaf elements decline to 0%, while *Betula* and *Quercus* maintain low but stable representations between 2-4% and 1% respectively. *Juglans* is also present at around 1% throughout most of the subzone. Poaceae and *Artemisia* maintain levels of around 10-20%, with *Artemisia* generally being the dominant of the two. Small spikes of anthropogenic/ruderal and grazing-related herbs including *Urtica*, *Impatiens, Plantago*, Cannabaceae to 2-4% between 225-215cm are correlated with an increase in both cereal pollens and coprophagous fungal spore concentration, before most of these decline between 215-185cm.

Zone 3b (285-125cm, ca. 2100-1500BP)

As with subzone 3a, *Pinus/Abies* dominate the arboreal pollen types (mean 35%/24%), while small percentages of *Betula* (mean 1%)*, Juglans* (mean 0.7%) and *Rhus* (mean 0.8%) are the major broad leaf trees. *Quercus* declines to 0% after 165cm/ca. 2000BP and is absent for any subsequent period. *Artemisia* declines markedly from 9% at 195cm to between 1.5-4% throughout the rest of the subzone. Both Poaceae and cereal grasses are strongly represented at 10-24% and 0.5-5% of the assemblage respectively, both peaking between 175cm and 160cm. These peaks appear to be correlated with smaller peaks in *Plantago, Rumex* and *Urtica*, as well as all three coprophagous fungal spore types.

Pollen Zone 4 (125-95cm, ca. 1500-800BP)

Pinus and *Abies* continue to dominate the arboreal pollens though their overall representation is decreased to around 20-30% and 10-15% of the assemblage respectively. *Salix* is the only other tree type with any representation above 1%, having maximum values of 4%. Open area shrubs *Sambucus* and *Viburnum* reach levels of 6-7%. Poaceae fluctuates between 10-20%, before rising to 30% at the top of the zone, while cereal pollens decline to <1%. Polygonaceae types (undifferentiated; *P.*

aviculare; *P. orientale*) maintain levels of around 3-5%, as does Amaranthaceae. With the exception of Asteraceae and Caryophyllaceae, grazing related herbs decline to <1%. Monolete fern spores rise to levels between 10-20%, and *Polygonum plebium* to between 3-6% and Cyperaceae to the highest absolute counts (87-258) throughout the pollen curve. High levels of these taxa favouring wet conditions appear to be the biggest driver of change in this pollen zone. Coprophagous fungal spores are poorly represented in this zone.

Pollen Zone 5 (95-0cm, ca. 800BP-Present)

Monoletes and marshy taxa decline sharply to <1% while coniferous *Pinus-Abies-Picea-Cedrus* dominate the assemblage with maximum proportional representation at 55%, 45%, 5% and 4% respectively. *Juglans* is the only broadleaved tree represented above 1% (mean 1.1%) though *Betula* is present around 1% at the start of this zone. The *Artemisia* curve declines to the lowest values above 295cm (0.8-1.5%, mean 1.1%). Poaceae ranges between 7-12% and cereals average 0.5%. *Rumex, Chenopodium* and *Plantago* reach maximum proportions of 5%, 3% and 2% respectively, while Asteraceae and *Urtica* remain around 1-2%. All other herbs fluctuated between 0-1%. Coprophagous spores are all present throughout this zone (mean *Podospora* 256/cm^2; *Sordaria* 1134/cm^2; *Sporormiella* 202/cm^2) though at levels lower than the maximum concentrations in Pollen Zone 3b.

6.2.6 Principal Components Analysis

Pollen variables in the PCA included summed total counts for conifers, trees/shrubs, grazing-related and other herbaceous taxa, Poaceae, *Artemisia,* ferns and marshy taxa, following groupings from the stratigraphic pollen plots. Other variables included macrocharcoal counts and coprophagous fungal spore concentrations, both of which were converted in influx rates before their inclusion. As there was good correlation between all charcoal size classes in the initial results, the two macro−charcoal sizes were summed and considered as a proxy of local to extra-local burning.

The first three principal components represented 55% of variation in the dataset, with PC1 (28.3% variance) and PCA3 (13.93% variance) inferred to be significant indicators of environmental change (Appendix B – Supplementary data). Driving the variance in PCA1 were strong negative loadings for ferns and marshy taxa (-0.46 and -0.45 respectively) and strong positive loadings for conifers (0.4), apparently representing wet/dry conditions in the landscape. Variation in PC3 was driven by strong positive values for Poaceae (0.47), charcoal (0.36) and fungal spore (0.59) influxes, and strong negative values for *Artemisia* (-0.61) and conifers (-0.25), leading to interpretation of this component as openness of landscape and grazing activity.

An exploratory plot of the data (Figure 6.8) show two major groupings of observations, with one large cluster falling to the left of the graph and a second to the right. As PC1 (x-axis) has been interpreted as a moisture gradient, and PCA3 (y-axis) as an indicator of grazing activity, observations falling further to the left may be indicative of a wetter environment, and those towards the top of the plot may be periods of intensified pastoralist activity in the landscape. Three samples fall outside the 95% confidence ellipse, two of which (165, 185) had extremely high counts of grazing related pollens, charcoals and fungal spores prior to their decomposition for PCA.

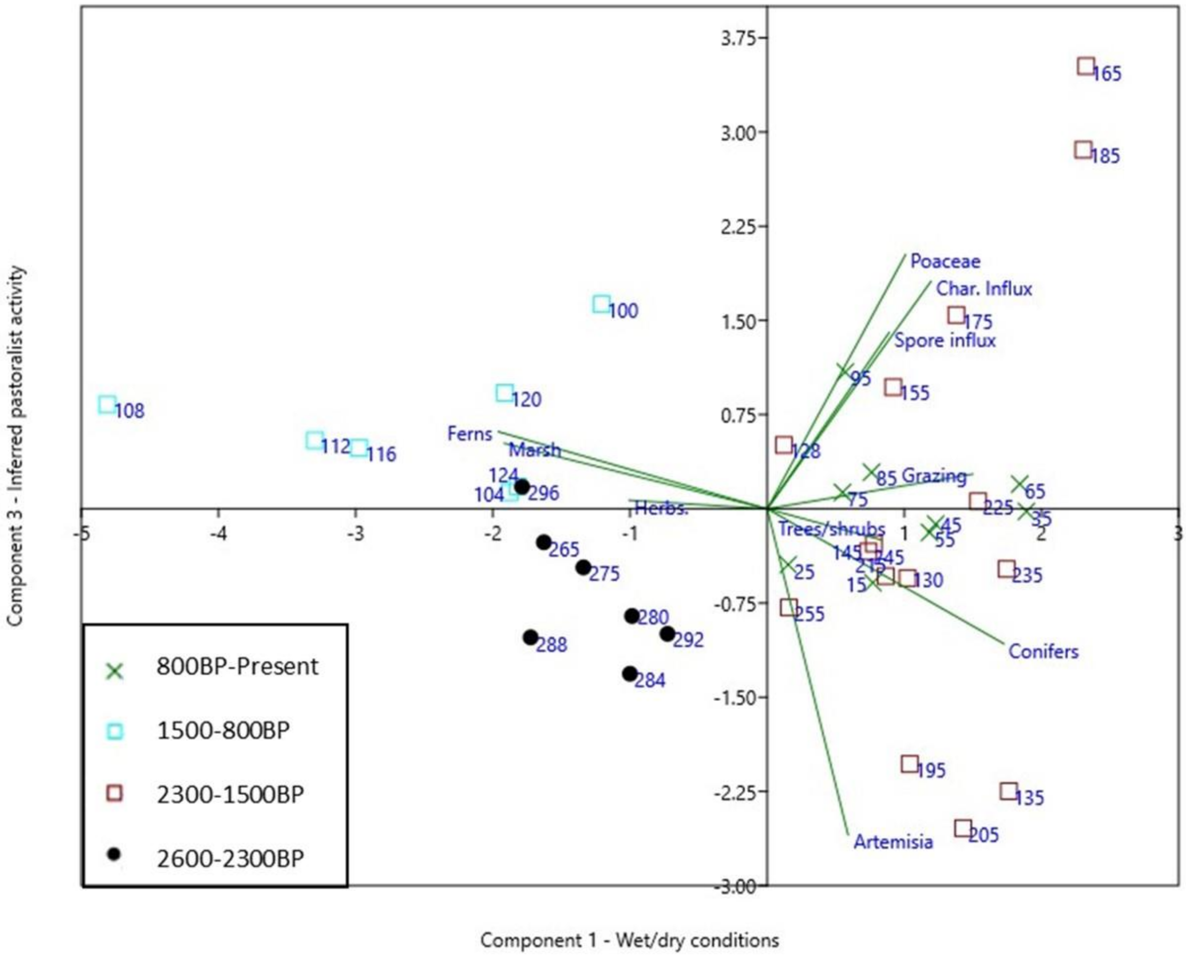

Figure 6.8: PCA biplot for core PH03. X-axis interpreted as indicating environmental conditions; Y-axis as indicator of pastoralist land use.

6.3 SG02

6.3.1 Logging

SG02 is 115cm long core with three stratigraphic units (Figure 6.9). Unit 3 (0-49cm depth in core) is a thick- bedded dark greyish brown (2.5Y 3/1) humified mud. Secondary organic components are primarily fibrous plant material, generally rootlets and leaf fragments. Two pairs of small (<3mm) bivalve shells were recorded at 7cm. There is a concentration of woody and fibrous organic plant material between 41-43cm. Below 43cm the matrix becomes more friable, with visible sand grains as well as rarely observed Panjal Trap gravels. Diffuse boundary with Unit 2 at 48-49cm.

Unit 2 (49-105cm) is a thick-bedded dark olive brown (2.5Y 3/3) compact clay. Clastic elements form the primary component of this unit, with organic materials concentrated in small sections. Occasional ironstone gravels 1-2mmø are dispersed throughout and a number of wood fragments (max size 10x25mm) are deposited at 83-34cm. Large leaf fragments up 4cm across are deposited between 85-90cm, bedded at an angle up to 45°. At 90cm colour changes to very dark grey (10YR 3/1). Compaction and stiffness of sediment also increases after this depth and sub-angular gravels 3-5mm become more frequent. There is a sharp boundary with Unit 3 at 105cm. Unit 3 (105-115cm) is a greenish grey (5GY 5/1) mud of unknown bedding thickness. This unit is heavily compact and appears to be almost completely composed of clastic elements. On dissection for subsampling frequent angular Panjal Trap gravels and iron stones 2-5mm in size were recorded.

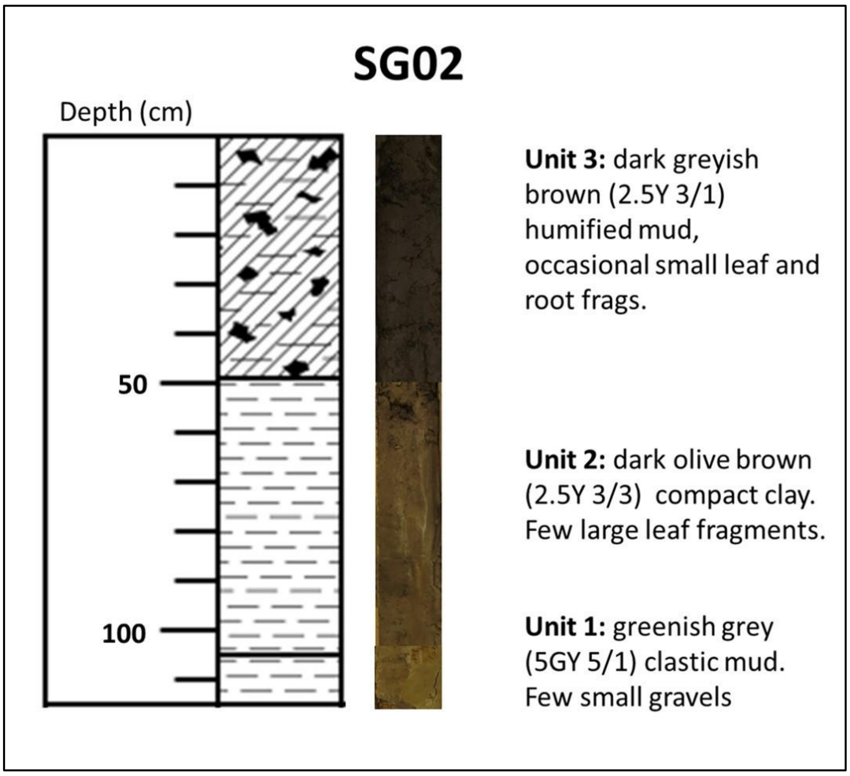

Figure 6.9: Stratigraphic plot and photographic log, core SG02.

6.3.2 Chronology

One charcoal and two wood fragments were dated at DirectAMS (Table 6.2). All calibrated ranges for the returned dates were in sequence and covered a span of roughly the last 2500 years. The upper and lowermost samples were located close to stratigraphic changes and aimed to chronologically "bookend" these transitions.

Table 6.2: Summary data of AMS dates from core SG02. Calibrated in Calib 7.1.

Sample no.	Lab code	Material	Depth (cm)	^{14}C age BP	2σ range (cal. BP)	% of probability distribution
SG02_1.1_48	D-AMS 032550	Wood	48	347 ± 23	315 - 411 420 - 485	59 41
SG02_2.1_79	D-AMS 032551	Wood	79	919 ± 26	769 - 772 781 - 920	0.3 99.7
SG02_1.2_105	D-AMS 031340	Charcoal	105	2491 ± 31	2458 - 2743	100

The Bacon age-depth model assumed a mean accumulation rate of 20yr/cm (based on d.max=115). The model was run in 24 sections of 5cm. All other settings were left as default. The mean uncertainty was 351 years. All three dates fell within this 95% confidence range (Figure 6.10).

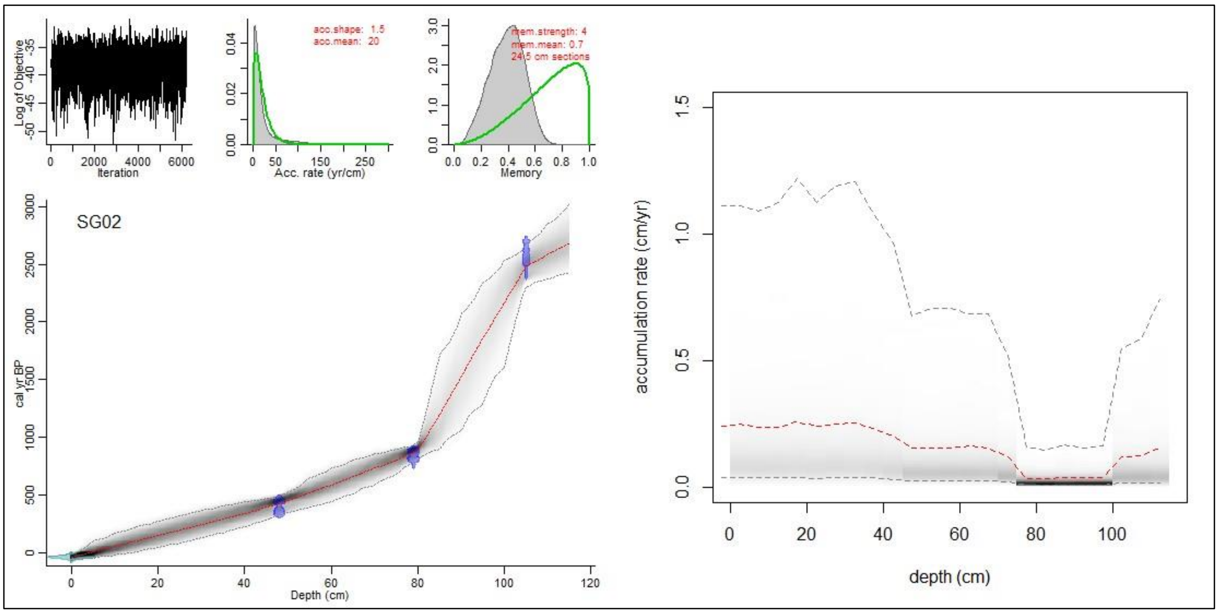

Figure 6.10: Left -Bacon age depth model for core SG02. Right - modelled mean accumulation rate in cm/yr.

Modelled mean accumulation rates are generally low (<0.01cm/yr) between the dated materials at 79 and 105cm (Figure 6.10) This rate steadily and consistently climbs after 75cm, reaching a maximum rate of 0.2cm/yr towards the top of the core. This change in accumulation rate appears consistent with the stratigraphic changes from the initial core logging, with the more rapid accumulation rates correlated to sections with higher organic debris.

6.3.3 Sediment particle size and magnetic susceptibility

Sediment particle size samples were taken at 5cm intervals. Sediment size varied throughout the core, though can be broadly classified into two units (Figure 6.11). Between 115-55cm, clay is the dominant component, ranging from 55-92% (mean 75 ± 13.56%) of the distribution. Sand comprises 5% at 85cm, and makes up no more than 1% of sediment elsewhere in this unit. Silt ranges between 8-45% (mean 23.5 ± 12%).

Between 55-0cm, the sand fraction rises sharply to between 4.5-33% (mean 22 ± 11.9%) of the sediment size distribution. Clay has a mean of 36.3 ± 11.9% and silt averages 41.7 ± 5.89%. The sand fraction and mean particle size demonstrate a very strong correlation ($r = 0.936$). Throughout the core, sediments are classed as very poorly sorted, though these reach maximum values between 35-15cm (mean σ_G 12.47 ± 0.53). Sand and sorting values are also very strongly correlated ($r = 0.993$).

Magnetic susceptibility К (Figure 6.11) values fluctuate throughout the core. Between 115-90cm, К values average 11 ± 2.01x10^{-1}SI. The mean К falls to 6.8 ± 3.4x10^{-1}SI between 90-75m. These values climb to an average of 9.7 ± 1. 3x10^{-1}SI between 75-60cm before reducing to an average of 3.2 ± 2x10^{-1}SI from 60-0cm. Lower К values appear to be correlated with rises in mean sediment size. These areas of the core also had higher amounts of organic detritus recorded during the initial logging stage.

6.3.4 Charcoal

Sixteen samples at 8cm intervals were taken for charcoal and pollen analysis (Figure 6.12). Overall counts of macrocharcoal were very low throughout the core. The highest counts for 125-250µm and >250µm charcoals were both at 24cm depth, totalling 9 and 5 respectively. Mean modelled influx rates were 0.48 particles/cm^2/year (125-250µm), 0.26 particles/cm^2/year (>250µm) and 3080 particles/cm^2/year (<125µm). Modelled influx rates and deviation from mean influxes both indicate a peak for all size classes at 45-25cm. Influxes of 125-250µm and >250µm charcoals are strongly correlated ($r = 0.8$), and there is a moderate positive relationship between influxes of each of these size classes and microcharcoal influx (for 125-250µm, $r = 0.51$; >250µm, $r = 0.64$).

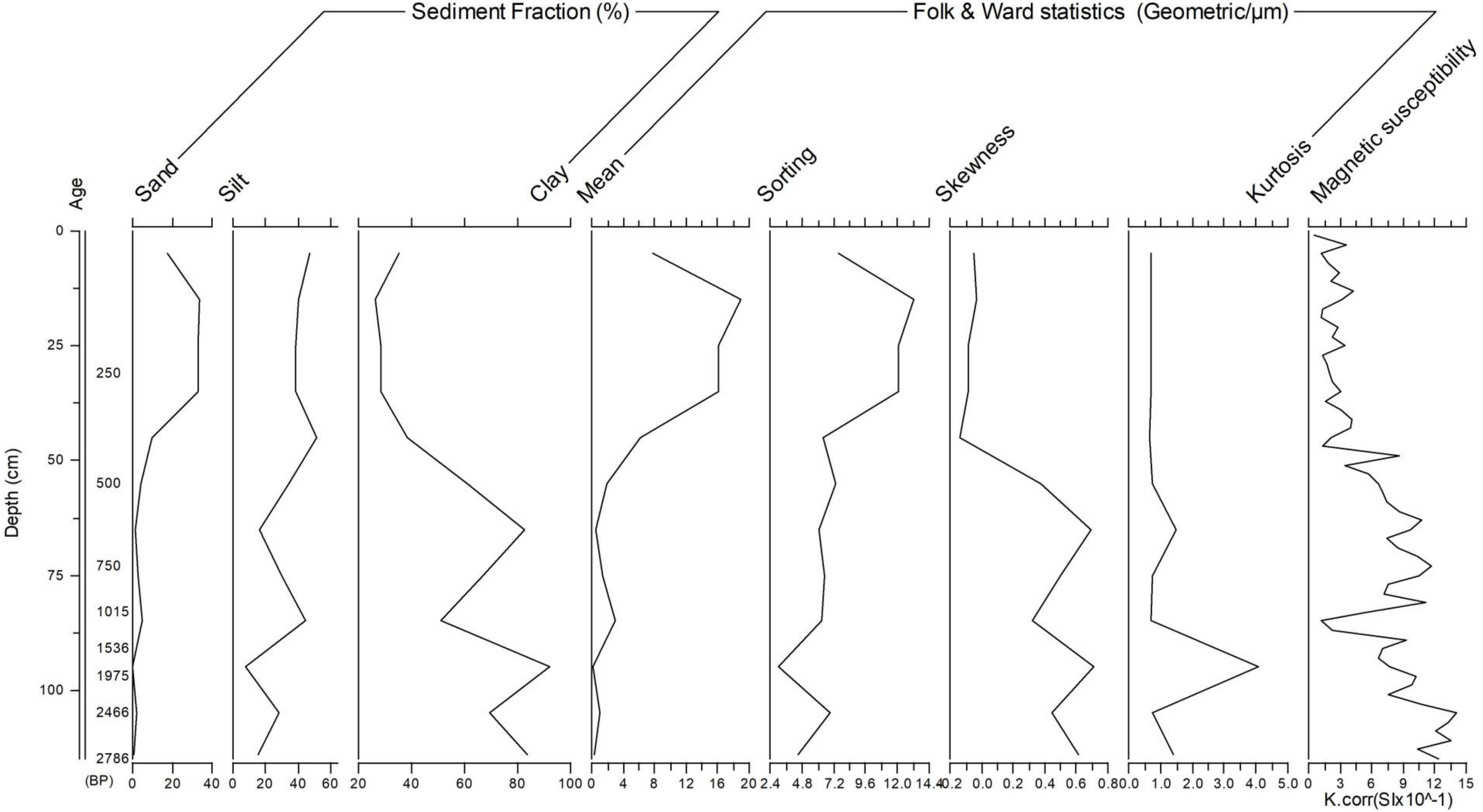

Figure 6.11: : Sediment particle size, statistical and magnetic susceptibility data for core SG02.

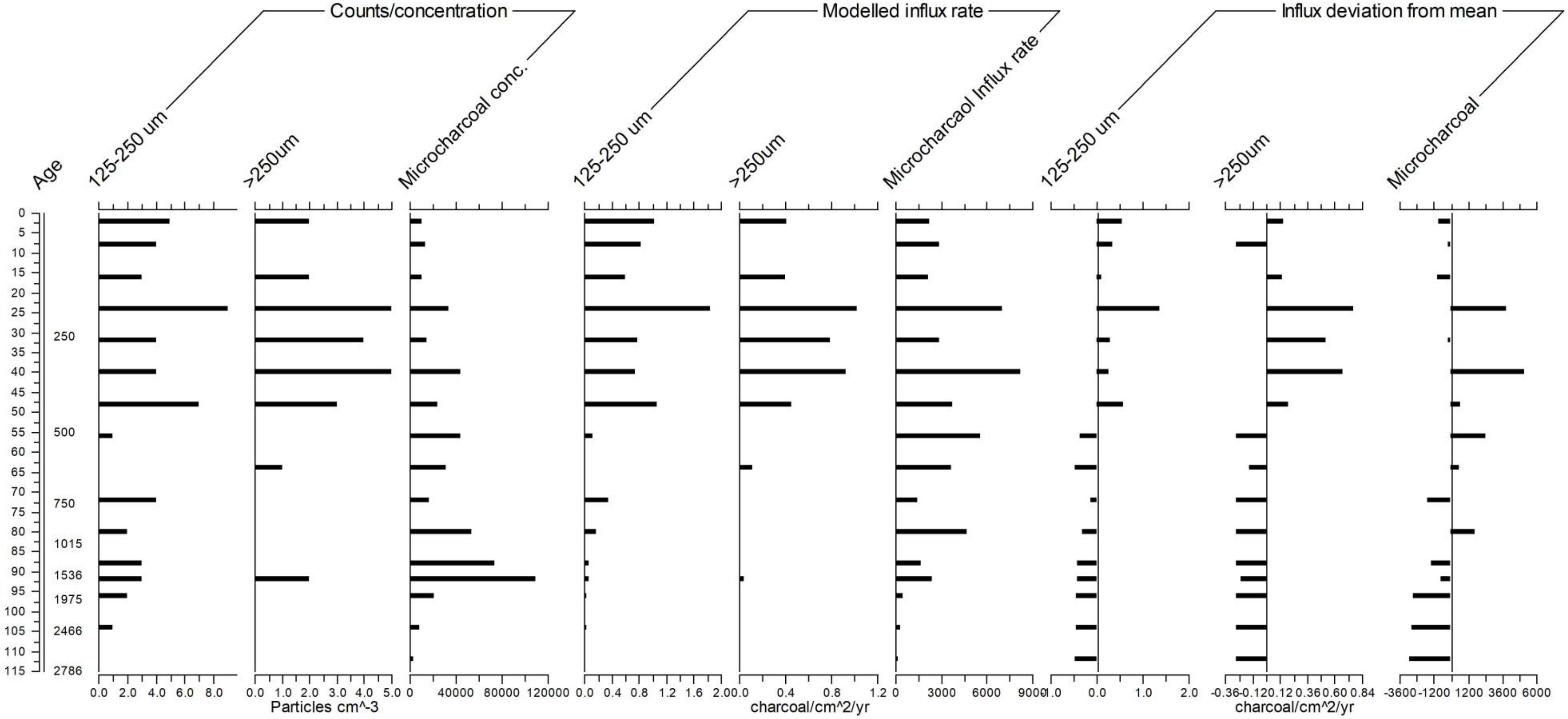

Figure 6.12: Charcoal counts/concentrations, modelled influx and long term variation for core SG02.

6.3.5 Pollen and fungal spores

A total of 16 samples were analysed for pollen counts. Total pollen counts generally ranged between 5-733 (mean 473 ± 174) (Figure 6.13, Figure 6.14). A total of 7591 pollens and 41 types were counted. A few types typically associated with marshy or wet environments (*Salix*, *Persicaria*, *Myriophyllum* and *Polygonum plebium*) had total counts of less than 10 for the entire assemblage and were excluded from analysis and plots. Five pollen zones were identified through CONISS analysis.

Pollen Zone 1 (115-104cm, ca. 2700-2400 BP)

At 112cm a total of only 5 pollens (2 each *Pinus/Abies*, 1 Ranunculaceae) were counted after one slide was scanned and 222 *Lycopodium* spores were counted and further counting was abandoned. At 104cm, Poaceae, *Pinus* and *Abies* respectively comprising around 21, 27 and 35% of the total of 115 pollens respectively. *Artemisia* (3.4%) *Betula* (2.7%) and *Viburnum* (1.7%) are the only trees or shrubs above 1%. Herbs present include Brassicaceae (1.7%) and Ranunculaceae (3.4%).

***Pollen Zone 2* (**104-80cm, ca. 2400-900 BP)

Poaceae (mean 12%), *Pinus* (mean 23%) and *Abies* (mean 20%) continue to be the dominant taxa in this zone. Other tree taxa are dominated by *Betula* averaging 8.5%. *Quercus* rises to 2% at the end of this zone. *Artemisia* fluctuates between 3-8% in an apparently antagonistic relationship to Poaceae. Cereal pollen is present (1%) at 88cm. Herbaceous taxa present include *Chenopodium*, *Urtica*, *Rumex*, Asteraceae and Ranunculaceae at 1-2% each. Monolete fern spores range between 5-8% of the total assemblage and Cyperaceae totals up to 66 pollens. Concentrations of *Podospora* and *Sordaria* are present at mean concentrations of 387 and 294 spores/cm^{-3} respectively.

Pollen Zone 3 (80-64cm, ca. 900-650 BP)

This zone is marked by the rise of *Betula* to up to 35%, becoming the dominant component of the assemblage (mean 28.45%). *Artemisia* also averages 7.9%, as Poaceae declines to an average of 5.9% of the assemblage. *Abies* and *Pinus* also decline to 17-20% and 15-16% respectively. *Quercus* disappears from the tree pollen spectrum and *Corylus* and *Carpinus* become established at around 2% each. Cereal pollen reaches its highest representation throughout the entire curve at 1.6% at 80cm. Most herbaceous types are now established at between 1-2%. *Sordaria* is present at similar levels to the preceding zone, while *Posodpora* and *Sporormiella* are represented discontinuously. Counts of Cyperaceae (88-90 grains) reach their highest values throughout the curve, while proportional representation of monolete fern spores drops to 3-5%.

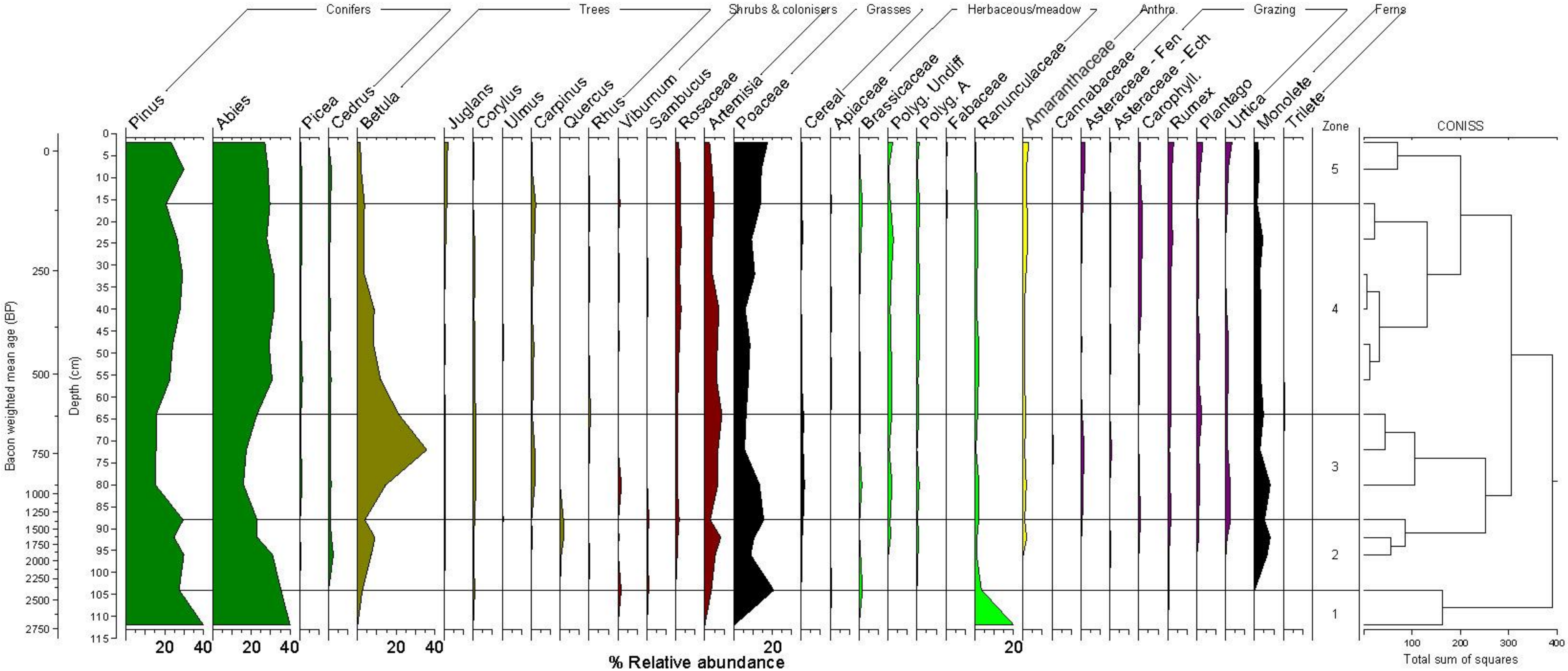

Figure 6.13: Pollen relative abundances and cluster analysis for core SG02.

Pollen Zone 4 (64-16cm, ca. 650-100BP)

Betula (mean 6.6%) declines sharply from the beginning of this zone and conifers are again the dominant arboreal types as well as dominant taxa overall (mean *Pinus/Abies* 25/30%). *Artemisia* declines to an average of 5% and Poaceae rises to a 9% average. Grazing related herbs *Rumex* (mean 2%), *Plantago* (mean 1.5%) and Caryophyllaceae (mean 1%), as well as Amaranthaceae (mean 1.5%) are the dominant herbaceous taxa. Coprophagous spores are present in the levels higher than in earlier zones (mean *Podospora/Sordaria/Sporormiella* - 364/514/425 spores/cm^{-3}).

Pollen Zone 5 (16-0cm, ca. 100BP-Present)

Pinus (mean 25%) and *Abies* (mean 28%) continue to dominate the assemblage overall. *Betula* declines to an average of 2.4% and *Juglans* rises to a mean of 1.6%. *Artemisia* ranges from 2.4-4.9% and Roasaceae rises to a range of 1.5-2.9%. Grazing related herbs including Asteraceae (cf. fenestrate; range 1-2.1%), *Rumex* (2-3%), *Plantago* (0.5-3.3%) and *Urtica* (1-3.3%) are the dominant non-arboreal taxa. Monolete spores comprise an average of 1.5% and Cyperaceae counts range from 20-60. With the exception of Podospora, concentrations of coprophagous spores slightly decrease (mean *Podospora/Sordaria/Sporormiella* - 670/330/348 spores/cm^{-3}).

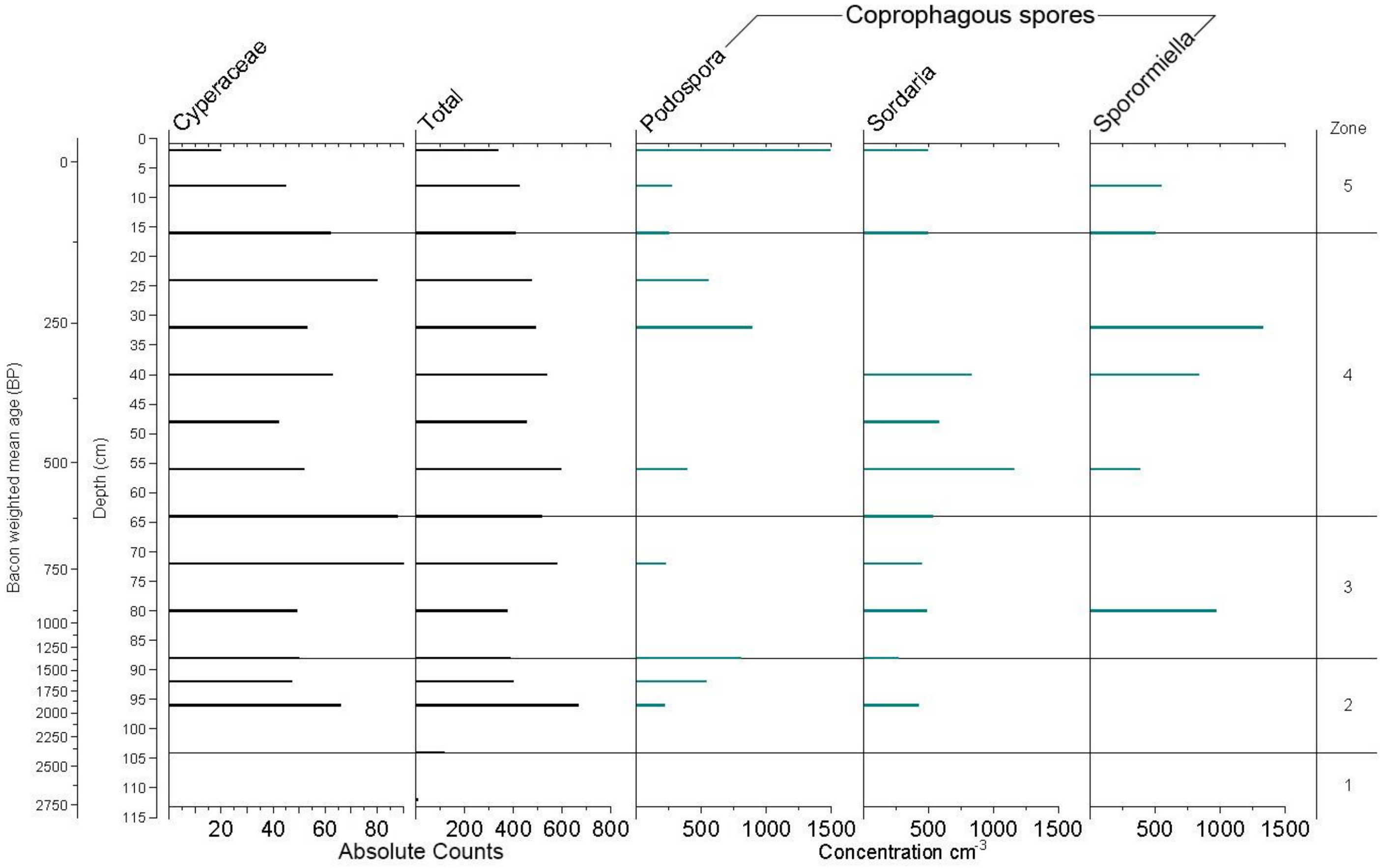

Figure 6.14: Total pollen counts and fungal spore concentrations for core SG02.

6.3.6 Principal Components Analysis

Variables for PCA included Poaceae, *Artemisia*, coprophagous spore influx, charcoal influx and summed pollen counts for conifers, tree/shrubs, ferns, herbs and grazing related taxa. As cereal pollens represented only 0.003% of the total pollen count, these were excluded as a significant variable for SG02. Samples at 112 and 104cm were also excluded due to their very low pollen concentrations.PC1-PC3 represented 79% of the variance in the dataset (Appendix B – Supplementary data), with PC1 (38% variance) and PC3 (19% variance) interpreted as significant for examining human-environmental interactions. Variation on PC1 is driven by strong positive eigenvalue loadings for grazing related pollens (0.32), charcoal (0.37) and coprophagous spore (0.38) influx and Poaceae (0.27). PC1 also has strong negative eigenvalues for *Artemisia* (−0.45) and trees/shurbs (−0.34). The antagonistic relationship between these variables indicates that variation on PC1 is likely as a result of intensified grazing activity. Variation on PC3 appears to be driven by strong positive eigenvalues for conifers (0.55) and *Artemisia* (0.21), indicating that positive loadings on PC3 may be indicators of a drier environment. A biplot (Figure 6.15) of the PCA indicates illustrates that variation on PC1 (eigenvalues ranging from −2.96-3.67) divides the data into two groups. With the exception of the sample from 88cm, all other sample depths with positive x-axis loadings were 48cm and above.

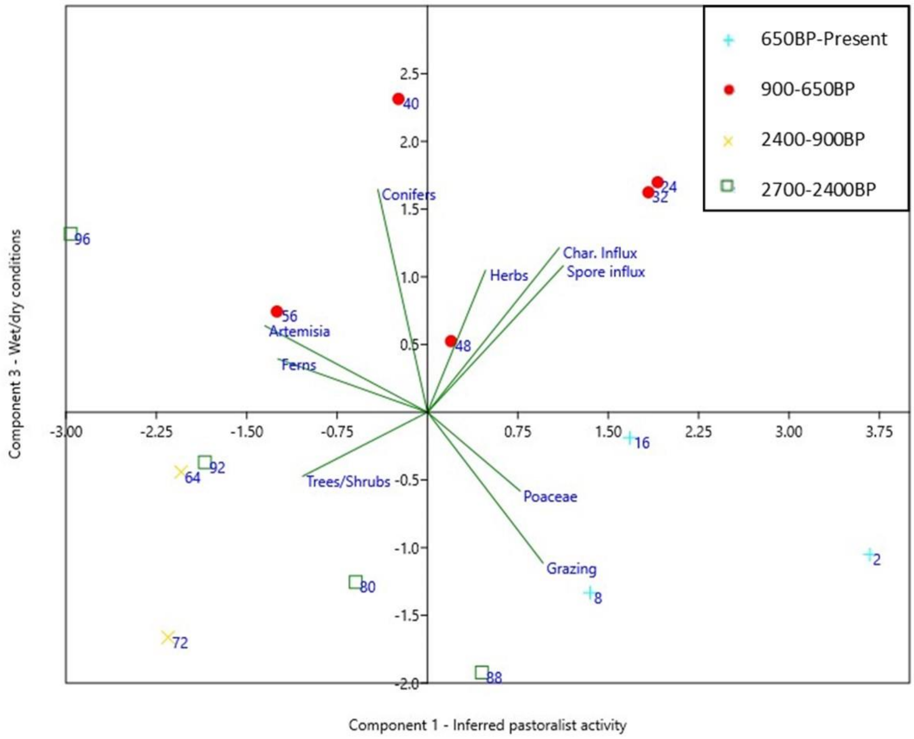

Figure 6.15: PCA biplot for core SG02. X-axis interpreted indicating pastoralist land use; Y-axis as indicator of environmental conditions.

6.4 TM01

6.4.1 Logging

TM01 is a core 130cm long and is composed of eight stratigraphic units (Figure 6.16). Unit 8 (0-25cm depth in core) is a medium-bedded very dark greyish brown (2.5Y 3/2) humified mud. Organic components include rootlets and small grass/Cyperaceae leaf fragments. Indistinct (2cm) boundary with Unit 7 between 23-25cm depth. Unit 7 (25-31cm) is a thin-bedded greyish brown (2.5Y 2/2) clastic mud bedded between 25-31cm. Small ironstones ø <1mm comprise a secondary component of this unit. There are very few visible organic components. There is an indistinct 2-3cm boundary with Unit 6 from 29-31cm.

Unit 6 (31-45cm) is a medium-bedded very dark greyish brown (2.5Y 3/2) humified mud. Clastic and organic components are both present in similar proportions, with the organic fraction comprising fine roots, *Carex* seed coats and small leaf fragments. Sand grains are visible in the clastic fraction and the matrix is brittle or friable throughout. At 44-45cm is an indistinct lower boundary. Unit 5 (45-58cm) is a medium-bedded dark very dark greyish brown (10YR 3/1) clastic mud. Small ironstone gravels ø <1mm comprise a minor component. This unit is deformable, with higher moisture content than Unit 6. At 58cm is a diffuse boundary with Unit 4.

Stratigraphic Unit 4 (58-80cm) is a medium-bedded black (10YR 2/1) peat primarily composed of highly fragmented plant material including rootlets, leaf fragments and *Carex* seed coats. The unit is soft and deformable. The unit terminates with a sharp lower boundary at 80cm. Unit 3 (80-85cm) is a thin-bedded very dark brown (10YR 2/2) clastic mud with few organic inclusions, terminating with a sharp lower boundary at 85cm.

Unit 2 (85-101cm) is a medium-bedded grey (2.5YR 5/1) clastic mud, with occasional greyish brown (10YR 5/2) mottling. The matrix is compact and deformable. Between 85-89cm a secondary organic component comprised of fine rootlets and small (<2mm) fragmented leaf material is visible. Below 90cm small (1-2mm) subangular gravels are present, increasing as depth increases, to 98cm. Lower boundary is indistinct. Unit 1 (101-130cm) is a greyish brown (2.5YR 5/2) clastic mud of unknown bedding thickness. Between 104-117cm is a concentration of rounded to subangular gravels 2-5mm in size. Below 117cm gravels decrease as depth increases. There are no major or minor visible organic components.

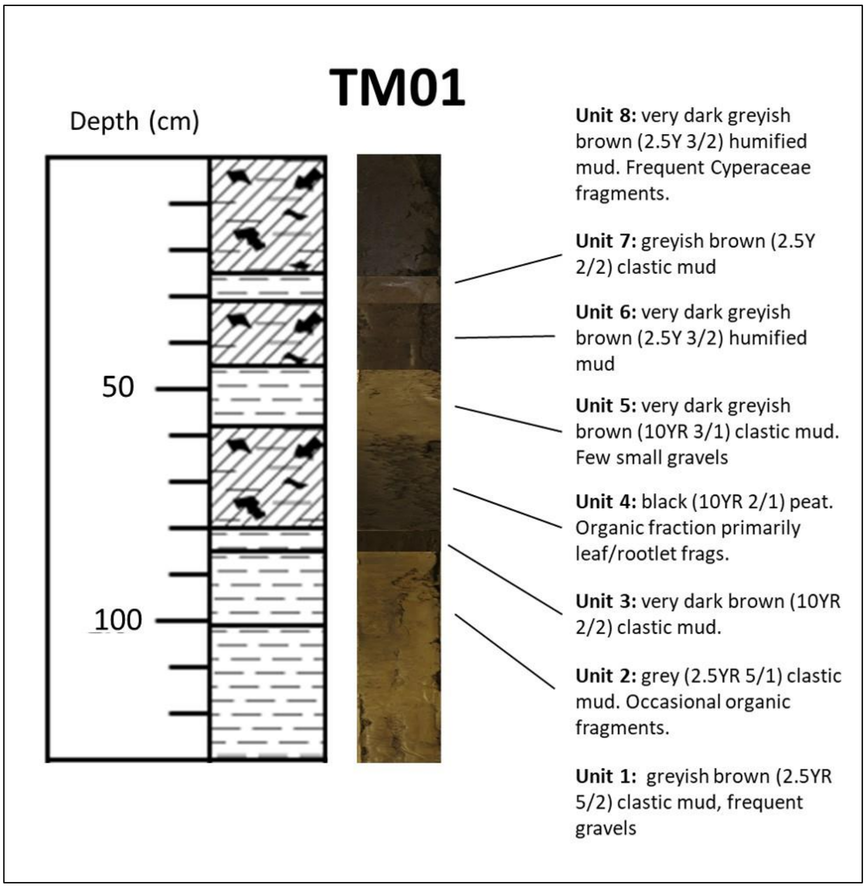

Figure 6.16: Stratigraphic plot and photographic log, core TM01.

6.4.2 Chronology

Six dates were acquired from bulk sediment samples at DirectAMS (Table 6.3). Sample TM01_1.1_40 represented an inversion, being out of sequence with above and below dates. Sample TM01_1.1_23 returned a modern date (36±26 years BP) and was unable to be calibrated (Stuvier et al. 2019). This sample was 23cm below the surface and may have been contaminated by modern intrusions. As sediment below 90cm appeared to be primarily clastic mud and gravel, obtaining a date on organic material was problematic and ages could only be derived using age depth modelling with a high range of uncertainty (Figure 6.17).

Table 6.3 Summary data of AMS dates from core TM01. Calibrated in Calib 7.1

Sample no.	Lab code	Material	Depth (cm)	^{14}C age BP	2σ range (cal. BP)	% of probability distribution
TM01_1.1_23	D-AMS 034134	Sediment	23	36 ± 26	N/A	N/A
TM01_1.1_33	D-AMS 034135	Sediment	33	2554 ± 29	2157 - 2263 2298 - 2343	63.6 36.4
TM01_1.1_40	D-AMS 032554	Sediment	40	2708 ± 28	2758 - 2855	100
TM01_2.1_61	D-AMS 032555	Sediment	61	2618 ± 30	2064 - 2084 2103 - 2212 2220 - 2308	3.3 47.3 49.4
TM01_2.1_77	D-AMS 034136	Sediment	77	2937 ± 29	2985 - 3175	100
TM01_2.1_88	D-AMS 031622	Sediment	88	3443 ± 35	3614 -3782 3786 - 3828	81.6 18.4

The age depth model in Bacon assumed a prior mean accumulation rate of 50 years/cm based on the overall length of the core (set by d.max=130). The model was run in 66 sections of 2cm thickness. All other settings were left as default. Dates TM01_1.1_40 and TM01_1.1_23 fell outside of the models 95% confidence range (Figure 6.17). Mean confidence range was 616 years, though this in part relates to the wide confidence range between TM01_2.1_88 and the base of the core (1500 years at 130cm).

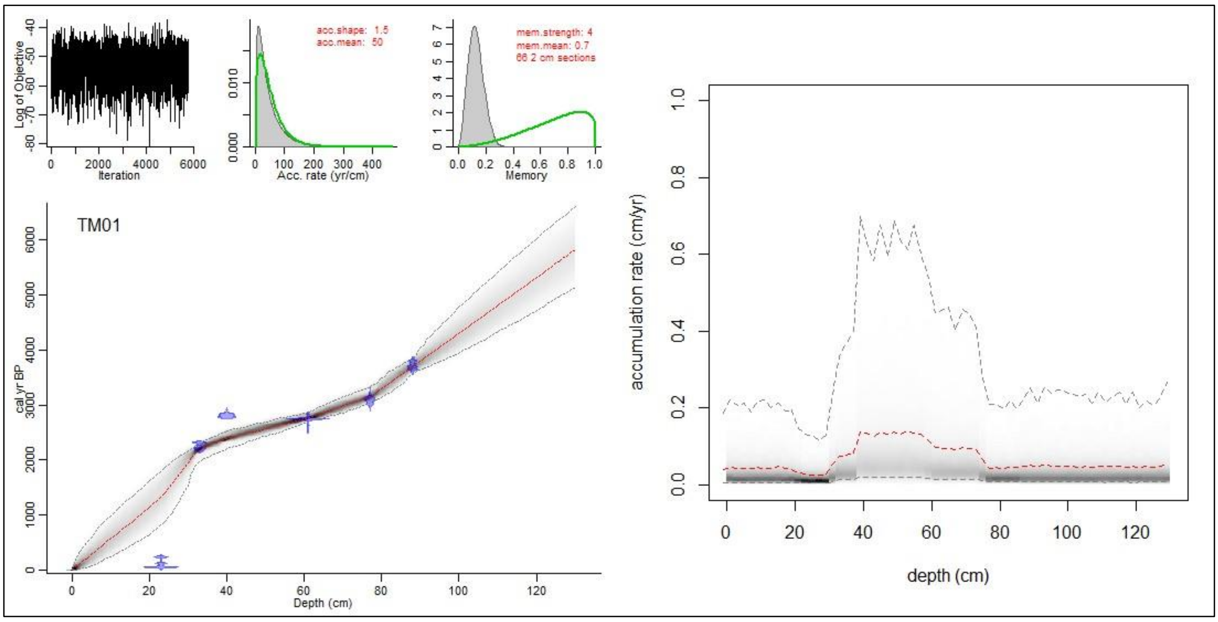

Figure 6.17: Left -Bacon age depth model for core TM01. Right - modelled mean accumulation rate in cm/yr.

Between 80-130cm, mean modelled accumulation rate (Figure 6.17) varied little (0.042-0.049 cm/year). Between 79-60cm, mean accumulation rates ranged from 0.049-0.12 cm/year. The highest accumulation rates were between 59-40cm (0.113-0.129 cm/year) before falling to 0.026-0.78 cm/year between 39-0cm.

6.4.3 Sediment particle size and magnetic susceptibility

Sediment size was variable throughout TM01 (Figure 6.18) (mean size range 0.28-8.23µm), though was typically dominated by clay (30-87.6%; mean 55 ± 13%), followed by silt-sized particles (11-60%; mean 39 ± 11%). Sand comprised between 0.2-20% (mean 5.4 ± 3.8%) of the sediment. Overall variation in mean sediment size can be grouped into five discrete regions by depth.

From 130-105cm, mean particle size is 2.97 ± 1.53µm, with sand composition ranging from 2-10%. Between these depths were also gravel counts (>2mm) ranging 2-18 per cm^2. Mean particle size falls to 1.1 ± 0.65µm between 105-82cm, with sand ranging 0.07-2.4% and increased clay fractions ranging from 35-87% (mean 70 ± 17%).

Between 82-30cm overall, mean particle size increases to 3.4 ± 1.2µm, apparently relating to higher proportional inputs of sand (3.4-11%; mean 6.4 ± 2.4%). From 30-25cm depth, mean particle size drops to 0.9 ± 0.5µm, with clay comprising 66-85%. Sand declines to between 0.04-2%, before rising to 3-20% (mean 8 ±6.9%) between 30-0cm depth. Also from 30-0cm, mean particle size ranges 2.4-8.2µm, silt comprises 41-47% (mean 43.7 ± 2%) and clay 37-55% (mean 48 ± 6.7%).

With the exception of two minima at 30cm (σ_G 3.8)and 92cm (σ_G 3.8), all sediments fell into the very poorly sorted class (σ_G range 5.2-9; mean 6.3 ± 0.74). Higher sorting values were moderately correlated with higher sand input ($r = 0.65$) and moderately negatively related to higher clay input ($r = -0.42$). Kurtosis (K_g) values averaged 8.4 ± 4.1 throughout the core, falling within the extremely leptokuric ($K_g > 3$) range, with three peaks at 92, 83 and 30cm. The strongest linear relationships for kurtosis are with silt ($r = -0.73$) and clay ($r = 0.7$). The strongest relationship for skewness (Sk_g) of sediment size distribution was with mean particle size ($r = -0.94$).

Magnetic susceptibility (Figure 6.18) was extremely variable throughout the core (K range 0.97-157.6x10^{-1}SI; mean 13.2 ± 24.2x10^{-1}SI). Between 130-105cm, mean magnetic susceptibility is 45 ± 40.6x10^{-1}SI, declining sharply to mean K 10 ± 4.64x10^{-1}SI at depths 105-82cm. Between 82-60cm, K has an average of 1.7 ± 0.6x10^{-1}SI before climbing to an average of 4.64 ± 1.47x10^{-1}SI for the remaining depths between 60-0cm. Because of the high variability of magnetic susceptibility values, there was no linear relationship to changes in particle size.

6.4.4 Charcoal

Counts for both macrocharcoal size classes were low throughout TM01 (Figure 6.19), ranging 0-8 for 125-250µm charcoals (mean 2.6 ± 1.8) and 0-3 for charcoals >250µm (mean 0.9 ± 1.1). Estimated microcharcoal concentrations range between 14891-141468 particles/cm^3 (mean 48058 ± 29209 particles/cm^3). Conversion of counts and concentration to influx rates indicated above average influx of all size classes between 70-80cm depth and 50-60cm depth. Between 0-16cm, influxes of macrocharcoals were also above the long-term average. There was a moderate positive relationship between influx rates of 125-250µm charcoals and >250µm charcoals ($r = 0.68$), as well as a weaker positive relationship between both these size classes and microcharcoal influx ($r = 0.33$ for 125-250µm; $r = 0.3$ for >250µm).

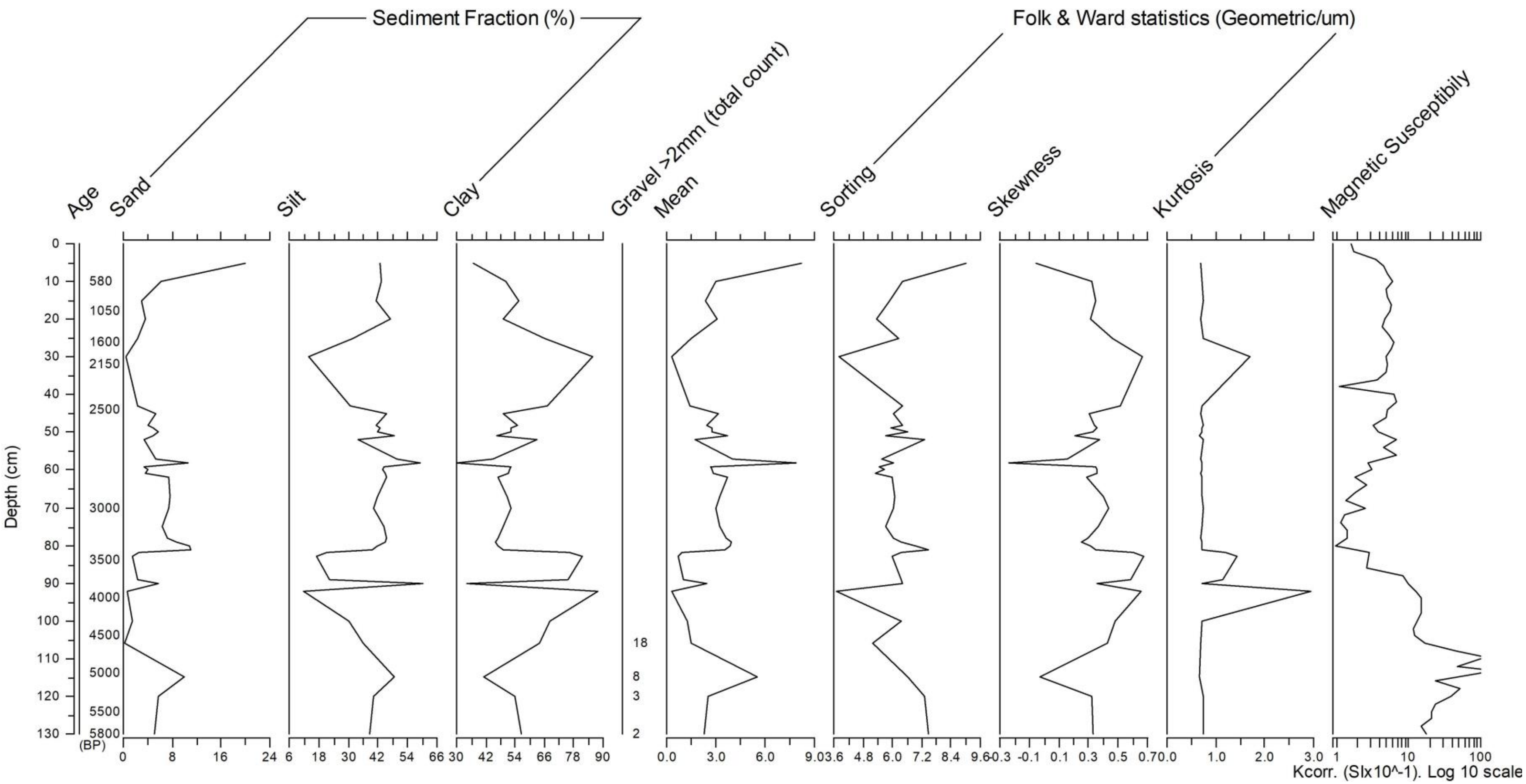

Figure 6.18: Sediment particle size, statistical and magnetic susceptibility data for core TM01. Log-10 scale applied to magnetic susceptibility.

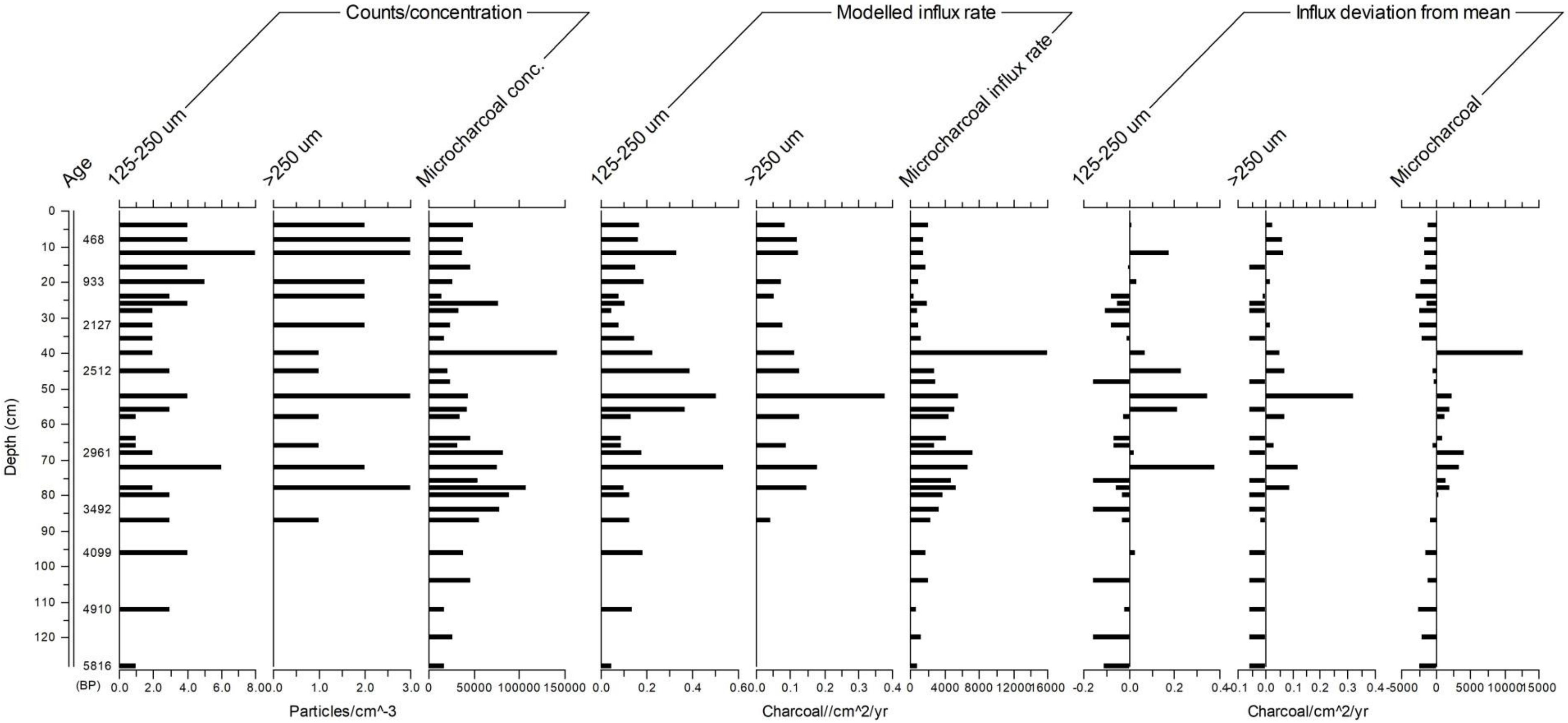

Figure 6.19: Charcoal counts/concentrations, modelled influx and long term variation for core TM01.

6.4.5 Pollen and fungal spores

A total of 32 pollen slides were counted (Figure 6.20, Figure 6.21, Figure 6.22), with total counts per sample ranging between 3-640 (mean 402 ± 188). Low pollen counts were associated with the clastic-gravel stratigraphic Unit 1. A total of 12,489 pollen grains from 38 types were counted. Six pollen zones were identified through using a total sum of squares CONISS cluster analysis based on square root transformation of absolute abundances. Cyperaceae was excluded from this analysis and from relative abundance calculations.

Pollen Zone 1 (130-96cm, ca. 5800-4100 BP)

Total pollen counts in this zone were low (3-39; mean 17 ± 17). Between 104-96cm, absolute totals range from 38-39, with Poaceae (13-47%), *Abies* (4.5-12%) and monolete fern spores (13-36%) being the dominant taxa. Cyperaceae counts range from 15-16 at these depths.

Pollen Zone 2 **(**96-84cm, ca. 4100-3500BP)

Pollen counts in this zone range between 486-625 (mean 583 ± 69). *Betula* (13.9-20%) dominates the arboreal taxa with *Quercus* (2.1-7%), *Abies* (6.3-8.8%) and *Pinus* (10-15%) comprising other significant components. *Artemisia* (13-29%) and Poaceae (10-16%) dominate the non-arboreal taxa, with *Rumex* (1-6%), Rosaceae (1-3%) and Polygonaceae (1-3%) being the other herbs present above 1%. Monolete fern spores decline to 1.5-3% and Cypereceae counts range between 150-215 total. *Sordaria/Podospora/Sporormiella* are all present (148-1849/0-297/630-731 spores/cm^3).

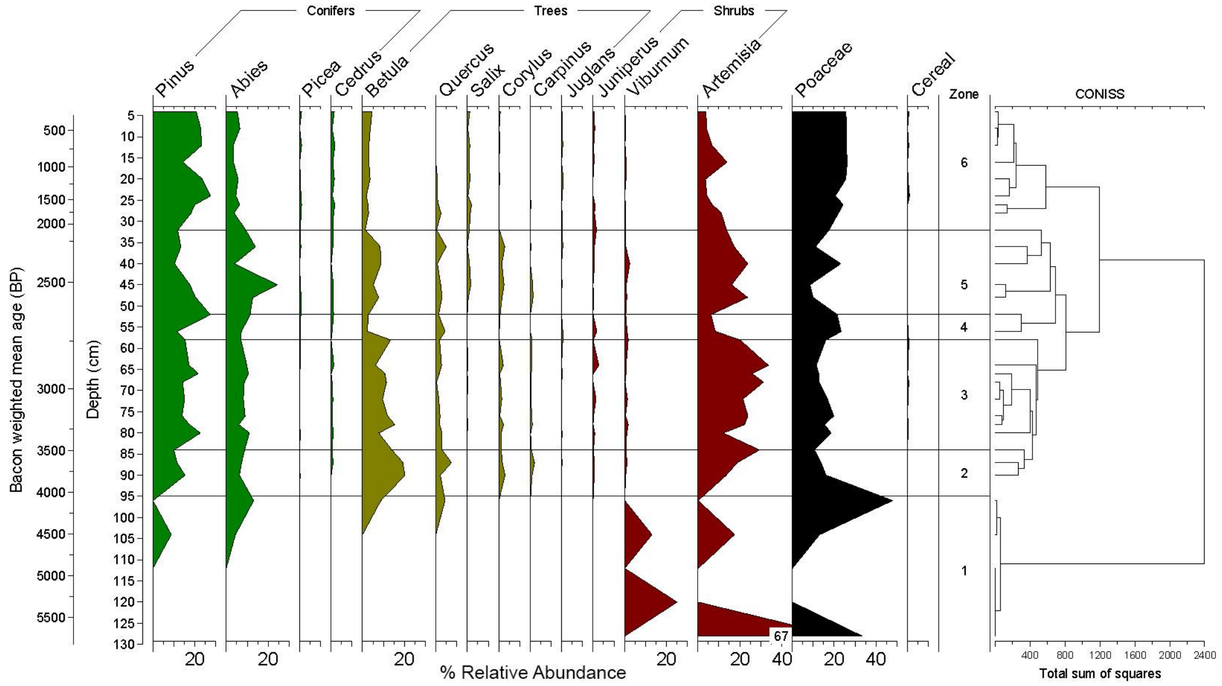

Figure 6.20:: Arboreal, shrub and grass pollen relative abundances and cluster analysis for core TM01.

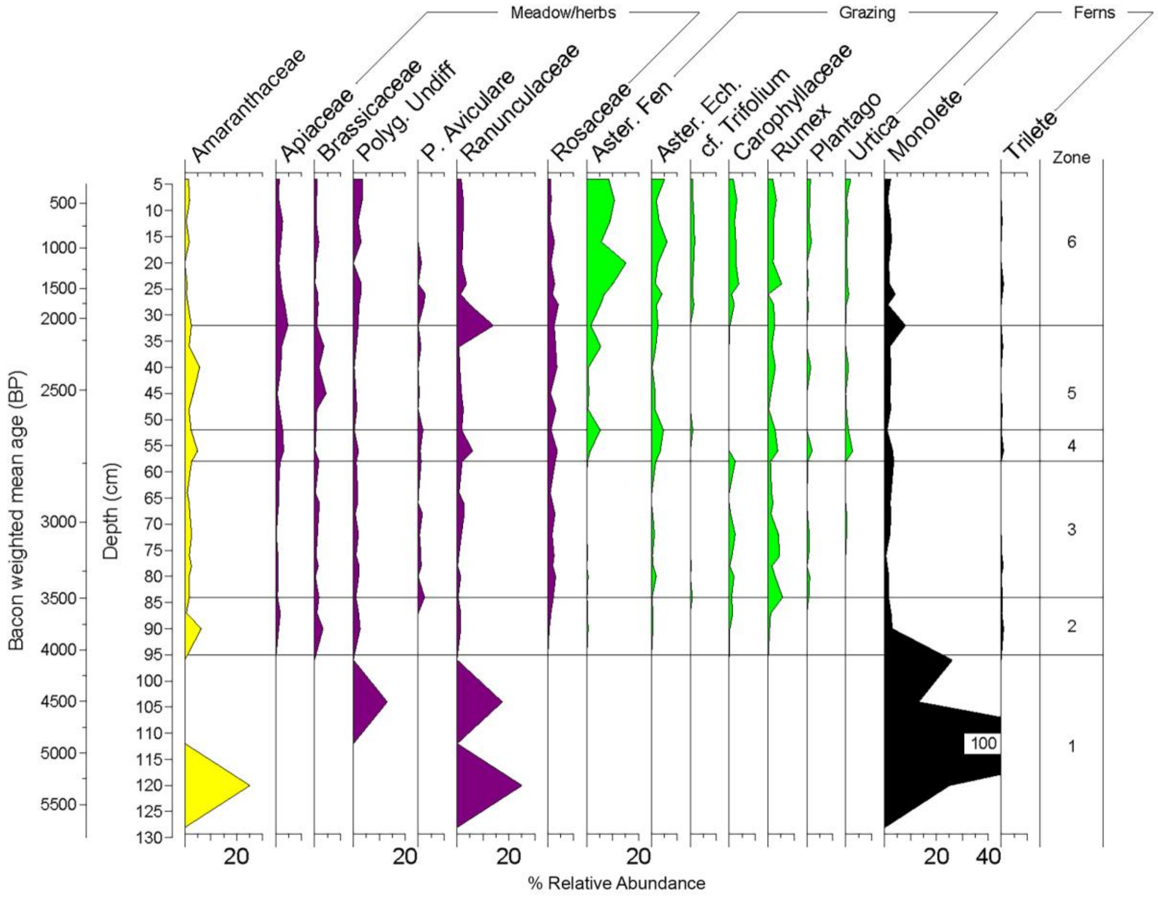

Figure 6.21: Non-arboreal pollen relative abundances for core TM01.

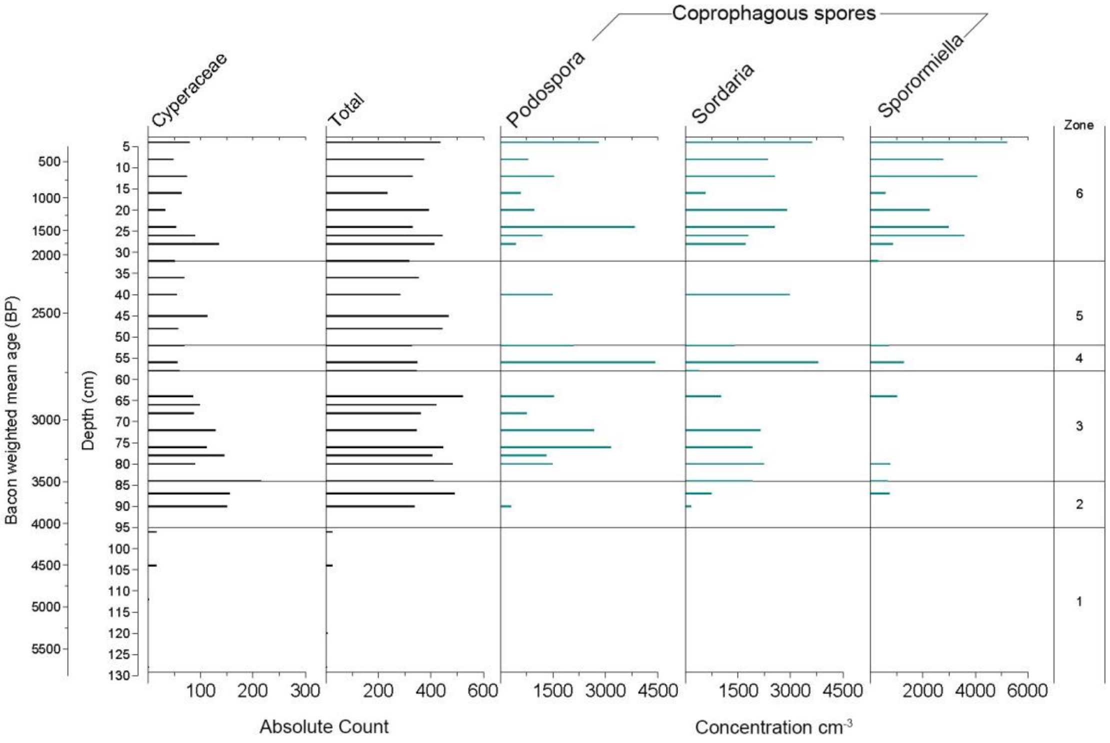

Figure 6.22: Total pollen counts and fungal spore concentration for core TM01.

Pollen Zone 3 (84-58cm, ca. 3500-2700BP)

Total pollen counts range 447-572 (mean 517 ±45). Coniferous *Pinus* (14-22%) and *Abies* (6-11%) are now the dominant arboreal taxa, while *Betula* ranges between 7-15%. *Quercus* declines to an average of 1.6 ± 0.77%. Relative abundance of *Artemisia* declines to 12% before climbing to 30% at the end of this zone, while Poaceae increases to a maximum of 20% between 84 and 78cm depth, before again declining to 12% at 66cm. Cereal pollen is present between 0-0.6%. Ranunculaceae and Amaranthaceae increase to between 1.5-3% each and *Rumex* averages 2.6 ± 1.3% throughout. All other herbs are at low levels comparable to Pollen Zone 2. *Sordaria* (1895-2233 spores/cm^3) and *Podospora* (1303-3158 spores/cm^3) are well represented between 80-72cm depth before abruptly dropping to 0. Cyperaceae counts between 87-145.

Pollen Zone 4 (58-52cm, ca. 2700-2600)

This zone is marked by a sharp decline in *Artemisia* (mean 7.2 ± 1.1%) and *Betula* (2.5 ± 0.25%). Poaceae increases to between 15-24%. Other notable increases include grazing related herbaceous taxa *Rumex* (3-4%), *Plantago* (0-2%), *Urtica* (1.5-2.6%), and fenestrate and echinate Asteraceae (1.5-5% and 2.5-4.5%). All coprophagous fungal spores increase in concentration (*Sordaria* mean 2590 ± 1200; *Podospora* mean 3254 ± 1190; *Sporormiella* 979 ± 284 spores/cm^3). Total pollen counts were 404-405.

Pollen Zone 5 (52-36cm, ca. 2600-2300 BP)

Total pollen counts for this zone range 337-580 (mean 439 ± 89). *Betula* (2.3-8.9%) and *Artemisia* (6-24%) return to proportions comparable with Pollen Zone 3, while Poaceae fluctuates at levels between 10-24%. Both Asteraceae types decline to <1% throughout most of the zone, before climbing to 5% (fenestrate type) and 2.5% (echinate type) towards the top of the zone. Amaranthaceae (2-6%), Apiaceae (0.5-35), Brassicaceae (0-4.5%) and Rosaceae (1-4%) are among the dominant families, with *Rumex* also present at 0-3.5%. Monolete fern spores climb to 8% towards the end of this zone. Coprophagous spores are absent except for concentrations of *Sordaria* (2978 spores/cm^3) and *Podospora* (1489 spores/cm^3) at 40cm depth.

Pollen Zone 6 (36-0cm, ca. 2300BP-Present)

Total pollen counts for this zone were 296-548 (mean 440 ± 80). *Pinus* is the dominant arboreal type (15-27%). *Betula* declines to between 2-3.6%, as does *Abies* a mean of 5 ± 1.2%. Above 20cm (ca. 1200 BP), *Quercus* is no longer present in the assemblage. Proportional representation of *Artemisia* (3-11%) is also lower than in the preceding zone. Poaceae comprises 22-26% of the total assemblage and cereal pollen are also represented discontinuously at levels below 1%. Grazing related taxa dominate the herbaceous component, most notably: Asteraceae fenestrate (5.5-15%); Asteraceae echinate (2-5%); Caryophyllaceae (1-3%); *Rumex* (2-5%). All coprophagous spore types are present at concentrations higher relative to most earlier pollen zones (*Sordaria* mean 2250 ± 851; *Podospora* mean 1511 ± 1121; *Sporormiella* 2780 ± 1464 spores/cm^3).

6.4.6 Principal Components Analysis

Pollen variables included grazing-related and other herbs, conifers, trees/shrubs and ferns. Other variables included summed macrocharcoal size classes, and coprophagous fungal spores, both converted to annual influxes using modelled accumulation rates. Principal components 1 (35.7%) and 2 (18.7%) together comprised 54.4% of variance in the dataset (Appendix B – Supplementary data). PC1 has strong positive loadings for variables that may be associated with pastoralist activity, including Poaceae (0.4), grazing related herbs (0.49) and coprophagous spores (0.32). Negative loadings on PC1 were trees/shrubs (-0.41) and *Artemisia* (-0.46). As high altitude *Betula* was the primary taxa in the tree/shrub grouping, both of these variables may be interpreted as land cover that is particularly susceptible to land clearing and grazing. PC2 has strong positive loadings for herbaceous taxa (0.65) and ferns (0.61) and weaker negative loadings for conifers (-0.14), trees/shrubs (-0.17), *Artemisia* (-0.2) and charcoal influx (-0.32). The antagonistic relationship between wet-favouring and dry-favouring taxa implies PC2 may be indicative of environmental humidity/aridity.

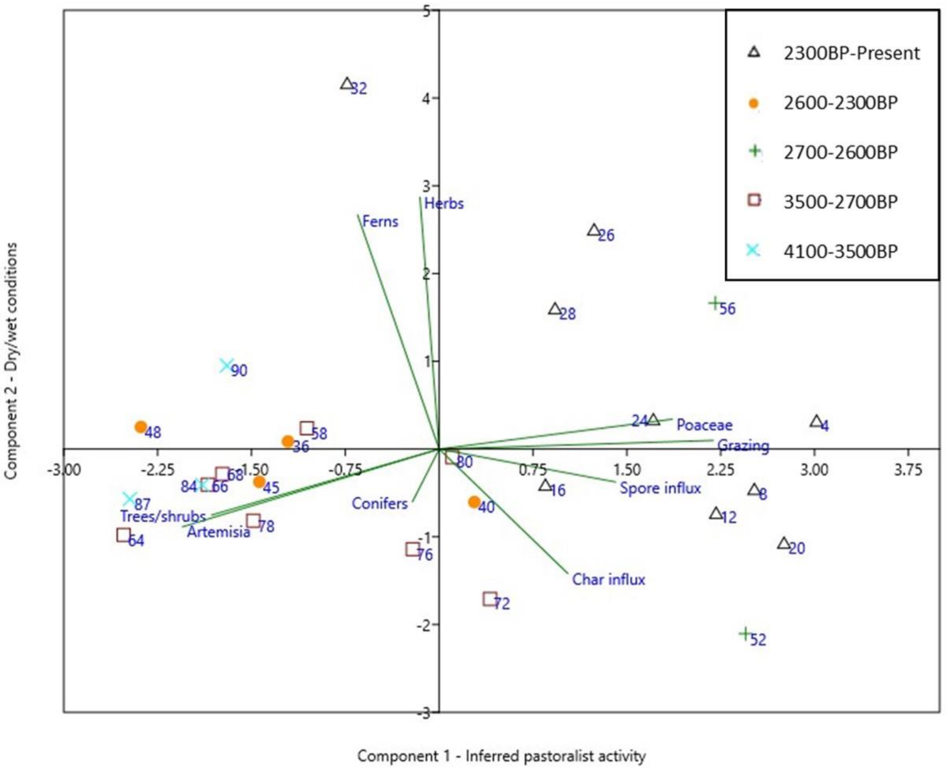

Figure 6.23:PCA biplot for core TM01. X-axis interpreted indicating pastoralist land use; Y-axis as indicator of environmental conditions.

A scatter plot (Figure 6.23:PCA biplot for core TM01. X-axis interpreted indicating pastoralist land use; Y-axis as indicator of environmental conditions.Figure 6.23) of the data on PC1 and PC2 shows a clear left-right division, with observations between 80-72cm, 56-52cm, and 28-2cm all falling within the right-hand two quadrants, interpreted as periods of pastoralist land use. Samples in these quadrants had a wide spread of PC2 values on the y-axis, possibly indicating these patterns of land use took place across environmental changes. Observations falling in the left quadrants had a narrower range of y-axis values, with the exception of the sample at 32cm depth which falls outside the datasets 95% confidence range. Most samples in this grouping fall in the lower left quadrant, indicating that arid periods may have reduced the utility of the pastures around the study site.

6.5 TM02

Core TM02 was not studied in detail due to the fact that the longer TM01 core produced a large data set from the same study that were able to satisfactorily address the research questions in this thesis, TM02 was reserved for future work. As TM02 was only logged, further analysis may yield additional data that may enrich the interpretation of TM01.

6.5.1 Logging

TM02 is a core 90cm long composed of four stratigraphic units (Figure 6.24). Unit 4 (0-20cm depth in core) is a medium-bedded dark olive brown (2.5Y 3/3) humified mud with a clastic primary component and secondary organic components including fine rootlets and leaf fragments. There is an indistinct lower boundary between 15-20cm. Unit 3 (20-40cm) is a medium-bedded light olive brown (2.5Y 4/3) clastic mud. Organic materials decrease as depth increases and the matrix is compact and deformable. This unit terminates in a diffuse lower boundary at 39-40cm.

Unit 2 (40-51cm) is a medium-bedded very dark greyish brown (10YR 3/2) humified mud. Organic components generally comprise small leaf or grass fragments and these increase as depth increases. There is a sharp lower boundary at 51cm. Unit 1 (51-90cm) is a dark greyish brown (2.5Y 4/2) humified mud of unknown bedding thickness. Clastic materials make up the primary component, with a secondary component of plant materials including grass and leaf fragments. Between 51-64cm, organic materials decrease with depth, before increasing as depth increases between 64-90cm. Between 64-90cm are occasional small rounded gravels ø1-2mm.

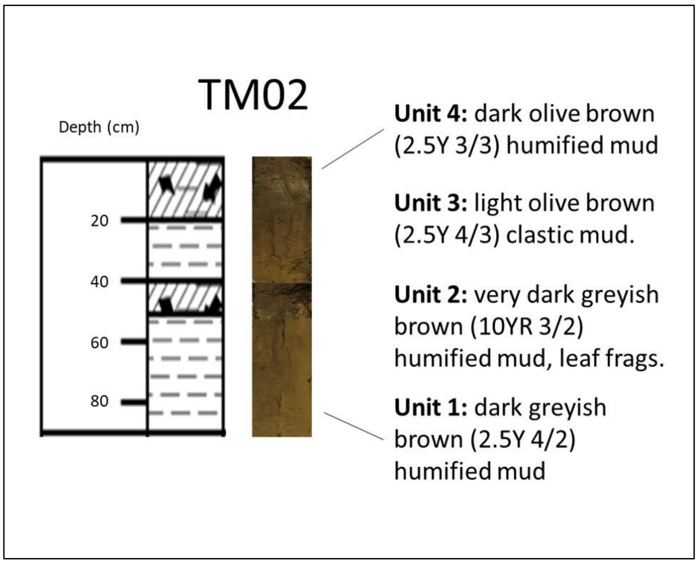

Figure 6.24: : Stratigraphic plot and photographic log, core TM02.

6.6 BS01

Analysis of core BS01 included logging, AMS dating and chronological modelling, sediment particle size and macro-charcoal counts. During logging several ceramic sherds and ochre pieces were recovered suggesting that the deposit may have been directly disturbed by human activity. This inference was supported by large inversions of AMS dates at depths correlating with these finds. Smear slides indicated low pollen concentrations, possibly due to alkalinity of the clastic matrix effecting poor preservation. Because of these factors the core was not fully analysed or interpreted.

6.6.1 Logging

Core BS01 is 90cm long and comprises one single sedimentary unit (Figure 6.25), composed of a thick-bedded dark greyish brown (10YR 4/2) clastic mud. Plant material including rootlets and leaf fragments are concentrated in the top 10cm, decreasing as depth increases. The sediment is moist, compact and deformable with moisture increasing in the lower 30cm of the core. Rounded gravels up to ø4mm are present throughout.

On dissection of the core for subsampling, a number of thin (3mm) brown on black, handmade ceramic body sherds were extracted between 41-45cm depth. At 61cm, a piece of ochre or low-fired clay 10x25mm in size was recovered.

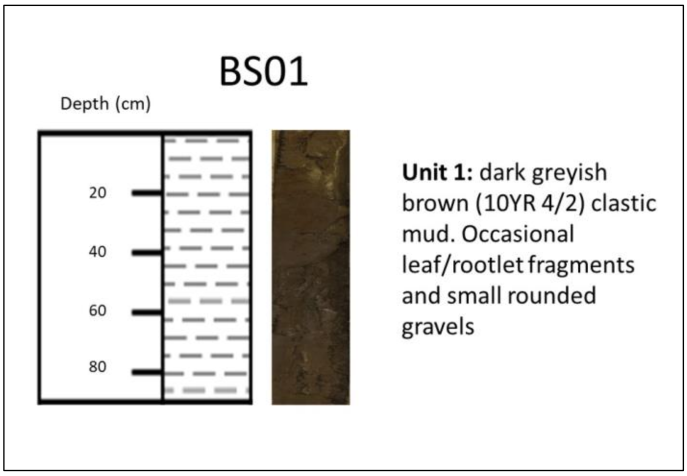

Figure 6.25: Stratigraphic plot and photographic log, core BS01.

6.6.2 Chronology

Two AMS dates were acquired from bulk sediment samples and a third from charcoal (Table 6.4). Returned dates indicate an inversion of >700 years between dates BS01_2.1_54 and BS01_2.1_41.

Table 6.4: Summary data of AMS dates from core BS01. Calibrated in Calib 7.1

Sample no.	Lab code	Material	Depth (cm)	^{14}C age BP	2σ range (cal. BP)	% of probability distribution
BS01_2.1_41	D-AMS 032556	Sediment	41	2519 ± 32	2490 - 2664 2654 - 2668 2676 -2743	68 2 30
BS01_2.1_54	D-AMS 032552	Charcoal	54	1772 ± 34	1605 - 1850	100
BS01_2.1_81	D-AMS 031623	Sediment	81	2663 ± 34	2745 - 2884	100

Age modelling (Figure 6.26) assumed a mean accumulation rate of 50yr/cm over the 90cm of the core (d.max=90). All other settings were left as default, which ran the model in nineteen 5cm sections. Date BS01_2.1_41 fell outside the models 95% confidence range (mean 574 years). Modelled accumulation rates range between 0.5-0.6cm/yr throughout the majority of the core, with a maximum range of 1-1.1cm between 40-50cm depth (Figure 6.26).

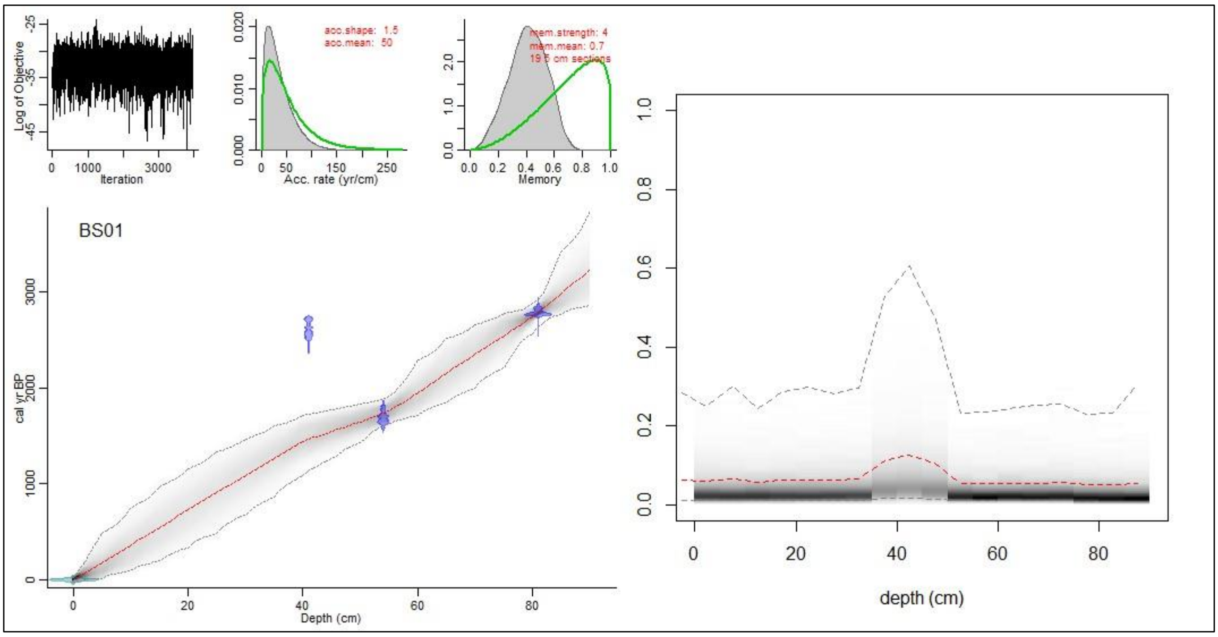

Figure 6.26:Left -Bacon age depth model for core BS01. Right - modelled mean accumulation rate in cm/yr.

6.6.3 Sediment particle size and magnetic susceptibility

Mean particle size varied little throughout BS01 (1.3-4.89 µm; mean 3 ± 0.98 µm, Figure 6.27). Overall sediment composition was dominated by clay (43-74%; mean 53 ± 8%) with a large secondary component of silt-sized clasts (23-48%; mean 42 ± 7%). The sand fraction ranged from

3-8.4% (mean 4.7 ± 1.7%). Between 23-53cm were gravels with total counts ranging 1-7 per cm^3. This section of the core also had above average clay fraction (mean 57.5 ± 10%) and sorting values (σ_G 5.7-6.9; mean 6.21 ± 0.36). Throughout the core σ_G ranged from 5.5-6.86 (mean σ_G 6.08 ± 0.4).

Higher clay fraction and σ_G values have a moderate positive correlation ($r = 0.54$) while silt and sorting values have a moderately negative correlation ($r = -0.66$). Sand and sorting values have no linear relationship ($r = 0.057$). Skewness and kurtosis also have their strongest linear relationships with higher clay percentages ($r = 0.89$ & $r = 0.79$ respectively).

Between 90-63cm, magnetic susceptibility К values range from $20\text{-}70 \times 10^{-1}$SI (mean $43 \pm 14.6 \times 10^{-1}$SI). These values rise sharply to an average of $72.4 \pm 21.5 \times 10^{-1}$SI (range $42.5\text{-}105.4 \times 10^{-1}$SI) between 63-38cm. From 38-6cm mean К fell to 11.7×10^{-1}SI (range $3.8\text{-}23.8 \times 10^{-1}$SI).

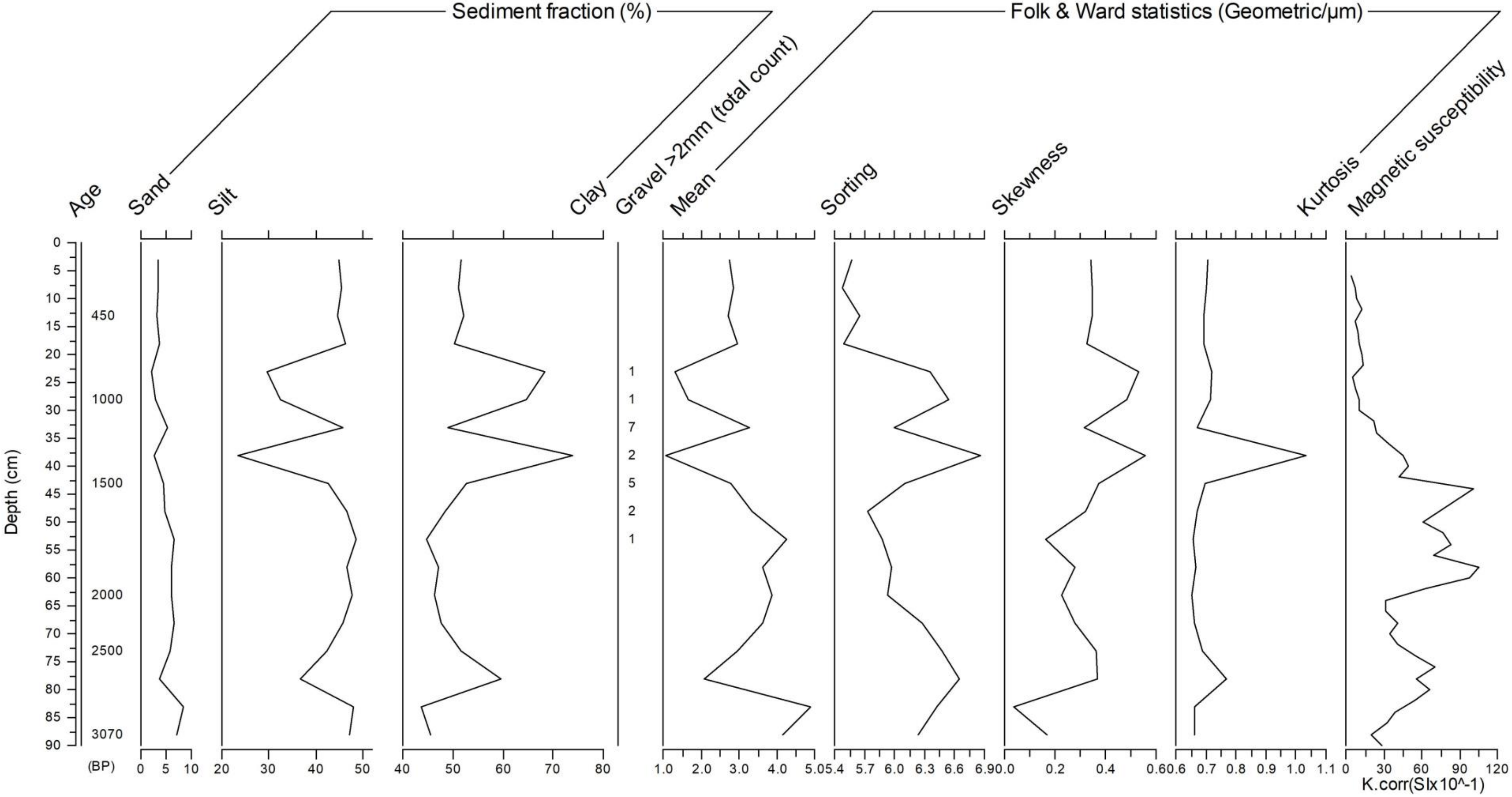

Figure 6.27: Sediment particle size, statistical and magnetic susceptibility data for core BS01.

6.6.4 Charcoal

Sixteen samples were processed for macrocharcoal analysis (Figure 6.28). As pollen slides were not counted for BS01, microcharcoal data is unavailable. Counts of 125-250µm charcoals were 3-181 particles/cm^3 (mean 19.6 ± 42), however with the exclusion of the sample at 88cm depth, all other counts were <23 particles/cm^3. Charcoal counts >250µm range from 0-7 particles/cm^3 (mean 2.7 ± 1.6).

Conversion to charcoal influxes using accumulation rates did not find any relationship between influxes of the two size classes (*r* = 0.08). Deviation of influx rates around the long-term mean indicated above average influx at multiple depths for the >250µm size class, however the only above average influx for the 125-250µm size was at 88cm.

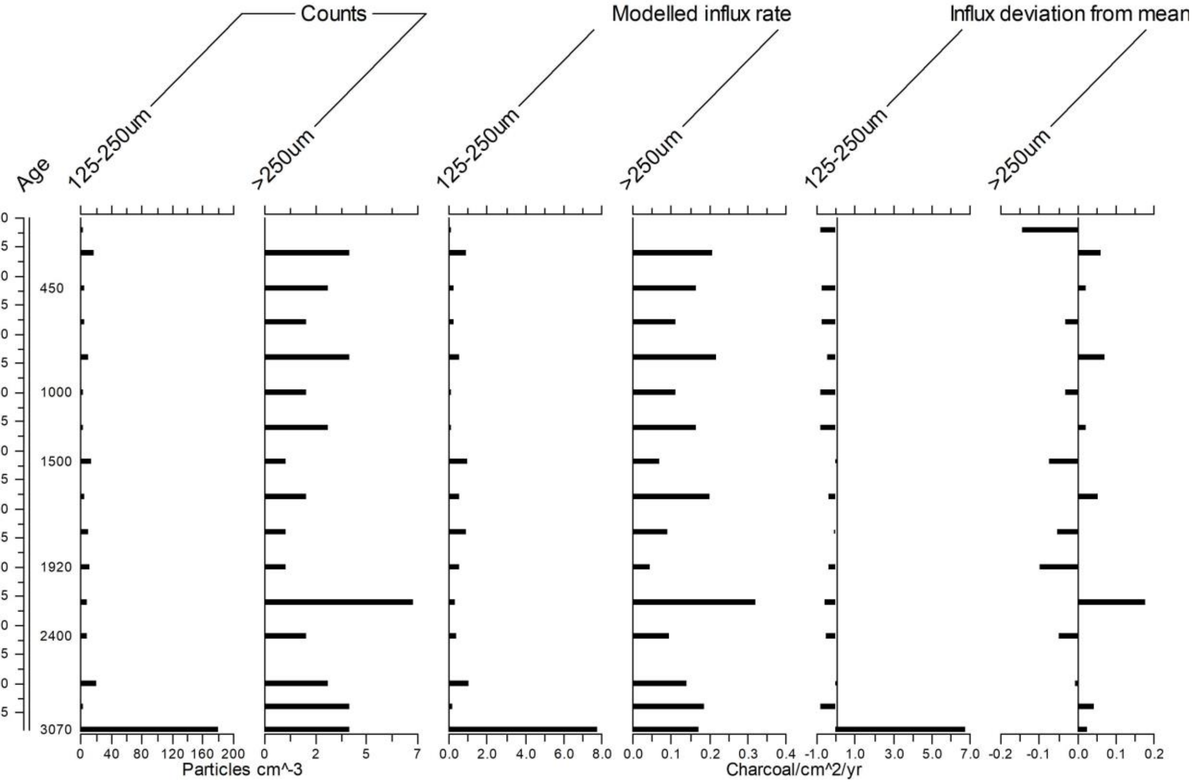

Figure 6.28: Macrocharcoal counts, modelled influx and long term variation for core BS01.

6.7 HG02

Core HG02 was logged and sampled for AMS dating. Because of the relatively young age of the core, as well as its sample location from a large water body on the valley floor with a larger site catchment, the decision was made to reserve HG02 for further study to address better suited research questions.

6.7.1 Logging

Core HG02 is 1300cm long and comprises seven stratigraphic units (Figure 6.29). Unit 7 (0-56cm depth in core) is a brownish grey (10YR 4/1) thick-bedded clastic mud. Occasional fine rootlet and leaf fragments are present throughout the unit, as well as a few infrequent charcoal fragments >1mm. This unit terminates with a sharp lower boundary. Unit 6 (56-63cm) is a medium-bedded, brownish black (7.5YR 3/1) humified mud with frequent plant fragments, terminating in a sharp lower boundary. Unit 5 (63-95cm) is a grey (7.5Y 4/1) thick-bedded clastic mud. Sediment matrix is compact and deformable, with an indistinct lower boundary. Unit 4 (95-112cm) is a medium-bedded dark olive-grey (2.5GY 4/1) heavily compact clastic mud. This unit as no visible organic inclusions and terminates in a sharp lower boundary.

Unit 3 (112-118) is a thin-bedded, brownish black (7.5YR 3/1) humified mud. Frequent rootlet and leaf inclusions as well as larger plant fragments up to ø5mm. This unit has a diffuse lower boundary with Unit 2 (118-120cm), a very thin-bedded grey (7.5Y 4/1) clastic mud similar to Unit 5, terminating in a diffuse lower boundary. Unit 1 (120-130cm) is a brownish black (7.5YR 3/1) humified mud of unknown bedding thickness, with a composition similar to Unit 3.

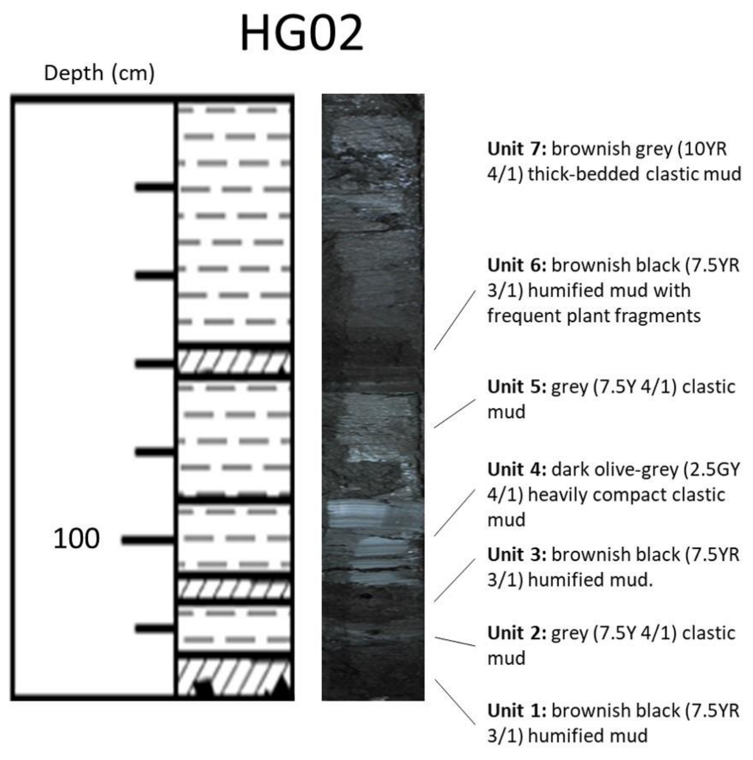

Figure 6.29: : Stratigraphic plot and photographic log, core HG02.

6.7.2 Chronology

Two AMS dates were returned from bulk organic/sediment samples at DirectAMS. Both dates are in sequence and are presented in Table 6.5. Age depth modelling was run with an assumed mean accumulation rate of 10 yr/cm, with fifteen sections 9cm thick. A base depth of 130cm was set with (d.max=130), and all other settings were left as default (Figure 6.30). The model's mean 95% confidence range was 310 years, with a maximum uncertainty of 540 years at 27cm depth.

Table 6.5: : Summary data of AMS dates from core HG02. Calibrated in Calib 7.1

Sample no.	Lab code	Material	Depth (cm)	^{14}C age BP	2σ range (cal. BP)	% of probability distribution
HG02-A1	D-AMS 023862	Sediment	65	1082 ± 30	933 - 1013 1019 - 1056	70.1 29.9
HG02-E1	D-AMS 023863	Sediment	124	1343 ± 28	1186 - 1205 1238 - 1306	8.3 91.7

Modelled mean accumulation rate varied greatly between depths 130-60cm and 60-0cm (Figure 6.30). The relatively stable rates within these age ranges and the sharp transition between them may be more a result of only two AMS dates in the model, and the higher uncertainty between 60-0cm than of a marked change in deposition rate.

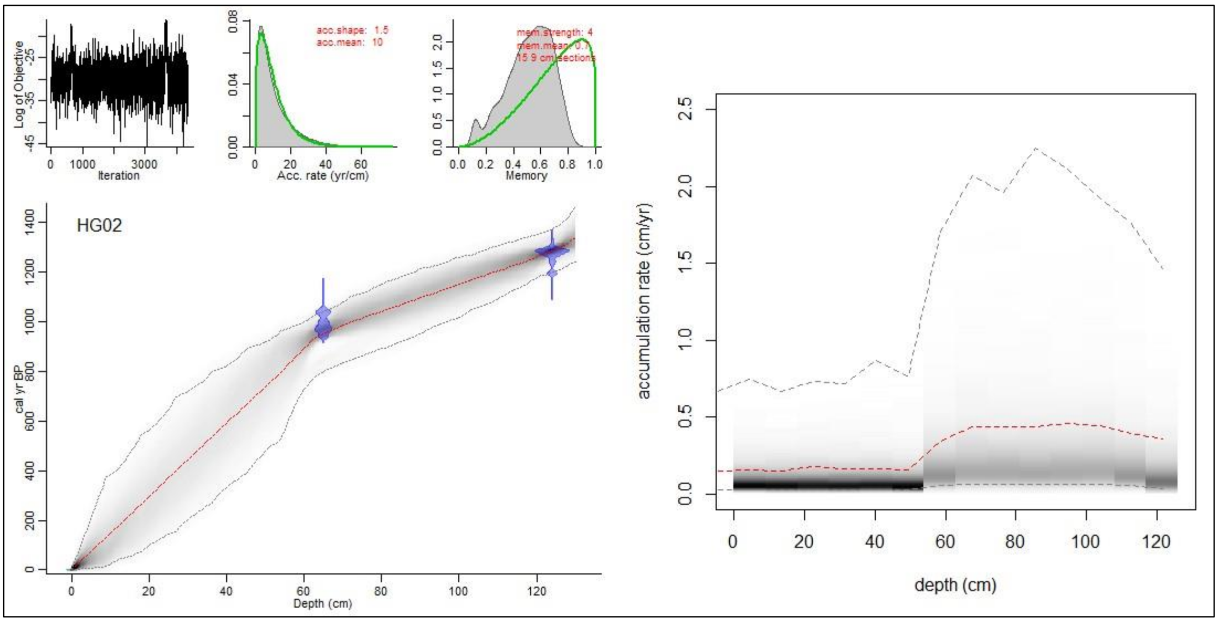

Figure 6.30: : Left -Bacon age depth model for core HG02. Right - modelled mean accumulation rate in cm/yr.

6.8 Summary

This chapter has presented uninterpreted data from six cores. The most complete and robust datasets were acquired from the three cores from the pastures in Budgam District - PH03, TM01 and SG02. The following chapter interprets these data to first reconstruct long-term environmental change in the Kashmir Valley generally, before considering indicators of pastoralist activity in Budgam District more specifically.

Chapter 7 Discussion

7.1 Introduction

This chapter interprets the data presented in Chapter 6, where they were generally presented in raw forms such as the relative abundances of all pollen types. Here data are selectively treated in order to answer the research questions of this thesis. As the cores from the mountain areas of the Budgam District (PH03; SG02; TM01) have the most complete data sets, they are the primary focus of discussion.

Section 7.2 examines the pollen data in their primary groupings as percentages of the overall pollen spectrum. These are discussed alongside the charcoal influx, sediment size and magnetic susceptibility data in order to interpret broad environmental and vegetational changes. These interpretations are compared across all the records from the Budgam District and synthesised into a general schema of environmental change for the western mountain flank of the Kashmir Valley. This is then compared with recent palaeoenvironmental studies from Kashmir, Westerlies-dominated Central Asia, mixed ISM/WD controlled areas of the Trans-Himalaya and ISM zones of the Central Himalaya.

Section 7.3 draws on data from the non-arboreal pollen spectrum and coprophagous fungal spores to identify periods of pastoralist land use around the sampling sites. These interpretations are contextualised against the environmental reconstruction. Section 7.4 then presents a discussion of the environmental proxies within the framework of Niche Construction Theory. The final Section 7.5 places Kashmir Valley pastoralism within the wider archaeological and historical context.

7.2 Environmental reconstruction

Examining pollen proxies for climate reconstruction in mountain areas, Ortu et al. (2006) note that altitudinal variation effects a steep ecological gradient and produces multiple closely spaced ecotones. Additional confounding factors identified are pollen types having multiple ecological indicator values, as well as upland transport of pollen by anabatic winds. These dynamics complicate previous reconstruction of climate through pollen proxies in Kashmir, which typically utilised ratios of coniferous to broad-leaved taxa (B/C) as indicators of warm-humid and cold-dry climates (Dodia 1983, Singh 1963).

Problems arise from the overrepresentation of coniferous pollens, while broad leaf taxa including *Betula*, *Corlyus* and *Juglans* may be pioneer species associated with anthropogenic impacts. Other pollen ratios used in climate reconstruction (Li et al. 2010) from arid to temperate regions of China, including *Artemisia*/Cyperaceae (A/Cy) and Arboreal/Non-Arboreal (AP/NAP), have been interpreted as indicators of maximum summer (July) temperatures, though these types are particularly sensitive to the effects of altitude or anthropogenic impact.

The sites in this study were typically small montane swamps selected for detecting the impacts of localised human activity rather than regional environmental change, therefore the above referenced indices may not be particularly informative. Recent quantitative modelling of landcover from pollen records in temperate North and Central Asia (Cao et al. 2019) found a high degree of deviation among cores from small bogs, indicating their suitability more for local or stand scale vegetation reconstruction. As a result of these considerations, the approach taken here is to plot relative abundances of taxa or groupings identified as significant in the pollen plots or PCA for a qualitative interpretation and comparison of localised changes in vegetation and sediment data across the three cores from Budgam District. Interpretation of these cores is undertaken from oldest to youngest chronologies.

Tosa Maidan (TM01)

In the TM01 record between ca. 5500-4100 BP (Pollen Zone 1) overall pollen counts are low (<40 total) and are dominated by monolete fern spores and herbs (Figure 7.1) High magnetic susceptibility, as well as the accumulation of gravels and larger-grained sediments during the first half of this period, suggests pluvial conditions around the sampling site with higher weathering and input of parent Panjal Trap materials from upslope. The poor representation of pollen during this period may be due to either higher energy deposition preventing the formation of bog-like conditions, or other taphonomic factors such as increased alkalinity related to input of basic ferromagnetic Panjal Trap parent material (Ganju 1944).

The period ca. 4100-3500 BP (Pollen Zone 2) sees a decline in fern spores and PCA2 scores, possibly indicating a transitional drying phase. Boreal trees, primarily *Betula,* dominate the tree taxa, which, given their low pollen productivity and dispersal efficiency (Cao et al. 2019), suggests colonisation of the immediate area by these pioneer species. Temperate trees, primarily *Quercus,* may also be indicative of sufficient warmth and humidity during this period.

From ca. 3500-2200 BP (Pollen Zones 3-5) conifers are the dominant tree types while *Artemisia* is the dominant non-arboreal taxon. The decline in boreal trees may be attributed to colonisation of *Betula* and *Corylus* stands by *Pinus* and *Abies*, a succession typical for the Kashmir Valley once forests are established (Vishnu-Mittre 1966). PCA2 scores fluctuate but are generally below 0 (−2.1-1.6; mean −0.48), likely reflecting an overall drier period (see Section 6.4.6). This may have aided the colonisation by conifers and the establishment of the current timberline around Tosa Maidan. Influxes of charcoal are generally above the long-term mean, with multi-modal peaks around 3000 and 2500 BP possibly linking increased burning in the landscape to drier environmental conditions. Magnetic susceptibility reaches a minima ($K<1x10^{-1}SI$) at the start of this period, slowly climbing to values around $10x10^{-}SI^{1}$ by 2500 BP. There is a peak in sand input of 12% ca. 3500 BP, before slowly declining to less than 4% by 2200 BP. These values indicate a possible sediment source other than weathering of Panjal Trap in the immediate vicinity of the site. Also fluctuations in herbaceous taxa, sediment size and magnetic susceptibility between ca.2600-2500 BP may be evidence of a brief wet phase.

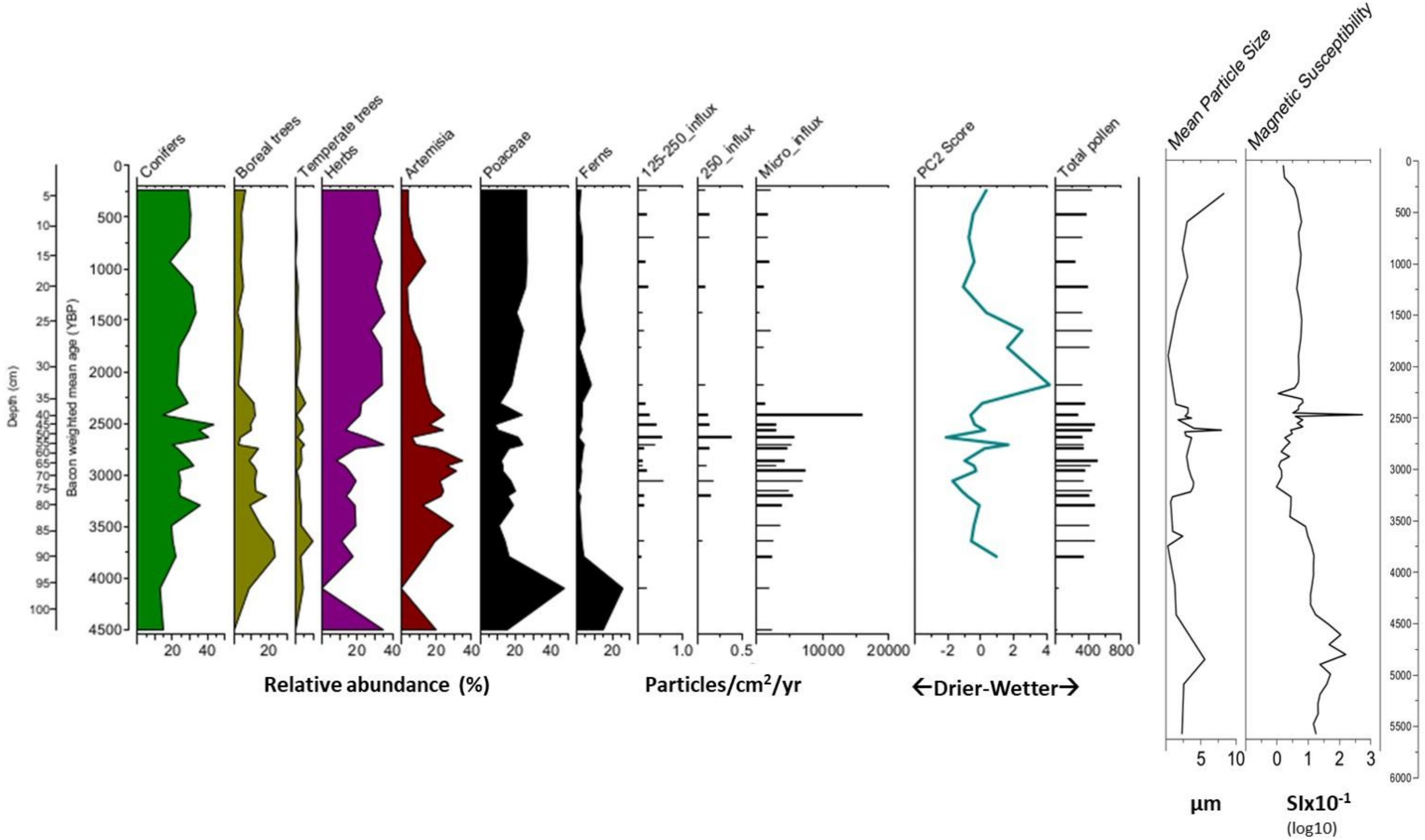

Figure 7.1:Relative abundances of summed pollen groups, charcoals influx, PC2 scores, mean particle size and Mag. Susc., TM01.

Wetter conditions from ca. 2200-1500 BP may be evident in increases in relative proportions of fern and herbaceous and Poaceae pollen and reductions in *Artemisia*, conifers and boreal trees. While temperate or thermophilous trees are only present at low levels, their decline proportional to boreal trees is less pronounced. Low levels of these types may also be driven by declining *Quercus* pollen due to the use of oak as a fuel wood by populations in the valley. Similarly, increases in grass and decreasing *Artemisia* may be partly attributed to grazing activity in the local area. These wetter conditions may be reflected in higher PC2 scores during this period. The increase in herbs could also indicate the establishment of a biome similar to the modern sub-alpine open meadow landscape. During this period the clay fraction of sediment reached a modal peak which may indicate a variation in weathering and source material. Estimating the timing of the beginning and end of this shift is complicated, as these changes fall between 40-20cm depth in core, where two outlier dates (TM01_1.1_23 & TM01_1.1_40) introduce a high range of uncertainty into the age model. This is particularly pronounced at the end of this period where uncertainty ranges are close to 1000 years between 25-20cm depth in core.

From ca. 1500-250 BP, a decline in ferns and temperate trees may be indicative of drier conditions as well as of the extinction of *Quercus* in the valley. Charcoal influxes of all three size classes are generally below the long-term average, an indicator of weaker fire activity in the site's immediate catchment.

Pari Has (PH03)

Taxa indicating wetter conditions (ferns, *Typha, Myriophyllum, Persicaria*) constitute the major pollen signal around the site between ca. 2750-2500 BP (Figure 7.2). While these taxa are dominant at low concentrations at the start of this period, they are well-represented when overall pollen counts rise. Enhanced magnetic susceptibility and high clay sediment fraction may be indicative of intensified weathering and pluvial conditions. Excluding the two samples at the very base of the core, charcoal influxes during this period are below the long-term mean.

At ca. 2500 BP there is an apparent transitional period, seen in the interbedding of humified muds and clay driving rapid fluctuations in sediment particle size and a sharp decline in magnetic susceptibility. The concentration of large wood fragments at 265-280cm depth in core may also be evidence for natural or anthropogenic disturbances around the site. These conditions continue to ca. 2200 BP, with fluctuating arboreal taxa dominated by conifers and other trees primarily consisting of *Betula, Corylus* and *Quercus*. The expansion of *Artemisia* and the decline of marshy taxa and ferns may indicate a transitional drying during this period. Influx of all charcoal size classes are generally below the long-term mean, with the exception of a small peak of above average influx of all three sizes ca. 2500 BP.

The period ca. 2200-1700 BP sees a stabilisation in coniferous dominance, while levels of other tree taxa remain relatively stable at low levels (<5% for both boreal and temperate types). This forest composition may indicate a drier phase, also supported by the almost complete decline in fern and marsh pollens. *Artemisia* is initially dominant among non-arboreal vegetation and its later decline may be attributed to intensification of grazing in the area rather than shifting climates. The disappearance of *Quercus* from the pollen curve at ca. 2000 BP may be a result of both climate and anthropogenic pressures. Low magnetic susceptibility and higher mean sediment particle size signal a possible shift in sediment source material that may be a result of drier conditions. Influxes of all charcoals are generally increased through this period, and though they generally remain below the long-term average, this may be attributed to the high peaks of all size classes ca. 2000 BP.

The sharp increase in ferns, herbs and marshy taxa ca. 1700-900 BP show a significant shift to a wetter local environment. Magnetic susceptibility increases to a mean of $5.9 \pm 2.12 \times 10^{-1}$SI and clay sized particles dominate the sediment classes (>90% of size distribution), pointing to intensified weathering of Panjal Trap parent material in the catchment area. The slow rate of accumulation suggests that these wet conditions were associated with cold winter precipitation or snow, in contrast with the faster accumulation of humified muds during drier periods. Though counts or concentrations of charcoals during this period appear high, the calculated annual influxes of all charcoal sizes reach their lowest levels in the record during this period as a result of the slow accumulation rate.

After 900 BP, conifers again dominate the overall pollen spectrum and present-day drier conditions may be evinced in the decline of ferns and marshy taxa. Shifts in herbaceous types may be strongly influenced by human activity here, and horticulture may also be a factor in the dominance of *Juglans* over all other non-coniferous trees. Vishnu-Mittre (1966) notes that Kashmir walnut trees were the primary source of gun stocks for the British and Indian armies during the 18th and 19th centuries, a likely economic driver of this increase. Localised burning may not be as pronounced as in the dry period ca. 2200-1700 BP, though influxes are generally higher than during the preceding wet phase. Overall drier conditions may be reflected in PCA1 scores averaging 0.99 through this period (see Section 6.2.6).

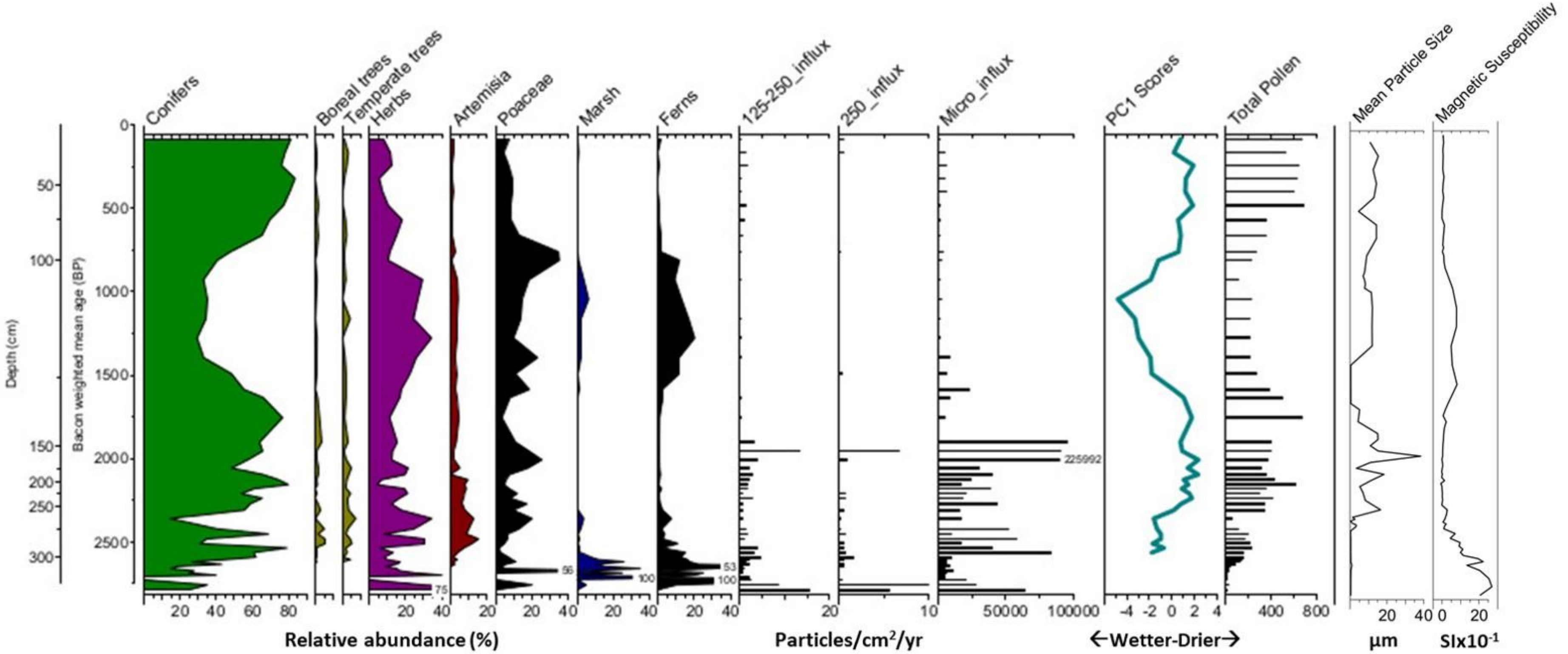

Figure 7.2 Relative abundances of summed pollen groups, charcoals influx and PC2 scores, PH03

Shali Ganga (SG02)

Generally there is little variation in the non-arboreal pollens in core SG02, with major changes driven by shifts in the relative abundances of conifers and boreal trees (Figure 7.3). Between ca. 2750 and 2400 BP, the pollen spectrum is dominated by conifers, though the sample at 112cm may be considered unrepresentative with a concentration of 5 pollen grains/222 *Lycopodium* marker spores. The period 2400-900 BP is marked by a gradual decline in conifer forest, driven by relative increases in ferns, herbs and other tree taxa after 2000 BP. These changes may indicate wetter conditions enhancing the growth of forest understory and driving higher PCA3 scores (see Section 6.3.6). However, only three samples have been drawn from this period and therefore temporal resolution is lacking. Influxes of all charcoal size classes are below the long-term mean, likely indicating less intense burning. Calculated influxes are derived from an accumulation rate based on two AMS dates only and should thus be interpreted cautiously. However, higher proportions of clay and high magnetic susceptibility values tend to support a slower accumulating clastic lithology rather than the rapidly forming peat/humified muds seen across all other cores in this study.

Conifers reach their lowest values in the pollen curve between ca. 900-650 BP. While this decline may be partly attributed to regional climate or environmental change, it appears to be driven by expansion of *Betula* which dominates the assemblage at levels as high as 35% at ca. 750BP. As both *Pinus* and *Abies* decrease during this period, the record may be a reasonable reflection of localised changes rather than weaker delivery of long-distance transported pine pollen. The presence of birches at this lower elevation is notable and may relate to a colder and drier climate – although the intensification of anthropogenic land clearing and use, seen in the increases in charcoal influx and cereal pollens, are a possible explanation. Drier conditions and the clearing of forest understory are also indicated by a decline in fern spores, while the disappearance of *Quercus* may be a result of climate stresses and intensified forestry activity.

From ca. 650 BP to the present, conifers dominate the tree taxa while lower proportions of herbs and ferns suggest the persistence of drier conditions. Temperate trees that may indicate warm-humid conditions increase after ca. 250 BP, though this is driven by higher representation of *Juglans* and may possibly be attributed to intensified arboriculture. Charcoal influxes across all three sizes reach their highest levels during this period with above average peaks of all classes between ca. 500-250 BP. Relatively low levels of magnetic susceptibility and a sharp increase in sand fraction and mean particle size may also point to higher localised erosion and lower pluvial input from weathered Panjal Trap materials.

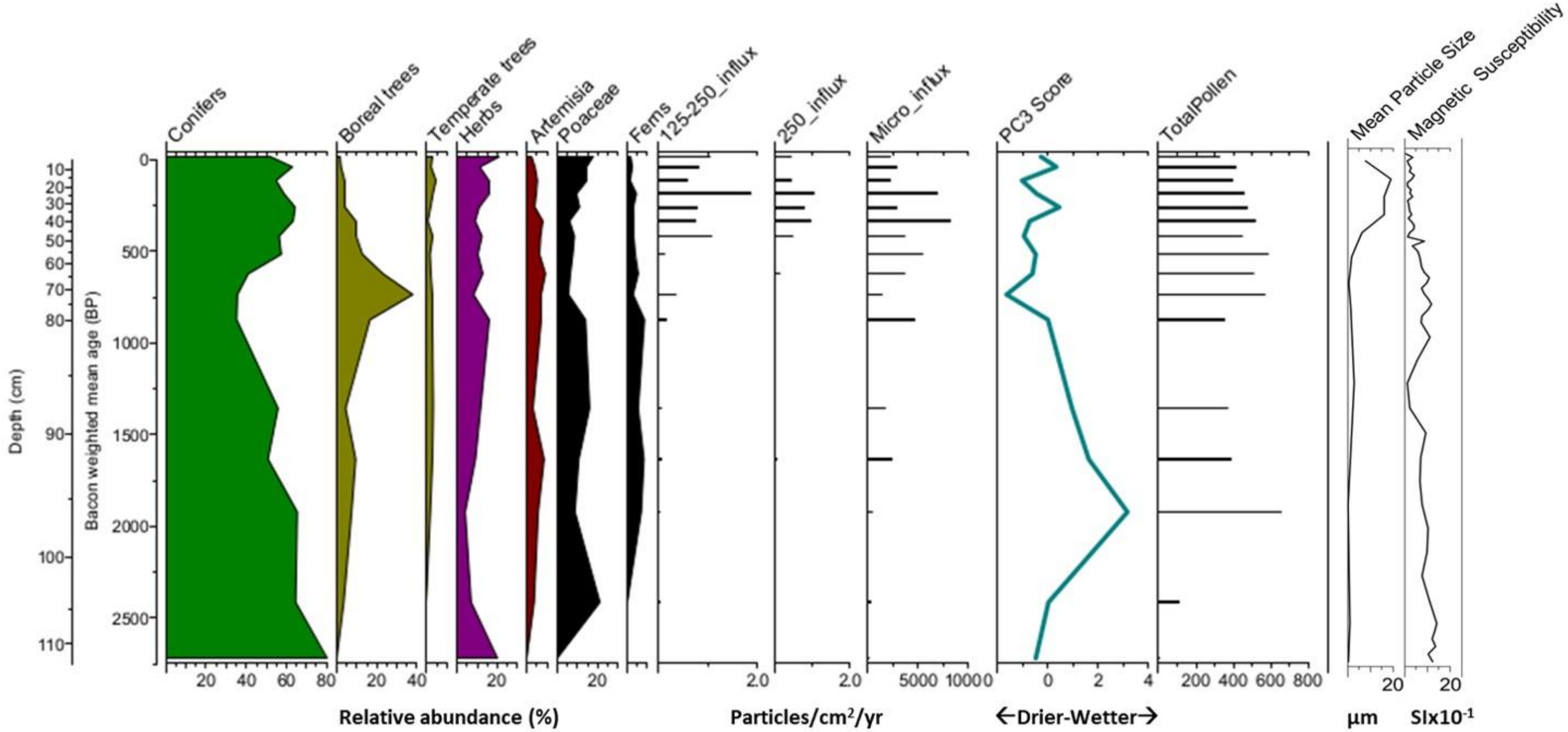

Figure 7.3:Relative abundances of summed pollen groups, charcoals influx, PC3 scores, mean particle size, mag. Sus. SG02

Synthesis of records

Environmental reconstruction from the TM01, PH03 and SG02 cores are broadly comparable, with changes finding good chronological agreement (Figure 7.4). *Pinus* and *Abies* dominate throughout all pollen spectra, indicating that coniferous forest is generally the dominant vegetation cover in the Pir Panjal mountain flanks throughout the study period, despite the fact that due to their pollen productivity and dispersal, relative pollen abundances of these taxa may not be reflective of proportional forest composition (Vishnu-Mittre & Robert 1971). Temporal altitudinal variation across the cores suggests that not all of these coniferous pollens were transported long distance. Prior to ca. 3000 BP, the only record available is the higher altitude TM01 core which appears to indicate wetter conditions to 4000 BP, based primarily on magnetic susceptibility and other sediment data. In a study of precipitation sources across the Kashmir Valley, Jeelani et al. (2017) found sampling sites at Gulmarg and Tangmarg had the highest depletion of $\delta^{18}O$ and $\delta^{2}H$ isotopes, interpreted as evidence for the weakest ISM delivery and higher WD-driven precipitation at these sites. Both Gulmarg and Tangmarg are located in the lower and middle altitude pasture zones of the Pir Panjal, with similar elevations and east-facing aspects to the sites in this study. This may allow us to infer precipitation delivery in the study area as dominated by cold winter rain and snow, rather than warm summer rains. At higher elevations such as Tosa Maidan, cold-wet periods of higher winter precipitation may drive periglacial type conditions characterised by grinding and accumulation of Panjal Trap gravels and clays as is evident at the base of the TM01 record. These wetter conditions begin to transition ca. 4000 BP to a drier environment dominated by conifers, *Artemisia* and *Betula*.

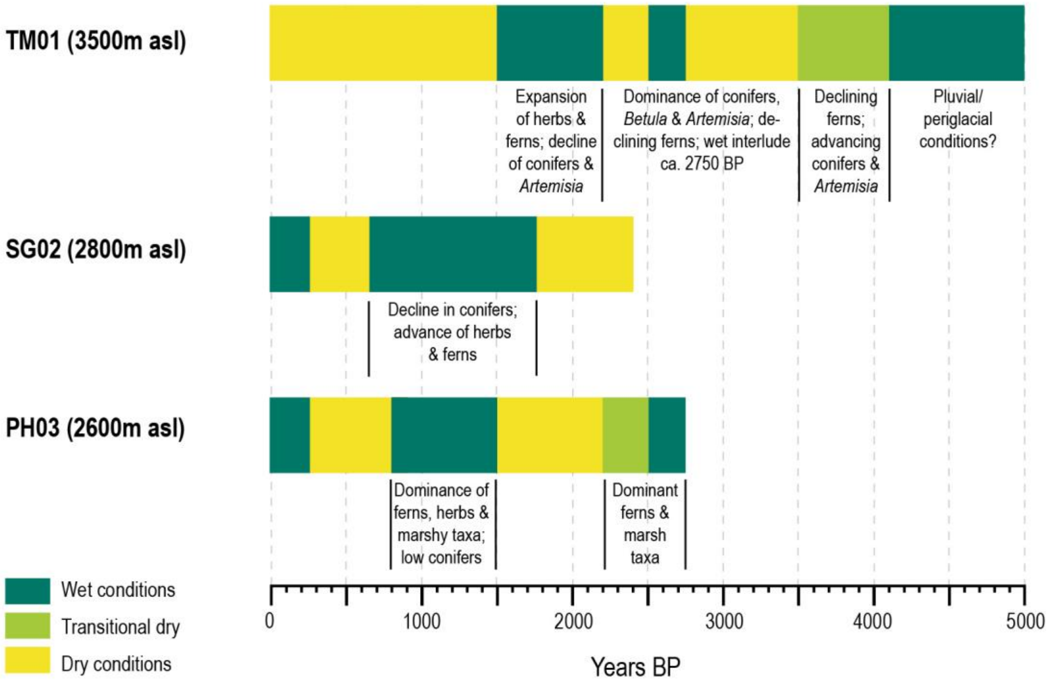

Figure 7.4: Comparison of inferred environmental change across three study records.

The environment around Pari Has is initially dominated by ferns and marshy taxa indicating wetter localised conditions. This may be comparable to the brief cold-wet onset at Tosa Maidan, characterised by an expansion of herbs and conifers and a decrease in *Artemisia* and *Betula* at the higher altitude.

Drier or transitional conditions characterised by changing magnetic susceptibility, relatively high proportions of *Artemisia* and declining ferns and marshy taxa are evident in all three records beginning ca. 2500-2400 BP and persisting until ca. 2000 BP at Tosa Maidan and Shali Ganga and ca. 1500 at Pari Has. While there is a succeeding wetter period characterised by higher magnetic susceptibility, increases in ferns and herbs and lower mean sediment size across all three records, age uncertainty in the TM01 and SG02 records, as well as low temporal resolution of the SG02 record, mean that assumptions on the timing and length of this period should be made prudently, particularly as environmental change at the end of this stage in the SG02 core appears to be driven by anthropogenic factors. The expansion of temperate tree taxa in the PH03 and SG02 cores during the last two centuries is driven by *Juglans* and appears consistent with historic accounts of expansion of walnut cultivation (Lawrence 2005 [1895], pp.352–354).

Comparison with regional environmental records

The environmental stages inferred from changes in pollen abundances, magnetic susceptibility and sediment size changes in the above records are in generally good agreement with geochemical and multi-proxy studies from the Wular (Shah 2019), Anchar (Lone et al. 2019) and Manasbal (Babeesh et al. 2019) lake records from the Kashmir Valley floor (Figure 7.5). The Wular and Anchar records indicate wetter conditions prior to ca. 4000 BP, corresponding with the earliest stages of the TM01 record. Desiccation of the Wular Lake margin, as well as indicators for drier conditions at Anchar Lake, support the interpretation of a generally drier phase in the TM01 record ca. 4000-2700 BP. The wet phase ca. 2700-2500 in the PH03 and TM01 records partially corresponds with an interpreted cold wet phase in the Manasbal record ca. 3300-2500 BP. A succeeding dry phase can be interpreted across all three records in this study, as well as in the Masabal and Anchar records, terminating between ca. 1800-1600 BP. Generally wetter conditions are interpreted across all records in the following period, followed by a dry phase beginning between ca. 1300-1500 BP. Following 1500 BP the Anchar record diverges, which may be attributed to impacts associated with the growth of the adjacent Srinagar city (Lone et al. 2019). Slightly wetter conditions in the PH03 and SG02 cores after ca. 500 BP may also be correlated with increased precipitation post-LIA in a secondary Wular Lake core (Shah 2019). These changes also find good correspondence with tree-ring data from the Western Himalaya indicating a sharp decline in precipitation ca. 900 BP, with low levels of rainfall until ca. 550 BP when there is some recovery in boreal spring precipitation (Yadava et al. 2016).

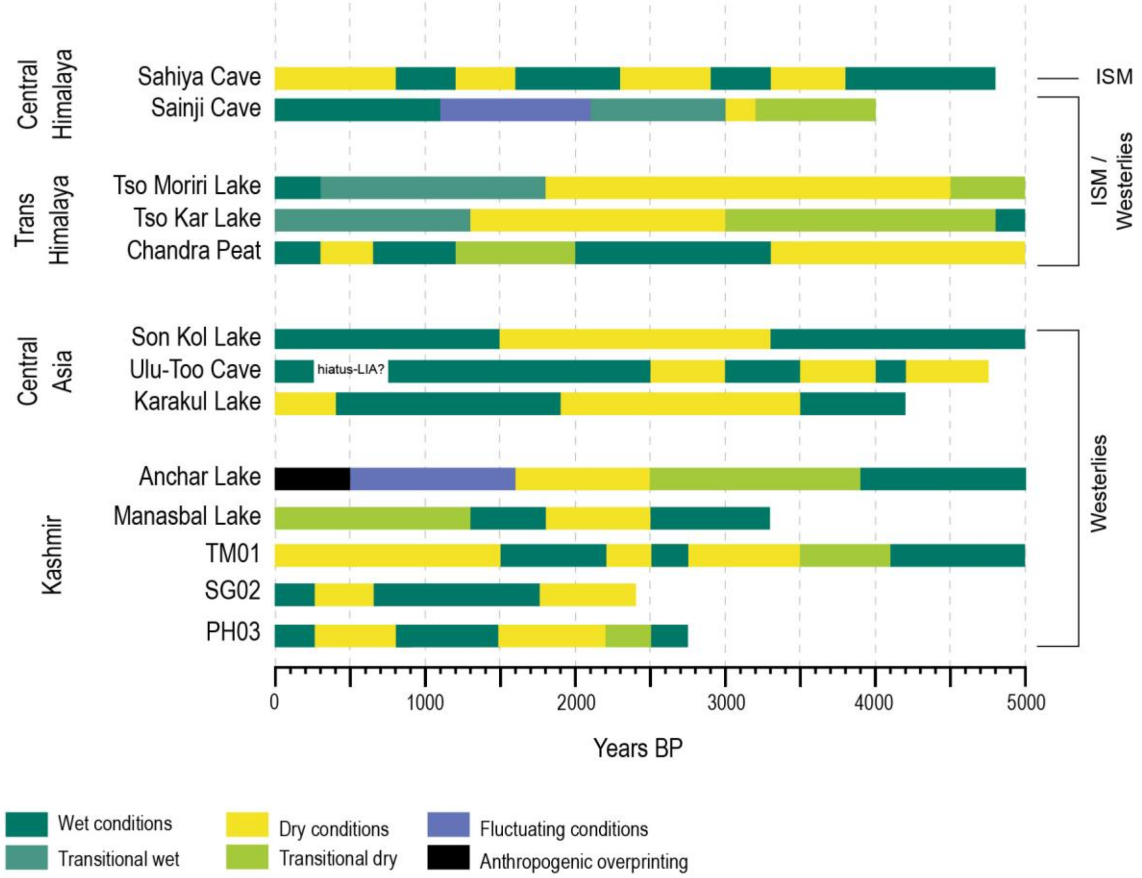

Figure 7.5: Comparison of inferred environmental changes in this study with proximal and regional studies: Manasbal lake (Babeesh et al. 2019); Anchar lake (Lone et al. 2019); Karakul lake (Mischke et al. 2010); Ulu-Too speleothem (Wolff et al. 2017); Son Kol lake (Schwarz et al. 2017); Chandra (Rawat, Gupta, Srivastava, et al. 2015, Rawat, Gupta, Sangode, et al. 2015); Tso Kar (Demske et al. 2009); Tso Moriri (Leipe et al. 2014); Sainji speleothem (Kotlia et al. 2015); Sahiya speleothem (Kathayat et al. 2017).

At a broader geographic scale, the records from this study find a better fit with environmental reconstructions from Westerlies-controlled Central Asia than with ISM-dominated regions of South Asia (Figure 7.5). There is good agreement between the Karakul Lake (Mischke et al. 2010), Pamir region of Tajikistan, and Kashmir Valley records. There is also reasonable agreement between the Kashmir records and the speleothem and lake records from Ulu-too and Son Kul in Kyrgyzstan (Wolff et al. 2017, Schwarz et al. 2017), though these demonstrate a higher degree of fluctuation and have been interpreted by the study authors as influenced by localised conditions driven by the interaction of the Western Disturbances and the Siberian anti-cyclone.

Records from the Trans-Himalayan (Rawat, Gupta, Sangode, et al. 2015, Rawat, Gupta, Srivastava, et al. 2015, Demske et al. 2009, Leipe et al. 2014, Kotlia et al. 2015) region in areas of convergence between the westerly and ISM regimes generally find some agreement with those of Kashmir, though there appears to be distinct temporal lag and geographical differentiation Figure 7.5. Of these records, the best alignment with the Kashmir data appears to be from the higher arid areas of Ladakh (Demske et al. 2009, Leipe et al. 2014) where the orography of the Himalayan ranges and Tibetan Plateau may lead to a more westerly dominated environment. Interestingly, Leipe et al.

(2014) correlate a period of reduced pollen productivity and minimal input of fresh water palynomorphs ca. 4500-2700 BP with ^{10}Be-dated morainic materials in the region (Hedrick et al. 2011) and interpret this as an indication for increased winter precipitation driven by stronger Westerlies and higher glacial sequestration of available water. These conditions have some temporal overlap with and may be analogous to the earliest (possibly periglacial) phase in the TM01 record.

There is generally poor agreement between the pollen records in this study and speleothem records (Kathayat et al. 2017) and pollen (Trivedi & Chauhan 2009) studies from the ISM-dominated Himalayan foothill regions. While some of this poorer fit may be attributed to the higher degree of fluctuation detected in the speleothem record, as well as the lack of well-resolved age modelling in the pollen study (Trivedi & Chauhan 2009), these likely indicate that the sites in Budgam District of the Kashmir Valley are primarily controlled by westerly climate regimes and dominated by winter precipitation. This interpretation is supported by the modern rainfall studies suggesting that sites on the east-facing flanks of the Pir Panjal generally receive the weakest delivery of ISM-driven summer rain across the Kashmir Valley (Jeelani et al. 2017). The closer agreement with proximal sites from the Kashmir Valley and the weaker agreement with more regionally dispersed studies suggests that the data from this study are robust and may also indicate a local, geographically circumscribed environmental niche within the Kashmir Valley.

7.3 Evidence for the long-term development of pastoralist ecology in Kashmir

Palynomorph, sediment and charcoal data in the three cores from Budgam District appear to be reliable proxies of pastoralist activity in the study area. Exploratory data from the PCA generally indicate a close relationship between variables known to be indicative of pastoralist presence in the landscape, including increases in pollens of pioneer trees and shrubs, ruderal plants and Poaceae (Li et al. 2008), coprophagous fungal spores (van Geel & Aptroot 2006, van Asperen et al. 2019) and macro-charcoal influxes. Mean particle size also generally increased during periods along with these variables, possibly attributed to mobilisation of coarser sediments in the catchment area by large groups of herbivores. Some plant types such as *Artemisia* have been noted to be highly sensitive to grazing pressures in Kashmir (Dad & Khan 2010, Vishnu-Mittre 1966) and therefore declines in this pollen type may be indicative of large groups of herbivores around the site. A number of these proxies have previously been summarised in Table 5.3. The following discussion aims to synthesise these datasets examining changes in the Non-Arboreal Pollen spectra, as well as variations in fungal spore, charcoal and sediment influx. As the Pari Has and Shali Ganga sites are situated within the tree line, localised forest clearing and landscape openness may also be an indicator of human activity. However, the high pollen productivity and dispersal of some Himalayan tree taxa, particularly *Pinus* (Roy et al. 2018, Quamar et al. 2018, Vishnu-Mittre & Robert 1971), leads to over-representation in the pollen record. Ratios of Arboreal/Non-Arboreal Pollens (AP/NAP) will be presented here but should not be considered as reliable indicators of anthropogenic opening of the landscape.

Neolithic Period (ca. 5000-3000 BP)

The TM01 core from Tosa Maidan is the only record in this study for this period (Figure 7.6). Total pollen counts and concentrations for ages concurrent with the Aceramic and Early Neolithic (ca. 5000-4000BP) are low and are unlikely to be representative of the extant vegetation around the site. The environmental data discussed in the section above suggest that this period was one of intensified westerly precipitation, likely delivered as heavy snowfall at altitudes around Tosa Maidan and limiting the utility of pastureland around the site (if transhumant pastoralists were indeed present in the area at this time). From ca. 4000 BP several indicators may show low-level pastoralist activity around the site, including influxes of macro-charcoals, small concentrations of coprophagous fungi and possibly anthropogenic Amaranthaceae pollen. At ca. 3700BP (90-88cm depth in core) there is also an increase in mean sediment size, driven by increased proportions of sand and silt.

There is a strong indication for pastoralist land use at Tosa Maidan during the Late Neolithic (ca. 3500-3000 BP). Grazing related pollen types average 12% of the NAP spectrum during this period, primarily comprising *Rumex* and Caryophyllaceae. Modal peaks of *Podospora* and *Sordaria* fungal spores and the presence of *Sporormiella* may also indicate an increase in the presence of herbivores around the site. A study of the dispersal and accumulation of these three fungal spore types in forested grasslands in Britain (van Asperen et al. 2019) finds multiple factors, including land cover and seasonality, in the dispersal and accumulation of coprophagous spores. The study concludes that fungal spores may be a better indicator of presence/absence of large groups of herbivores than proxies of grazing intensity or landscape openness. The study also found good statistical correlation between *Sordaria* and *Podospora* influxes, as well as *Sordaria* as a good proxy for herbivory within and at the margins of coniferous forest. These relations, as well as the statistical covariation of fungal spores with pollen indicators of grazing in the PCA, support the interpretation of pastoralism at Tosa Maidan during the Late Neolithic.

Mean particle size also increases to an average of 2.9µm throughout this period, and there are peaks of above-average charcoal influx across all size classes. The environment between 3500-3000 BP was interpreted as a drier phase in the section above. While this may complicate the interpretation of sediment deposition and fire activity, the correlation of these variables with other indicators related to pastoralism may indicate at least some anthropogenic contribution. Overall intensification of pastoralist activity interpreted through these data is reflected in PC1 scores of above 0 for the first time in the TM01 record.

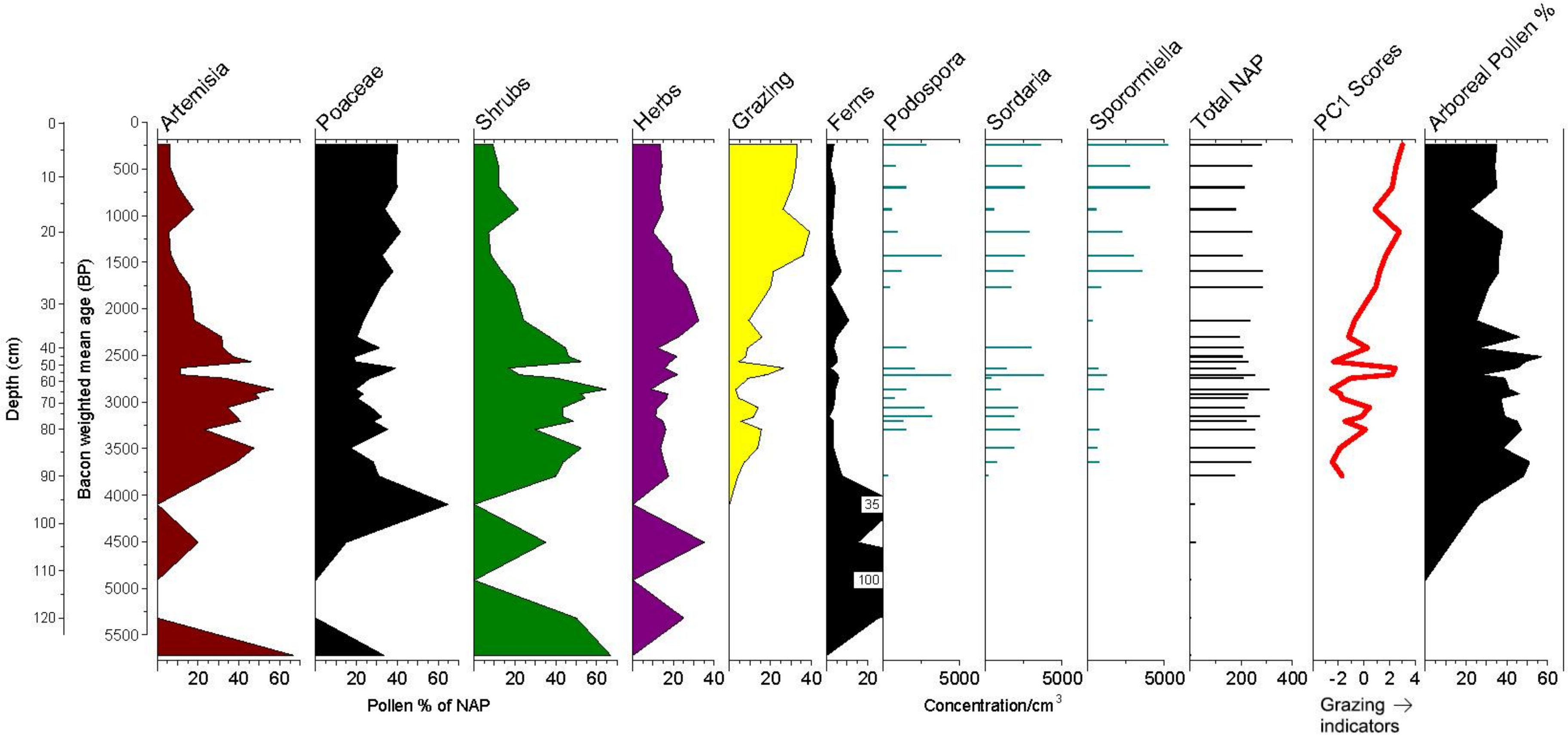

Figure 7.6: Pollen groups & types, fungal spores and PC1 scores interpreted as pastoralism indicators, TM01.

Iron Age/Proto-Historic Period (ca. 3000-2000 BP)

The age of all three cores from Budgam District spans at least part of this phase, although proxies for pastoralist activity are only evident in the Pari Has (PH03;Figure 7.7) and Tosa Maidan (TM01) records. In the TM01 between ca. 2800-2600 BP (60-52cm depth in core) a sharp increase in grazing pollen indicator taxa, Poaceae and coprophagous spores, along with above-average influxes of macro-charcoals and a decline in *Artemisia*, may be indicative of a short period of increased pastoralist land use. Environmental conditions around both sites between ca. 2600-2500 BP (TM01) and 2700-2400 BP (PH03) are interpreted as wetter phases, during which evidence for pastoralism declines or is not generally evident. It is unclear whether this may be genuinely representative of usage around the site or “overprinting” by more strongly distributed environmental markers.

In both records ca. 2300-2200 BP there is a moderate increase of most proxies interpreted as grazing indicators that may be evidence of a second brief period of pastoralist land use. If interpreted in this way, grazing intensity appears to be higher at Tosa Maidan than Pari Has. As human activity in the study area appears to be lower between 3000-2000 BP, one explanation may be lower land use pressure across the region. Pastoralist land use may be directed to exploitation of sub-alpine meadows above the timber line, without the need for energy-intensive expansion of pasture land into forested areas.

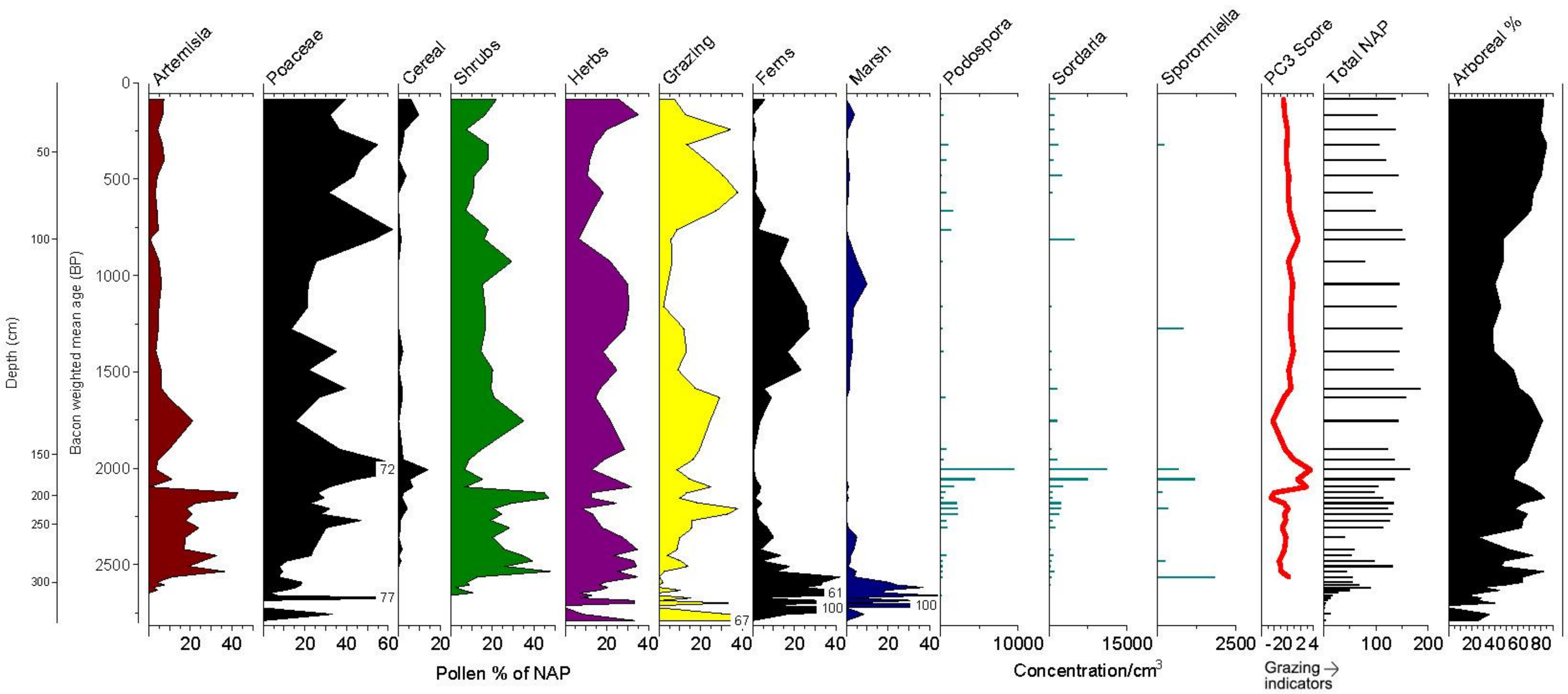

Figure 7.7:Pollen groups & types, fungal spores and PC3 scores interpreted as pastoralism indicators, PH03.

Kushan Period (ca. 2000-1500 BP)

As in the preceding cultural period, the TM01 and PH03 cores have multiple proxies that can be interpreted as evidence for pastoralist activity. In the PH03 record between ca. 2000-1900 BP (185-165cm depth in core) sharp increases of multiple variables including Poaceae and indicator pollen, macro-charcoal and coprophagous fungi as well as sharp declines in *Artemisia* suggest an intensified pastoralist land usage around Pari Has. During this period cereal pollens compose up to 5% of the overall pollen spectrum. At the present day, summer agriculture is practiced in the Doodhpathri area close to the study site, and this pollen data may be early evidence for the initiation of these systems of cultivation above ca.2200m ASL on the Pir Panjal mountain flanks. This period also has the highest sand and lowest clay proportions in the particle size record. These sediments are also very poorly sorted (σ_G >6). Silt-sized clasts remain generally stable indicating that variation in this closed sum is possibly caused by the mobilisation of coarser grained sediments. This sediment distribution is generally comparable to a colluvial deposit, typically mobilised as a result of deforestation or other agro-pastoralist activity (Goldberg & Macphail 2006). All measures of pastoralism begin to decline after ca. 1900 BP and this, as well as a recovery of *Artemisia,* may be indicative of only low-level pastoralist usage of the landscape by ca. 1700 BP.

Palynomorph indicators of pastoralist activity at Tosa Maidan climb more slowly after ca. 2000 BP, steadily increasing to ca. 1500 BP. Coprophagous spores are absent or present in only low concentrations initially, while the relative increase of Poaceae and decline of *Artemisia* appears gradual. The relatively slow-modelled accumulation rate in this phase complicates higher resolution temporal sampling; however, all proxies indicate a protracted 500-year increase of intensifying pastoralist land use around the site. Mean sediment size drops to a minima of 0.3µm ca. 2100 BP (30cm depth in core) before steadily rising throughout this period. This interpretation of slowly increasing land use at Tosa Maidan contrasts with the sharp intensification and contraction at Pari Has and may be due to geographical factors such as land cover or topography.

Historic-Modern Periods (ca. 1500 BP-Present)

Between ca. 1500-800 BP (135-100cm depth in core), environmental evidence suggests a strong shift to wetter conditions at Pari Has. This period sees a sharp reduction in all proxies associated with pastoralist activity and it is unclear whether this is a result of other environmental signatures masking these proxies, or whether there was a period of diminished use. Wetter conditions tend to suppress the reproduction and dispersal of coprophagous spores (van Asperen et al. 2019), as well as burning in the landscape, but their very low concentration and annual influxes would suggest that the minimal grazing around the site would have been the likely result of local environmental conditions.

The same time period sees a slight decline in concentrations of *Podospora* and *Sporormiella* spores in the TM01 record, possibly suggesting lower grazing activity while macro-charcoal influxes remain below the long-term average. Grazing-related pollen taxa (*Rumex, Trifolium*, Caryophyllaceae) remain at a stable levels through this period, while taxa indicating higher levels of disturbance (*Plantago*, *Urtica*) are present at very low, fluctuating levels. The overall expansion of grazing-related herbs is primarily due to higher proportions of Asteraceae which may also be a natural meadow component, driving higher PC scores for grazing. Despite the overall weaker grazing signal, the steady decline of *Artemisia* as well as higher proportions of Poaceae may still indicate moderate pastoralist land use.

From 800 BP to present, indicators for pastoralist activity in both records begin to increase. In the PH03 record, increased concentration of *Podospora* and *Sordaria* spores, relative abundances of *Rumex*, *Plantago*, *Urtica* and cereal pollens, and coarser more poorly-sorted sediments appear to be evidence of moderate agro-pastoralist land use around the site. *Artemisia* declines to the lowest levels in the pollen curve. The clustering of all observations from this period in the PCA, including sample depths from close to the top of the curve, may allow us to infer a mixed agro-pastoralist economy analogous to present-day usage.

At Tosa Maidan there is a general upwards trend of proxies for pastoralist land use after ca. 800 BP. In particular, there is a sharp increase in the sand fraction of the sediment size distribution, as well as σ_G values indicating very poorly sorted sediment. As in the PH03 record, these proxies may be interpreted as a pattern of land use comparable to the present.

At Shali Ganga, the SG02 record may present a small amount of evidence for agro-pastoralist land use ca. 1300-750 BP (88-70cm depth in core, Figure 7.8). The sharp increase in *Betula* pollens, as well as cereal pollens averaging 1.2%, may be indicative of land clearing and cultivation. Due to the site's altitude, this could possibly be associated with low-level summer season pastoralist land use, an interpretation supported by low concentrations of *Sordaria* spores. An intensification of pastoralist land use is apparent at ca. 400 BP (48cm depth in core) to present. During this period pollen proxies indicate that grazing at Shali Ganga increase and particle size data is dominated by coarser, very poorly sorted sediment. There is a secondary intensification ca. 250 BP possibly indicating the development of modern land use.

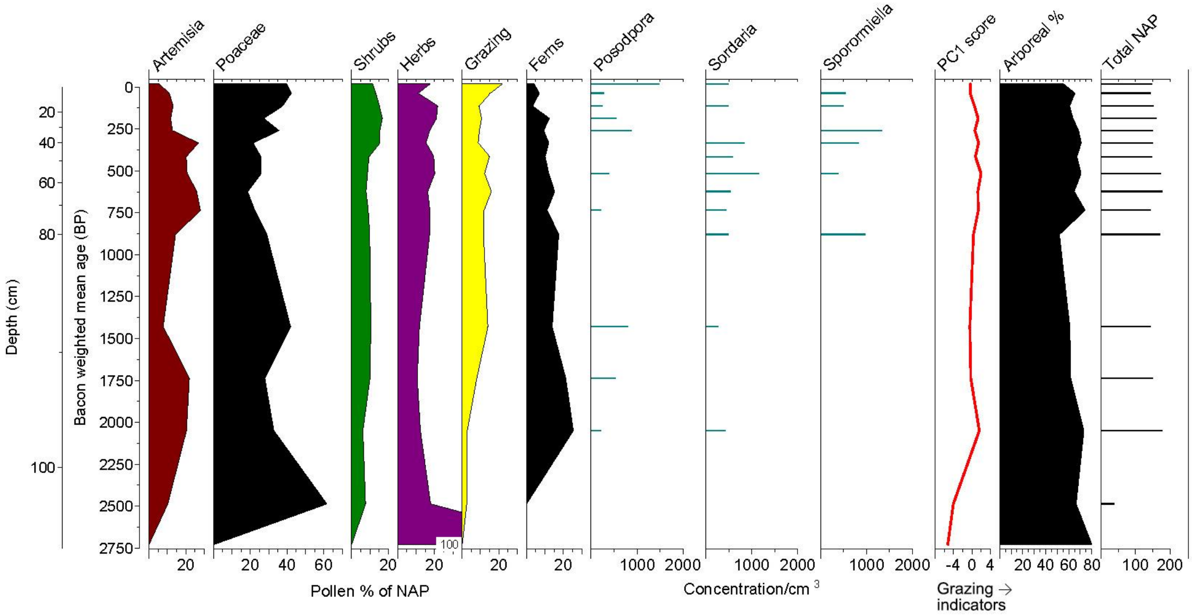

Figure 7.8: Pollen groups & types, fungal spores and PC1 scores interpreted as pastoralism indicators, SG02..

Summary

Comparison of the three records provides insight into long-term patterns of pastoralist ecology in Budgam District. While there is some agreement in phases of intensification of land use across the records, the presence of particular events at some sites and their absence at others suggests that the pollen catchment at each of the sites may reflect local conditions, particularly changes in non-arboreal pollens and palynomorphs. The spatio-temporal variation between the sites may be evidence of differentiated usage of varying altitudinal and vegetation zones across the Pir Panjal flank of the Kashmir Valley. Interestingly, intensifications of land use all appear to generally correspond with drier environmental phases, though whether this is the result of overprinting by stronger environmental signatures in wet phases is unclear.

Moderate to low-level pastoralist land use may be interpreted in the high altitude TM01 core, intensifying through the late Neolithic period, before an apparent contraction after ca. 3000 BP. Evidence of human activity from ca. 3000-2000 BP is discontinuous, with upward fluctuation of indicators at ca. 2700 BP and 2200 BP in the TM01 and PH03 cores. The Kushan period ca. 2000-1500 BP sees a sharp increase in proxies for pastoralism in both of these records. Supplementary evidence such as the presence of charcoal and ceramics in the Baisaran (BS01) core from the Himalayan side of the Kashmir Valley may indicate a wider colonisation of the mountain flanks during this period. Following this period there is an apparent environmental deterioration and decline in pastoralist land use. After ca. 800 BP the intensification of markers of pastoralist land use is evident in all three records from Budgam District.

7.4 Pastoralist niche construction and social-environmental systems

Niche Construction Theory maintains that niche constructing activities are inherent in the behaviour of any organisms within their ecological niche, and extend to human ecological and cultural practices (Odling-Smee et al. 2003). It implies that any form of pastoralist land use is necessarily such niche constructing activity. Within the data from the Budgam district sites, evidence for pastoralist niche construction is best classified as indicating either *inceptive perturbation* (e.g. modification of vegetation or changing of the soil landscape) or *counteractive relocation* (e.g. changing patterns of land use as a result of other environmental pressures) (Table 3.1). Some processes of perturbation can be inferred from the study data, even if they remain largely “invisible” in the proxies used here. These would include changes in microbiota due to increased dung accumulations or the competitive pressures on other animals resulting from the presence of large herds of domestic herbivores. These niche-constructing activities may help us to consider the long-term resilience of pastoralist social-environmental systems.

At Tosa Maidan there appear to be three stages of increased pastoralist activity, ca. 3700-3000 BP, 2700-2500 BP, 2000 BP-present. The period ca.3700-3000 BP exhibits a low-level of perturbation, where moderate levels of palatable herbs such as *Rumex* and Caryophyllaceae were maintained. At this stage there does not appear to be heavy pressure on sensitive taxa such as *Artemisia,* and levels of Poaceae generally remain below 20% of the pollen spectrum. In the later part of this period there are signs of diminished pastoralist activity, evidenced by increases in *Artemisia* as well as decreases in relative abundances of *Rumex* and Caryophyllaceae, and concentrations of coprophagous fungi.

Between ca. 2700-2500 BP there is an apparent phase of intense pastoralist land use leading to degradation of the ecological niche. Caryophyllaceae and *Artemisia* decline and relative increases of *Plantago, Urtica,* Poaceae and Asteraceae could indicate overgrazing. A sharp upward fluctuation in mean sediment size and influxes of both macro-charcoal size classes and a marked decline of *Betula* pollen also point to land-clearing activity around the site. Diversity of plant taxa recovers after this period until ca.2000 BP where there is a steady upward but fluctuating trend in indicators for grazing. Throughout this period the ecological niche appears to be maintained through suppression of high-altitude trees and shrubs such as *Betula* and *Abies* and *Juniperus* as well as periodic episodes of less intensive land use such as between ca. 1000-800 BP when a recovery of *Artemisia* is contemporary with a decrease in coprophagous spores.

Evidence for niche constructing activities at Pari Has and Shali Ganga take on a slightly different character due to their lower elevation and forest cover. In the PH03 record a large influx of all charcoal-size classes at the base of the core ca. 2700 BP can be attributed to human-induced burning of the forest landscape, particularly as the climate is interpreted as cold-wet at this time. Detecting anthropogenic opening of the landscape remains problematic as conifer forest pollens are likely over-represented (Sugita et al. 1999). However, several types in the pollen spectrum such as *Plantago* and Caryophyllaceae are representative of plants with photosynthetic requirements for an open environment (Behre 1981). Behre also notes that *Persicaria* pollens are typically only found in moister grazed forest understory. The data in the PH03 core indicate a transition from a more closed forest canopy to a more open environment between ca. 2300-2100 BP. *Urtica* and Cannabaceae pollen are also evidence for disturbance of the landscape in this period, as does an increase in mean sediment particle size. This was followed by a rapid intensification of agro-pastoralist activity evinced by sharp increases in cereal pollen, coprophagous fungal spores, pollen indicators of grazing, charcoal influx and mean particle size. This could be considered a period of *counteractive perturbation* following the initial earlier colonisation, whereby more intensive forms of grazing and possibly cultivation followed from external environmental or social factors, or as pull factors such as the newly exploitable pastoralist niche around the site.

The decline of proxies for pastoralism and cultivation around Pari Has between ca. 1500-800 BP can be interpreted as a form of *counteractive relocation* where local environmental conditions may have made the area unsuitable for agro-pastoralism. Alternatively it could be argued that these wetter conditions drove higher mountain runoff and led to intensification of cultivation on the valley floor. This interpretation is tentatively supported through the archaeobotanical record, which reflects a diversification and expansion of both winter and summer agriculture (Lone et al. 1993). During this period, fluctuating low to moderate signals for pastoralist land use at the high altitude meadow around Tosa Maidan implies that the pastoralist landscapes were either dispersed over a wider geographic space, or there was a shift to lower investment herding close to the timber line. At that point, suppression of forest growth and maintenance of the pastoralist niche would have been less labour intensive.

The forest clearing and agro-pastoralist land use around Shali Ganga occurs much later than that around Pari Has, with significant evidence only after ca. 500 BP. Despite the relative proximity of the two sites, limiting factors include both the topography as well as the lack of the economic or environmental imperative to make use of this part of the landscape. The data interpreted as indicators of pastoralist or agro-pastoralist land use in the records from Budgam District are both discontinuous within records and changes are often asynchronous across the records. Comparing these data, it is possible to interpret a dispersed or “patchy” (Spengler 2014) pastoralist landscape across the district, where sheltered niches such as Pari Has that, while suitable for enrichment and cultivation during favourable environmental conditions, could have been increasingly difficult to maintain when the labour investment of the area’s agro-pastoral groups became more productively directed elsewhere.

This system of land use around Pari Has can be compared with observed agro-pastoral use at the present day, where groups of herders move to the Doodhpathri area from the lower altitudes of Budgam District at the start of summer. Depending on environmental conditions, strategic decisions are made as to whether to remain in the area and engage in cultivation of summer crops (typically maize), move the herds to higher altitude sites such as Tosa Maidan, or undertake a division of labour in order to engage in a mixture of these two choices. These *counteractive perturbation*s can be considered strategies embedded within a flexible social-ecological system that is able to respond to changing environmental and historical circumstances at annual or even seasonal scales.

These social-ecological systems appear to be long-standing adaptations in the Budgam District where the accumulation of thousands of years of agro-pastoralist labour across the district may be detected among the accrued changes in the palynomorph, sediment and charcoal records in this study. While this study presents evidence from only one district on the Pir Panjal flank of the Kashmir Valley, there is scope for expansion of the methods used here to other areas of the valley. And as the adaptive responses of pastoralist groups are contingent not only on environmental but socio-cultural and economic factors also, it is now possible to turn to a *longue durée* consideration of how pastoralist systems interacted with broader historical forces.

7.5 Pastoralism in Kashmir in historical context

Ethnographic and historical studies of agro-pastoral populations in the Central and South Asian mountains and Tibetan Plateau have generally emphasised relationships between pastoralist groups and states, particularly in regard to land access and rights, economic and social reforms, and ecological management (Dong et al. 2016, Khazanov 1994). While a major focus of these studies is the transformation of pastoralist economy within the socialist and post-socialist landscape of the former USSR and China (Kreutzmann 2012), they often stress that pastoralist populations are not simple units of economic organisation or food production but are enmeshed in local and regional institutions and norms. In a case study from Chitral in the eastern Hindu Kush where the mountainous environment gives rise to a number of ecological niches, pastoralism is undertaken as part of a mixed agricultural economy controlled by factors including land use rights, herd size and composition, settlement patterns and seasonal movement, and the richness or degradation of resources (Nüsser et al. 2012). Seasonally mobile pastoralism and cultivation in Chitral is generally practised by the Gujjar community, while ethnic majority Kho people are typically engaged in sedentary agriculture. Similarly, in the Himachal region of the Western Himalayas varying forms of sedentary, tethered or fully mobile pastoralism and cultivation are practiced by different ethnic groups, based on various socio-cultural, economic and environmental factors (Singh 2012). The agro-pastoralist groups in these areas are also enmeshed socially and economically with neighbouring agricultural and urban populations, participating in trade of secondary goods such as dairy, skins and wool, as well as in negotiations over access to resources such as pastureland, forests and areas of cultivation. These studies emphasise that pastoralist ecology and economy does not exist in isolation from other populations engaged in different forms of land use in the same ecological zone, nor from more hegemonic institutions of power.

Discerning these interactions between pastoralist and neighbouring groups during historic periods is complicated by the fact that historical accounts are usually fragmentary descriptions of nomadic groups on the periphery of ancient Chinese or Persian states (Frachetti 2008). For pre- and proto-historic periods, articulating the relationships between prehistoric cultivators and herders in Central and South Asia is often only traceable through material evidence for contact and exchange (Kenoyer 2004, Spengler 2015). Archaeologically these may be recognised through the remains of agricultural crops in pastoralist niches not suited to cultivation and often found in burial or ritual contexts (Spengler et al. 2014) or through evidence for long-distance trade of raw materials, technologies or finished good from materials such as lapis lazuli, copper, tin or carnelian that would be passed through or ultimately provenanced in areas of mountain pastoralism (Frachetti 2012, Kenoyer 2004, Mei 2000). Economic exchange between pastoralist groups and sedentary populations has been classified as either direct or mediatory trade (Khazanov 1994). In the former, herders directly exchange animal products with settled populations for agricultural or other material goods. Khazanov (Khazanov 1994, p.202) notes that as pastoral nomads often have a specialised productive base, they are particularly interested in market engagement with more diversified sedentary economies. This interest in trade also drives the second type of exchange where luxury or exotic goods are traded between pastoralist and other groups during one season, to be traded with other nomadic or sedentary groups during incidental contact at some other point during a seasonal migration. For example, pastoralist group A trades goods with settled population B while based in lowland winter camps. During migration to summer pastures, group A trades with another pastoralist group C who then exchange with pastoralist group D and agricultural settlement E during their autumn return to the lowlands. Due to variability in pastoralist migration, economic practices and land-use patterns, these exchanges can form highly complex networks of non-uniform contact and exchange (Frachetti 2012).An archaeological model for examining these contacts has been proposed by Young (2003) through the integration of ethnographic, zooarchaeological and archaeobotanical data, where it is argued that varying forms of seasonal movement, settlement and selection of various domestic crops and animals allowed for adaptation to differing environments of northern mountain valleys and plains of Pakistan. This diversification may have allowed for the stability of cultural norms presumed to be in upheaval during the Late Bronze Age and early Iron Age in the region.

The norms that governed the production and exchange of goods, land access or other resource utilisation in the Inner Asian mountains may be conceived as “non-uniform institutional complexity” (Frachetti 2012), where these general norms may be mediated through localised environmental or social conditions. These then more localised institutions give rise to more heterogenous forms as pastoralist groups interact with neighbouring populations within or adjacent to their ecological niches. A similar approach examining localised responses to environmental conditions has been used as an explanatory mechanism to account for the rise of culturally diverse agro-pastoralist groups in Xinjiang, from populations likely derived from the same economic base (Betts et al. 2018). These approaches may provide us with a framework for understanding the long-term social, economic and environmental basis for pastoralism in the Kashmir Valley.

Archaeological evidence for mobile or transhumant pastoralism during the Neolithic in Kashmir is rather limited. Faunal remains indicative of an animal economy are limited to a single appended report from Gufkral (Sharma 2013) which indicates a protracted dietary shift from wild animal consumption at the start of the Neolithic, to mixed consumption of domestic caprids and cattle (totalling around 65% of the assemblage) and wild animals by the late Neolithic. Despite the presence of domestic animal remains, this in itself is not evidence for mobile pastoralism as animals could be raised in a form of tethered husbandry around agricultural villages if grazing resources were sufficient. Evidence for grazing in areas adjacent to Neolithic villages may also be inferred from the archaeobotanical assemblage from a conical storage pit at Qasim Bagh dated ca. 4000-3500 BP (Spate et al. 2017). While the dominant botanical remains comprise domestic wheat and legumes, a large quantity of weedy *Polygonum* (*n*=192), *Carex* (*n*=43) and Amaranthaceae (*n*=36) seeds are also present in the botanical assemblage. One pathway for these seeds into the assemblage may have been as agricultural weeds, however they may have also been deposited as a result of burning of animal dung for fuel (Spengler 2019, Miller 1984). Detecting burning of animal dung in archaeological assemblages is best achieved through multiple proxies which have yet to be applied to the site. Quantities of macro-charcoal were not strictly controlled in the original study, however unpublished anthracological data indicates that possibly only small quantities of *Abies* and *Salix* were burned in-situ (Shen Hui, pers. comm. September 2018), indicating that dung may have been an important fuel source at the site. A similar package of weedy type seeds has been used to infer the burning of animal dung at a proto-historic site on the western Tibetan Plateau, interpreted to be the result of grazing of domestic animals at marshy environments proximal to the settlement (Song et al. 2018). Similar inferences may be tentatively made at Qasim Bagh, where the archaeological site is situated on a raised Karewa terrace adjacent to the expansive wetland at Hygam, the margins of which are currently used for livestock grazing and fodder production (Hamid 2009).

The archaeological data from these two sites indicating the development of some form of animal husbandry is coeval with the earliest evidence of high-altitude grazing in the TM01 record in this study. While it is not possible to link the development of grazing in sub-alpine pastures with the animal economy on the valley floor, the potential presence of herd animals in both ecological zones may be interpreted as an early expansion of summer season landscape utilisation in the Kashmir Valley. If both forms of economy were practised by the same populations or within the same archaeological cultural complex, this may represent the earliest evidence of high-altitude meadow utilisation by Kashmir Neolithic populations, previously thought confined to the alluvial Karewa landscapes on the valley floor and margins (Yatoo 2012). While there is no evidence in the environmental records in this study for pastoralist activity in the mid-mountain forest belts during this period, lithic microwear studies of stone axes and chisels from Burzahom (Pant et al. 1982) indicate the development of wood cutting and the technological basis for modification of the forest environment. The presence of *Abies* charcoal at Qasim Bagh and *Pinus* charcoals at Burzahom (Lone et al. 1993) is possible evidence of some forestry activities in the middle-altitude conifer forests situated at some distance from the Neolithic settlement sites.

An alternative explanation for altitudinally differentiated patterns of land use in the Kashmir Valley may be through the presence of two discrete populations, one engaged in agriculture and tethered animal husbandry on the valley floor, and a second more mobile pastoralism engaged in herding and secondary cultivation in the mountain zones. This variation in landscape usage may be comparable with the economic and social differentiation in the Chitral case study (Nüsser et al. 2012), or with the practices of Gujjar pastoralists and Kashmiri farmers in the valley in historic and modern times (Husain 2008). Both engaged in forms of transhumant herding and cultivation but with different emphasis on their dominant economic base. A model for contact and exchange between the two groups can be read in a description of the summer arrival of mobile Gujjar-Bakarawal nomads in high pastures of Warwan, a sub-valley to the east of the Kashmir basin (Sharma 2018). Exchange between the Bakarwal and sedentary Warwani farmers takes place through trade and exchange of material goods but also through feasting and the ritual sharing of nomadic “institutionalised values” (Sharma 2018) – adaptability, mobility, and economic and environmental resilience. These ethnographically and historically documented exchanges provide an empirical basis for Frachetti’s “non-uniform institutional complexity” among prehistoric populations of Inner Asian mountains. These “non-uniform institutions” such as mobility and local environmental adaptability may help to explain the persistence of Neolithic agro-pastoral groups in Kashmir, as well as other Himalayan valleys such as Swat (Stacul et al. 1987), lasting over 2000 years on the margins of rapidly expanding and integrating civilisations such as the Harappans in the northern Subcontinent and the Bactria-Margiana Archaeological Complex of southern Central Asia.

If we accept the interpretation of the TM01 record as having evidence for summertime usage of high -altitude pastures by a herding group distinct from the Kashmir Neolithic farming populations, this may help to build a better understanding of networks of exchange between the Kashmir Valley and surrounding regions. Isotopic studies of ceramic, stone and lead artefacts from Harappa (Law, 2008) indicate that galena for lead artefacts and glaze as well as alabaster for ground stone bowls during the Harappan 3C phase (ca. 4600-3900 BP) was likely mined in the Kashmir Valley. Finds of a singular proto-Harappan Kot Diji style pot at Burzahom (Khazanchi & Dikshit 1980) and Harappan-style bracelets, copper pins and carnelian beads at Burzahom and Gufkral (Ghosh 1969, Sharma 2013) indicate some contact between Harappan civilisation and Kashmir Neolithic populations, but there is no direct evidence for the presence of Harappan groups in the Kashmir Valley. Law (2008) has hypothesised that exchanges took place between Kashmir and Harappa, possibly mediated through trade with a seasonally mobile pastoralist population, or directly by a pastoralist group who were directly engaged in mining and resource extraction as a secondary activity during summer season occupation of mountain pastures. Prior to the current study there appeared to be no direct or indirect evidence of pastoralist activity in the mountain flanks of Kashmir.

The transport of raw materials out of the Kashmir Valley into regions to the south may also take place in parallel with the ingoing trade of agricultural domesticates. The earliest development of cultivation in Kashmir appears to be based on arid-adapted emmer wheat and barley, initiated by either the adoption of cultivars by a pre-existing but undocumented hunter-gatherer population, or through the wholesale migration of a proto-Harappan related farming group (Pokharia, Mani, et al. 2017). Emmer wheat and barley in the agricultural package were quickly replaced by compact wheats (*T.* cf. *aestivum*/*durum*) as well as broomcorn millet (*Panicum miliaceum*) at the sites of Qasim Bagh (Spate et al. 2017) and Pethpuran Teng (Alison Betts pers. comm. March 2019). The former of these two appears to be a phenotypic adaptation suited to agro-pastoralist systems of mountainous Inner Asia (Motuzaite Matuzeviciute et al. 2018, Liu et al. 2016), while millets appear to be transported out of northwest China into Central Asia by networks of seasonally mobile pastoralists (Spengler 2015). Kashmir was already hypothetically connected to these networks of pastoralist-agricultural exchange ca. 4000-3000 BP due to the presence of both West and East Asian domesticates (Stevens et al. 2016). The record from Tosa Maidan may help support this inferred contact with direct evidence of pastoralist ecology in Neolithic Kashmir.

The Iron Age (ca. 3000-2000 BP) was a period of social and economic reorganisation of agro-pastoralist groups in Central Asia (Chang 2018) as well as regional cultural and economic differentiation in South Asia ca. 3000-2600 BP followed by a period of urban reintegration and expansion of regional polities (Coningham & Young 2015). For Central Asian agro-pastoralists, this period appears to be one of an expanded agricultural base, increased social hierarchy and organisation into political confederations (Chang 2018, Spengler et al. 2017). These changes were historically believed to be a background for incursions into South Asia by Central Asian nomadic confederations, however reappraisal of chronological and genetic evidence indicates a more complicated pattern of interaction (Coningham & Young 2015, Narasimhan et al. 2019). An archaeological focus on the Harappan Bronze Age and historic period empires means that this period is poorly understood in South Asia generally, and in Kashmir in particular (Yatoo 2015). While archaeological deposits from this phase are noted at Buzahom and Gufkral (Shali 2001), published reports on human occupation in the valley are only available from Semthan (Mittra 1983). During the North Black Polished Ware (NBPW) and Indo-Greek Iron Age phases, the archaeobotanical study from the site (Lone et al. 1993) reports the expansion of bi-seasonal, and in particular summer agriculture with the introduction of South Asian urd and mung bean and the dominance of rice among the cereal remains. The interpretation of environmental records from this study, as well as the recent Anchar (Lone et al. 2019) and Manasbal (Babeesh et al. 2019) lake cores indicate generally cold wet conditions across the Kashmir Valley at this time. As this precipitation would have been delivered primarily as winter snow, an emphasis on summer agriculture may have been an adaptive mechanism to a higher spring-melt runoff. Similar environmental conditions may have driven previously mobile pastoralist groups to more settled patterns of agriculture on alluvial fans in southeast Kazakhstan during this period (Spengler et al. 2017).

One of the aims of this study was to detect pastoralist activity in the mountain flanks of the Kashmir Valley during the Iron Age, due to the relative lack of published archaeological records. Contra to interpretations by Agrawal (1992) of an environmental decline driving a societal collapse across the valley floor, crop and charcoal remains in the archaeobotanical record from Semthan seem to indicate a wide utilisation of diverse resources (Lone et al. 1993). The sharp increase in grazing indicators in the TM01 record ca. 2700-2600 BP may be evidence for a brief intensification in land usage. The decline in these indicators following this period, as well as the evidence for wet conditions in the PH03 record, may indicate environmental changes unsuitable for higher altitude grazing at this time. These conditions may have shifted economic focus towards cultivation on the valley floor, though conclusive interpretations for this period should be made cautiously due to the still limited archaeological and environmental record.

Past work on the Kushan period has tended to emphasise the cultural syncretism of rulers and elites rather than social, economic and environmental conditions of populations living under Kushan control. These studies have traditionally drawn on numismatic, architectural and epigraphic evidence, rather than domestic or landscape oriented studies (Mukhamedjanov 1996). This gap in knowledge is less pronounced in Central Asia where the expanded archaeological and environmental record has allowed for insight into non-elite socio-environmental organisation. This period is generally understood to be a continuation of the earlier Iron Age process of sedentisation in areas suitable for agriculture, while continued exploitation of grasslands drove pastoralist populations towards more highly mobile forms of nomadism (Rapin 2007). Archaeological evidence from the region also indicates an expansion of agriculture into new geographic niches as the development of irrigation and damming technologies allowing for upland cultivation in mountain valleys of high surface runoff in turn driving mixed agro-pastoralism to higher elevations (Mukhamedjanov 1996). In South Asia, these forms of land management and usage are poorly understood during the Kushan period, due to a focus on the ways in which religious and trade elites benefitted from the Kushan rulers' policies rather than examination of the lives of the agrarian populations (Liu 2001). Based on their nomadic origins and continued depiction in nomad clothing, Liu (2001) argues that the Kushan rulers of northern South Asia would have likely expressed tolerance for the economic and social organisation of agro-pastoralist populations under their control. The economic priority of Kushan elites was the prioritisation of nascent Silk Road trade between urban centres of Eurasia, which may have been best mediated through peripheral pastoralist populations in the mountain zones of Inner Asia (Frachetti et al. 2017).

As in other areas of South Asia, the Kushan period of Kashmir is identified through typological analysis of architectural and artefactual materials (Mani 2000, Shah 2012). Botanical remains from the Kushan periods at Kanispur (Pokharia, Mani, et al. 2017) and Semthan (Lone et al. 1993) provide some insight into the agricultural economy during this period, with dominant cereals recovered at each site being barley and wheat respectively. Summer rice and millets total around 22% of the assemblage at Kanispur and 28% at Semthan. Also at Semthan, an increase in the abundance of several *Galium* species, *Lithospermum* and *Vicia* has been interpreted as evidence for intensified foddering and dung burning linked to the expansion of the agro-pastoral economy ((Lone et al. 1993). Comparable quantities of *Vicia*, *Chenopodium*, *Rumex* and *Polygonum* at Kanispur may support similar conclusions at that site (Pokharia, Mani, et al. 2017).

The settlement of the Kushans in Kashmir has been interpreted as an in-migration of a Central Asian nomadic elite, entering through passes to the north around Gilgit, the route which links Kashmir to other major regions of Central Asia (Shah 2016). Preliminary survey and analysis of Kushan settlement pattern in Kashmir indicates a concentration of sites in the north of the valley, interpreted as being a result of the initial route of colonisation, as well as a means of controlling the primary trade and travel routes that link the valley to Central Asia to the north, and the Kushan capitals at Taxila to the west via the Jhelum river route (Shah 2016, Shah 2012, Yatoo 2012). Shah (2016) notes that the majority of settlements are agricultural sites clustered close to the Jhelum flood plain. Archaeological survey of the Baramulla District (Yatoo 2012) indicates colonisation of mountain flanks above 1800m ASL during this period. The Ashrat Nard Kushan site recorded during 2018 fieldwork in this study, around 5km east of Pari Has, is situated ca. 2200m ASL and may represent a higher colonisation by Kushan groups controlling mountain pastures and forest zones.

The evidence for agro-pastoralist land usage from the PH03 record drastically increases during the early Kushan period, where bio-markers associated with grazing, coarse sediment input and charcoal influxes all indicate a pronounced impact on the landscape. During this period there is also an increase in cereal grass pollens, likely indicating an agricultural intensification around the site. This form of land usage may have been possible through technological developments for managing mountain runoff at higher altitudes, as described by Mukhamedjanov (1996) elsewhere in Kushan Central Asia. The pastures in the mountain zones of Budgam District are situated adjacent to the Jhelum River gorge to the north. It may be possible that intensified agro-pastoralist land usage in this area may have been associated with attempts to control this key trade route, either by Kushan rulers themselves or through local nomadic intermediaries.

At Tosa Maidan indicators for pastoralist land use increase steadily throughout the entire Kushan period. This may be indicative of practices such as localised modification of the forest landscape for lower level discontinuous grazing and cultivation closer to settlements, as is evident at Pari Has, while high altitude pastures may be persistently utilised. Grazing pressure on these sub-alpine meadows may increase as technological developments including new crops and land and water management systems may have expanded agriculture into areas previously utilised for the herding of animals.

The post-Kushan period in Kashmir saw a number historical processes including the rise of local dynasties, ongoing urbanisation and centralisation of power in the valley that led to the development of a Kashmiri cultural and political identity (Shali 2001, Bamzai 1994). These changes allowed for the geopolitical expansion of the Kashmiri state out of the valley and into adjacent regions of Ladakh, Tibet, the Punjab, Swat and Central Asia. Interpretation of archaeobotanical data from Semthan (Lone et al. 1993) as well as accounts by the Chinese Buddhist pilgrim Xuanzang (ca. 1400 BP, Shah 2012) indicate that the period ca.1500-1000 BP was typified by a diverse agricultural and horticultural economy driven by optimal climate conditions. During this time there was also a proliferation of settlements and monumental architecture (Kak 1933) that has been interpreted as evidence for a large economic surplus during this time. These generally wetter conditions supporting agriculture across the valley floor may be evidenced in the PH03 and SG02 cores from Budgam District in this study, as well as in the Manasbal Lake record (Babeesh et al. 2019).

These wetter conditions may have had the ecological effect of masking any evidence for pastoralist activity in the PH03 and SG02 cores, which is diminished ca. 1500-1000 BP. A second explanation is that this environmental phase may have shifted the economic focus from mid-mountain zones to the valley floor, as groups previously engaged in mixed-agro pastoralism may have taken up full-time cultivation. This may be attributed to factors such as wetter conditions making management of pastures in forest belts more difficult, while agriculture may have been more profitable. The generally strong evidence for high-altitude pastoralist activity in the TM01 record may be evidence for a shift in grazing land use away from the valley floor and forest belts and towards more remote, open environments. The increase in evidence for pastoralist land usage in all of the records after ca. 1000 BP may be a result of changing political and environmental conditions. The overall drier conditions may have allowed for easier modification of the forest biome while placing stresses on agriculture on the valley floor. Tree ring studies from the Western Himalayas have found some correlation between drier conditions and poorer agricultural surplus weakening Indian states on the one hand, while facilitating movement of Central Asian pastoralist confederations across mountain zones into South Asia on the other (Yadava et al., 2016). Though not conclusive, this study raises some of the push-pull dynamics between agricultural populations, pastoralist groups, historic states and the environment in Kashmir as well as adjacent areas of South and Central Asia since the rise of centralised polities in the valley.

The environmental records in this study evince that pastoralist activity on the Pir Panjal mountain flank of the Kashmir Valley was discontinuous, likely a result of the entanglement of mobile pastoralist ecology with the immediate environment as well as neighbouring human populations and long-term processes of climate change. The phases of heightened pastoralist activity have a significant overlap with the Neolithic and Kushan cultural phases, which may have bridged ancient populations on the Kashmir Valley floor with neighbouring regions, as well as expanding the productive base of these societies. Following the rise of centralised states in the valley, pastoralist groups may have been drawn into more complex social systems, where land use and access to resources are constantly renegotiated between herders, farmers and bureaucratic power. While the evidence from this study indicates that these dynamics would likely have intensified after ca. 1000 BP, these environmental proxies are not sufficient for examining the complexity of these relationships. These preliminary data must now be expanded through further archaeological and environmental fieldwork, and rich ethnographic and historical research.

Chapter 8 Conclusions

This chapter reviews and summarises the interpretations presented in Chapter 7, beginning with a discussion of findings related to long-term patterns of pastoralist land use in Budgam District. The inferred environmental changes are then used to contextualise agricultural changes in the Kashmir Valley. Section 8.2 is a critical assessment of the methods used in this thesis, undertaking considerations of the proxies best suitable for reconstructing pastoralism in the valley. This section also identifies a number of methodological problems and proposes ways these may be addressed. This discussion is expanded in Section 8.3 that outlines avenues for future research. The final Section 8.4 concludes the thesis with a brief consideration of the way in which research questions outlined in Chapter 1 have been addressed.

8.1 Overview of findings

The primary aim of this study has been to undertake a preliminary reconstruction of long-term patterns of pastoralist land use in the Kashmir Valley. While ultimately the spatial aspects of the study were confined to one area of the Pir Panjal flank of the valley, there appears to be significant altitudinal and temporal differentiation between the study sites, suggesting mobile pastoralism to be an adaptable system of summer-season land use above 2000m ASL beginning in the later Neolithic period. In addition to examining pastoralism, several other data in the study may aid in interpretation of past human-environment interaction in the valley more generally.

Pastoralism in Kashmir Valley mountains

The data from the three cores from Budgam District (TM01, PH03, SG02) provide the first evidence for the development of upland herding on the Pir Panjal flank of the Kashmir Valleys as early as 4000 BP. Due to the younger ages of the core samples taken from mid-mountain forests, it is unclear whether the earlier forms of pastoralism were concentrated on the more open sub-alpine areas above 3000m ASL or whether various forms of herding and associated landscape modification spread across the entire valley.

Environmental interpretation of the data in this study, as well as from Manasbal (Babeesh et al. 2019) and Anchar (Lone et al. 2019) lakes indicate a transition to a drier climate between ca. 2500-1700 BP. This period is contemporary with the proto- and early-historic periods when Kashmir was integrated into the Kushan empire. At Pari Has, the PH03 data shows the strongest signal for pastoralist land use, while at Tosa Maidan similar indicators increase steadily through this period. Yatoo's (2012) survey in Baramulla District also found the highest number of single-period sites in mountain areas away from the valley floor during this time, while the stray finds of Kushan ceramics and rock carvings around Aru village (2700m ASL) noted during this study's fieldwork are significant evidence for upland colonisation during this period. As these areas are inaccessible during winter, they would likely have been integrated into spatially dispersed systems of transhumant herding or agro-pastoralism. These forms of socio-ecological adaptation are understood to expand throughout the Iron Age in Central Asia (ca. 2800-1500 BP; Spengler et al. 2017). While the development of agro-pastoral systems in Kashmir likely developed on a different trajectory owing to a local Neolithic tradition, by this time we may add Kashmir to a "world-system" throughout the Inner Asian mountains, modulated by the culture, ecology and economy of pastoralist populations (Chang 2018, Frachetti et al. 2017).

There appears to be a third phase of intensified upland pastoralist activity across all three records beginning at around 800 BP. The onset of drier conditions is apparent in environmental proxies in this study, as well as in other Kashmir and regional records (Babeesh et al. 2019, Lone et al. 2019, Yadava et al. 2016). Various phases of wetting and drying associated with the Medieval Warm Period and Little Ice Age have been linked to the consolidation and expansion of nomadic-pastoralist empires out of Central Asia (Yadava et al. 2016, Pederson et al. 2014). At this time Yadava et al. (2016) argue that deteriorating climates drove Central Asian pastoralists into South Asia leading to plunder and conquest in the subcontinent. There is little in the archaeological record or in historical accounts to link this to pastoralists in Kashmir (Shali 2001), and it is more likely that this upland pastoralism was part of a mixed system of herding and cultivation, allowing for the expansion and resilience of food-producing systems during periods of drier climate.

Agricultural systems

The environmental data from this study as well as those from valley floor lake sediments (Shah 2019, Babeesh et al. 2019, Lone et al. 2019) build a strong case that development of agriculture during the Kashmir Neolithic took place during phases of aridification rather than warm-humid periods as was previously believed (Agrawal 1992). The oldest known archaeobotanical assemblage, from Kanispur (Pokharia, Mani, et al. 2017), dominated by barley with a small number of emmer wheats, has been interpreted as an agricultural package adapted from adjacent hilly areas of northern South Asia where weakening ISM precipitation drove shifts towards arid-tolerant winter growing crops as part of complex systems of selective intercropping to adapt to variable environmental conditions (Petrie & Bates, 2017). This agricultural package appears to be rapidly adapted to better suit summer-season cultivation in the Kashmir Valley (Spate et al. 2017, Betts et al. 2019). Rather than aridification driving vulnerability in agricultural systems in Kashmir, wetter conditions driven by intensified winter precipitation may have had a detrimental effect on cultivation in the valley. Shah (2019) notes that historic famines in 1831 and 1878 were the result of higher levels of autumn rainfall rather than drought. The onset of wet conditions ca. 1500 BP (this study; Babeesh et al. 2019) may have implications for the end of the Kushan Period in Kashmir. Agrawal (1992) has previously argued that scientists may need to take seriously the mythological traditions in Kashmir. Given Kalhana’s description in the *Rajatarangini* of excessive snow causing the destruction of Kushan agricultural systems in Kashmir (Stein 1900) this may indeed be warranted.

In addition to evidence for herding, the presence of cereal pollens at Pari Has during the Kushan period provides preliminary evidence of the expansion of cultivation above the valley floor alluvial landscape. This site is located close to modern summer-agricultural villages and this data presents supporting evidence for the expansion and diversification of settlement patterns during the early-historic period (Yatoo 2012).

Forestry and horticulture

As oak stands are absent from the Kashmir Valley today, there has been extensive comment on the presence of *Quercus* pollens in Pleistocene Karewa deposits (Vishnu-Mittre 1966), as well as in Holocene pollen cores from Tosa Maidan and Hygam (Singh 1963, Vishnu-Mittre & Sharma 1966). Subsequent anthracological study had identified two oak-type charcoals from Neolithic and proto-historic period deposits at Burzahom and Semthan (Lone et al. 1993). *Quercus* pollen is present in all three cores from Budgam District, dropping out of the PH03 record ca. 2000 BP and from the SG02 and TM01 records by ca. 1250 BP. This extinction has been attributed to the onset of cold-dry conditions (Vishnu-Mittre & Sharma 1966), however, given the variety and ecological diversity of Himalayan oak species (Singh & Singh 1987) as well as the reconsideration of climate phasing in this study, human impact may have been a driver of the decline of oak forests or stands, particularly if the use of *Quercus* as fuel wood is attested to archaeologically (Lone et al. 1993). The temporal and altitudinal gradient between the PH03 and other records may suggest an earlier exhaustion of oak resources at lower elevations closer to human settlements.

The increase in *Juglans* pollen towards the top of the PH03 and SG02 cores may be indicative of intensified walnut horticulture during the last few centuries. Lawrence (2005 [1895]) noted that prior to the late 19th century, walnut oil was an acceptable form of taxation payable to the state. While this use may have driven the expansion of walnut horticulture, given the increased demand for the fruit as well as wood for furniture and gunstocks, the commissioner states:

"*walnut may not be felled except with permission of the State, and my impression is that walnut-planting will before long set in with activity… This year (1894) I have at last succeeded in inducing villagers to sow walnuts, and in every village seed has been sown."* (Lawrence 2005, p.353 [1895]).

This statement presents a good example of corroboration between historical accounts and palaeoenvironmental data, even if only from the last 200 years.

8.2 Assessment of methods

Reconstruction of pastoralism is the main aim of this thesis, therefore the viability of methods used are focussed on this question alone. In general, evidence for pastoralist land use around the study sites was strongest when there was a convergence of multiple proxies, including changes in sediment size, charcoal influx, pollen indicators and coprophagous fungal spores. As these proxies have different sources, dispersal mechanisms and pathways into the environmental archive, covariation of these may be a meaningful indicator of natural and anthropogenic processes. In this study it was often the case that these proxies did exhibit strong covariation on at least one of the components in the PCA of the cores analysed.

Pollen proxies for reconstructing past land use or land cover are complicated by the entanglement of multiple factors including climate change, anthropogenic impact and other environmental processes. In the forested mid-mountain flanks of the Kashmir Valley that comprise much of the study area, the expansion and intensification of pastoralist land use would imply both the clearing of forest canopy in the case of the former, as well as changes in the diversity and composition of non-arboreal taxa in the latter. Ratios of arboreal to non-arboreal have often been used uncritically as indicators of landscape openness, failing to account for variation in pollen productivity and dispersal mechanisms (Sugita et al. 1999). In Kashmir, surface moss polster studies have indicated this ratio is particularly misleading due to the over representation of *Pinus* pollen even on valley floor areas where pine stands are absent (Vishnu-Mittre & Robert 1971). Throughout all of the pollen records in this study, there was little variation in the AP/NAP ratio that may be indicative of an anthropogenic opening of the landscape. In the PH03 record, the only significant change in the arboreal pollen curve was driven by a sharp decline in *Pinus* pollen between ca. 1500-800 BP, which may have related to other environmental conditions rather than representing any actual change in the openness of the landscape.

Landscape openness may be inferred from non-arboreal plant taxa that are typically present in open grazed meadows but absent or poorly represented in forest communities, such as those represented by *Plantago* or Caryophyllaceae type pollens (Behre 1981). In addition to these, shrubby colonisers such as *Viburnum* and *Sambucus* observed growing at forest margins of cleared areas and on open ground around the study sites may also be indicators of anthropogenic opening of the landscape. Due to the relative pollen productivity and dispersal mechanisms of these plants, their presence or absence in the palaeoenvironmental record is possible evidence for anthropogenic opening of the landscape, but not demonstrative of the *degree* of openness.

As with inferred landscape openness, pollen-types that may be associated with the impact of herbivores on the landscape or other anthropogenic disturbances cannot be interpreted as evidence of herding-induced impacts alone. The enrichment of palatable taxa such as *Rumex, Trifolium* or Caryophyllaceae-types can be interpreted as a result of grazing impacts around the study sites, however this may be also be controlled by other natural processes. Co-variation of these taxa with higher proportions of Poaceae and disturbance indicators such as *Urtica* and *Plantago* and declines in grazing sensitive taxa such as *Asteraceae* allows for a more robust interpretation. This should be further supported through the use of other non-plant or abiotic proxies.

Similar to these pollen types, coprophagous fungal spores indicating the presence of animal herds have often been interpreted as evidence of forest-clearing relating to pastoralism (Feeser & O'Connell 2010). While these proxies do exhibit good potential for these reconstructions, spore productivity, dispersal and taphonomy are not yet fully understood (Perrotti & van Asperen 2019). Preliminary pollen trap studies from a grazed coniferous forest in Britain indicate that multiple factors – including season, vegetation cover and moisture conditions – impact the accumulation of *Podospora, Sordaria* and *Sporormiella* type acospores differently (van Asperen et al. 2019). The study also found little variation between the accumulation of coprophagous spores and grazing intensity during summer, though there was a higher degree of accumulation in winter traps which van Asperen et al. (2019) attribute to reduced competition between dung fungi and other coprophagous organisms such as beetles. This has two implications for the current study, the first being that fungal spores are not necessarily related to anthropogenic opening of the landscape. The second is that as the sites in this study are only accessible and utilised during summer, the factors driving higher concentrations of fungal spores must be carefully considered. From this second implication, two opposing hypotheses may be proposed: the first that concentrations of fungal spores are representative in presence/absence only and not necessarily indicative of intensified pasturing; the second is that concentrations of spores increase *despite* competition from other corprovores as higher volumes of herbivore dung linked to higher stocking density reduces overall scarcity of this resource. While the results from a single validation study in Britain may not be directly comparable with the Kashmir study sites, application of these data alone as evidence for past forms of land use must be approached critically. These questions emphasise the need for local and regional validation studies to be conducted throughout Asia (Baker et al. 2013).

8.3 Potential for future work

The environmental traces of pastoralist populations in the middle- and high-altitude areas of Budgam District can now be explored further through systematic archaeological survey around the study sites. While locating material remains of mobile groups who used the area only seasonally is difficult, any data retrieved may contribute to our understanding of the relationship between these pastoralist groups and the inhabitants of agricultural settlements on the valley floor, particularly in the pre- and protohistoric periods. Were these separate populations in incidental contact as they shared parts of the landscape, or were upland herders tethered to farming settlements who migrated seasonally to higher altitudes? The potential for changes in these systems through time also remains unexplored as systems of more mobile pastoralism or transhumant agro-pastoralism may be adopted or abandoned in response to environmental or social factors. Features such as high altitude burials, settlement, rock art or other evidence of place making would help better understand these questions.

The ceramic fragments from the BS01 core, as well the stray finds and rock relief features recorded in the survey of the Aru Valley and Pahalgam areas suggest some form of land use or inhabitation of this area as early as the Kushan Period. This study failed to locate deep deposits suitable for producing long records of human impact in these areas of the Greater Himalayan flank of the Kashmir Valley. As in the way that the high passes of Budgam District link Kashmir to the west, the Lidder Valley is one of the key routes linking Kashmir to Ladakh, Tibet and Central Asia. The antiquity of these linkages could be better understood through further palaeoenvironmental sampling as well as archaeological survey and testing.

The issue as to how much the pollen data is truly representative of forest cover or landscape openness may be approached through quantitative models such as REVEALS (Regional Estimates of VEgetation Abundance from Large Sites) (Sugita 2007b) and LOVE (LOcal Vegetation Estimates) (Sugita 2007c). These models employ a Landscape Reconstruction Algorithm (LRA) based on background estimates of pollen abundances derived from factors such as pollen source area, relative pollen productivity and pollen fall speeds. While small sites such as in this study have a higher degree of deviation from expected background pollen abundances (Sugita 2007b), the use of multiple small sites across an altitudinal gradient have effectively contributed to the reconstruction of fluctuations in land cover and human land use in areas such as the uplands of southern Sweden (Fredh et al. 2019). While ideally new fieldwork recording vegetation composition and surface pollen accumulation is required to model relative pollen productivity and fall speeds for Western Himalayan plant taxa, previously modelled values from China and Europe have been applied to pollen records from Central and Northern Asia (Cao et al. 2019). These reconstructions have the potential to refine our understanding of past landscape modification by pastoralists in Kashmir, as well as to feed into regional models of land use/land cover that in turn aim to refine global climate change models (Gaillard et al. 2015, Stephens et al. 2019).

8.4 Conclusion

This thesis presents the case for middle- and high-altitude agro-pastoralism as a significant social-ecological adaptation in the Kashmir Valley. As much as farmers drove settlement on the valley floor during the Neolithic, the presence of herders at higher altitudes may have expanded the productive base of the society, as well as connected Kashmir to networks of exchange and interaction in the IAMC. These findings indicate that transhumant pastoralism was likely present in the Kashmir Valley as early as 4000 BP. These mobile and flexible systems of herding and cultivation appear to be discontinuous on the valley flanks, shifting in order to adapt to changing climate or environmental conditions. Discontinuity in pastoralist land use may indicate in Budgam District may indicate that this was an socio-ecological strategy in the study area that was able to respond to other environmental or social changes across the region. Periods of lower intensity pastoralist land use may be indicative of the abandonment of this system in the study area during wetter periods when more suitable systems of economic productivity may be pursued to capitalise on higher water availability on the valley floor. The intensification of upland herding during more drier climate phases may be similarly interpreted as a means of mitigating the adverse effects of aridity in other areas of the Kashmir Valley. These interpretations may link past forms of agro-pastoralism in the Kashmir to the flexible and adaptive pastoralist socio-ecological systems described in Section 3.2, where well managed pastoralist ecologies contribute to the environmental wellbeing of the pastoralist ecological niche more generally. In addition to being an important part of the rich cultural heritage of the valley, properly managed systems of upland pastoralism may help to support Himalayan forest and meadow biomes currently threatened by changing climate and environmental uncertainty.

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Appendix A -Sediment Classification

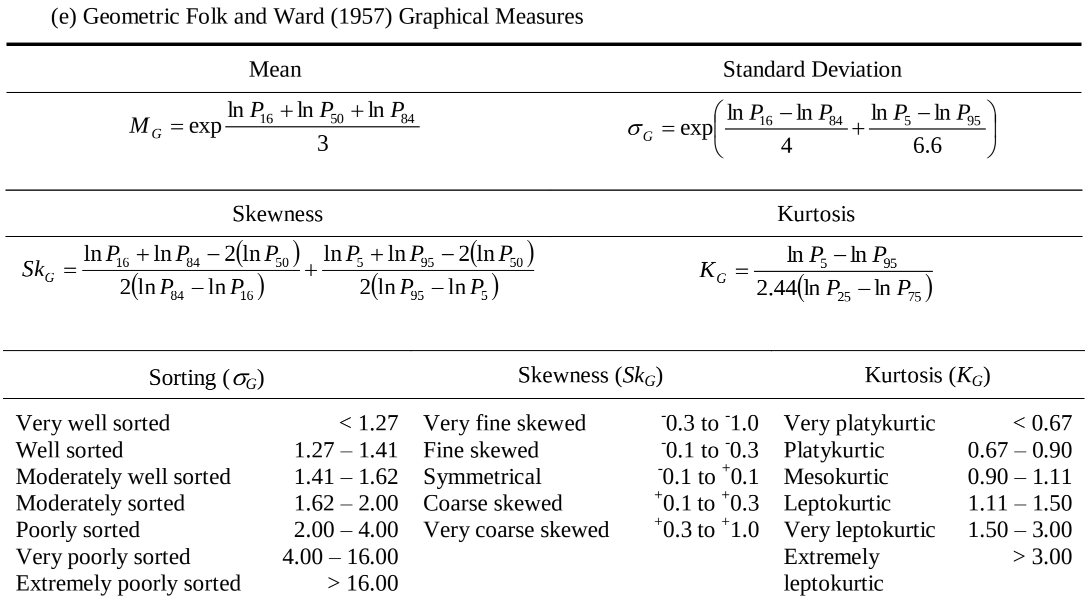
Soil description conventions from Schnurrenberger et al. (2003)

Bedding description	Thickness
Very thick-bedded	>100cm
Thick-bedded	30-100cm
Medium-bedded	10-30cm
Thin-bedded	3-10cm
Very thin-bedded	1-3cm

Bedding plane/boundary	Description
Sharp	Changes noted over <1mm
Diffuse	Boundary 1mm-1cm
Indistinct	Changes noted over >1cm

Sediment class	Subgroup	Principal types	Major modifiers
Clastic	-	Sand Silt Clay	Fabric Grain Size Sorting
Chemical	Evaporites Carbonates	Gypsum/Gypsite Limeston/dolostone/carbonate mud	Mineral Size Fabric
Biogenic	Carbonaceous Fossiliferous	Anthracite/Lignite/Peat Sapropel/Ooze/Hash	Plant taxon Fragmentation Organism class (e.g. diatom, shell)

Statistical measures and particle size conventions adapted from Blott & Pye (2001)



(e) Geometric Folk and Ward (1957) Graphical Measures

Mean	Standard Deviation
$M_G = \exp\frac{\ln P_{16} + \ln P_{50} + \ln P_{84}}{3}$	$\sigma_G = \exp\left(\frac{\ln P_{16} - \ln P_{84}}{4} + \frac{\ln P_5 - \ln P_{95}}{6.6}\right)$
Skewness	**Kurtosis**
$Sk_G = \frac{\ln P_{16} + \ln P_{84} - 2(\ln P_{50})}{2(\ln P_{84} - \ln P_{16})} + \frac{\ln P_5 + \ln P_{95} - 2(\ln P_{50})}{2(\ln P_{95} - \ln P_5)}$	$K_G = \frac{\ln P_5 - \ln P_{95}}{2.44(\ln P_{25} - \ln P_{75})}$

Sorting (σ_G)		Skewness (Sk_G)		Kurtosis (K_G)	
Very well sorted	< 1.27	Very fine skewed	$^{-}0.3$ to $^{-}1.0$	Very platykurtic	< 0.67
Well sorted	1.27 – 1.41	Fine skewed	$^{-}0.1$ to $^{-}0.3$	Platykurtic	0.67 – 0.90
Moderately well sorted	1.41 – 1.62	Symmetrical	$^{-}0.1$ to $^{+}0.1$	Mesokurtic	0.90 – 1.11
Moderately sorted	1.62 – 2.00	Coarse skewed	$^{+}0.1$ to $^{+}0.3$	Leptokurtic	1.11 – 1.50
Poorly sorted	2.00 – 4.00	Very coarse skewed	$^{+}0.3$ to $^{+}1.0$	Very leptokurtic	1.50 – 3.00
Very poorly sorted	4.00 – 16.00			Extremely leptokurtic	> 3.00
Extremely poorly sorted	> 16.00				

Table 2. *Size scale adopted in the GRADISTAT program, modified from Udden (1914) and Wentworth (1922).*

Grain Size		Descriptive term	
phi	mm		
		Very Large	Boulder
-10	1024		
		Large	
-9	512		
		Medium	
-8	256		
		Small	
-7	128		
		Very small	
-6	64		
		Very coarse	Gravel
-5	32		
		Coarse	
-4	16		
		Medium	
-3	8		
		Fine	
-2	4		
		Very fine	
-1	2		
		Very coarse	Sand
0	1		
	microns	Coarse	
1	500		
		Medium	
2	250		
		Fine	
3	125		
		Very fine	
4	63		
		Very coarse	Silt
5	31		
		Coarse	
6	16		
		Medium	
7	8		
		Fine	
8	4		
		Very fine	
9	2		
		Clay	

Appendix B – Supplementary data

PH03

PCA Loadings

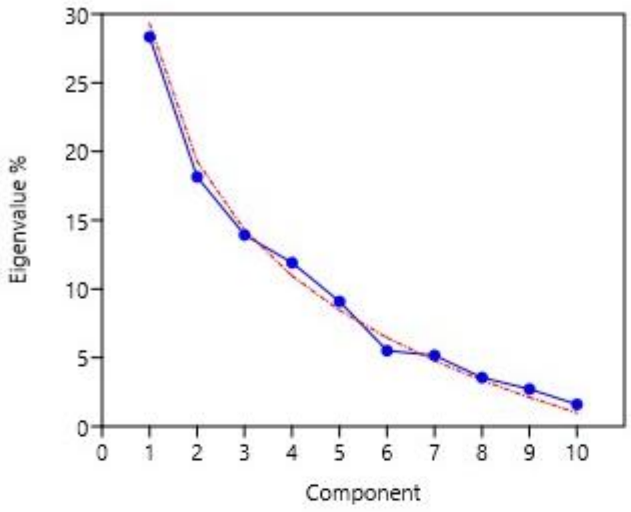
	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10
Conifers	0.40656	0.23369	-0.25309	-0.21747	-0.19076	0.50969	0.088645	0.29512	-0.52644	-0.02203
Trees/shrubs	0.1961	0.63065	-0.05831	0.056387	0.062332	-0.06896	-0.40186	-0.07943	0.25805	-0.56055
Artemisia	0.1389	-0.06197	-0.61131	0.35805	0.43822	0.061383	0.12376	0.35769	0.34198	0.13767
Poaceae	0.23745	0.17169	0.47665	-0.45558	0.38761	0.10441	-0.05699	0.29278	0.31886	0.35724
Herbs.	-0.23691	0.54769	0.016008	0.31358	0.26782	0.099388	-0.01316	-0.3497	-0.29719	0.50292
Grazing	0.35295	0.32456	0.065131	0.11618	-0.37651	-0.3805	0.63959	-0.01965	0.19649	0.13317
Ferns	-0.46155	0.22815	0.14462	0.088122	0.013305	-0.32847	0.053468	0.70992	-0.27139	-0.13294
Marsh	-0.45163	0.13892	0.12289	0.040823	-0.13896	0.63814	0.38147	0.009214	0.38302	-0.20279
Spore influx	0.2094	-0.09698	0.33072	0.59917	-0.39391	0.20986	-0.39193	0.24768	0.12162	0.22227
Char. Influx	0.28115	-0.16819	0.42634	0.36538	0.47886	0.083509	0.31756	-0.06959	-0.2749	-0.39983

PCA Scores

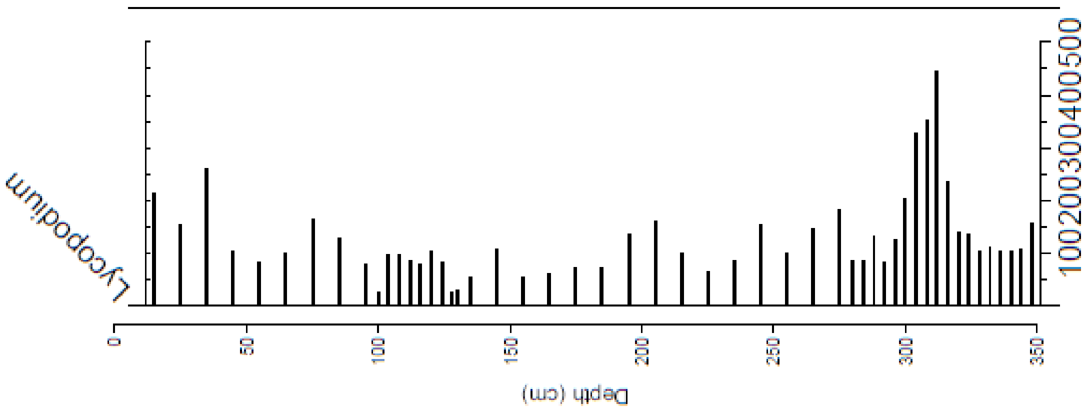
	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10
15	0.76994	1.707	-0.58802	-0.72797	0.24507	0.79694	-1.0237	-0.05557	-1.3267	0.10787
25	0.15346	1.0021	-0.4447	-0.1891	-0.86258	1.2909	-0.10168	-0.86643	-0.18204	-0.6021
35	1.8901	1.2501	-0.02076	-0.80756	-1.5349	-0.08539	1.0843	-0.11388	-0.15603	0.25286
45	1.2289	-0.80578	-0.12159	-1.7391	-0.23801	0.94526	-0.09407	0.23116	-1.0722	0.48376
55	1.1842	-0.23956	-0.18811	-1.5314	-0.48579	0.72844	0.21944	0.22642	-0.4244	0.28114
65	1.8416	1.0751	0.19657	-1.2654	-1.1695	0.53433	0.76687	0.31527	0.003901	-0.28734
75	0.54971	-0.58653	0.13057	-0.64396	-1.3463	-0.49419	0.80478	-0.71729	-0.0872	0.26568
85	0.76103	0.044035	0.29131	-1.0288	-0.67866	-0.75713	-0.30984	-0.1908	0.2464	-0.48857
95	0.56977	-0.08292	1.0886	-1.9233	0.92027	-0.33145	-1.2215	0.10385	1.0656	0.24314
100	-1.205	-0.20446	1.6283	-1.8523	0.5003	-0.56182	-0.85513	1.3415	0.45473	-0.37602
104	-1.8774	-0.874	0.13248	-0.44589	-0.35864	0.1207	-0.43495	-0.71948	0.36534	-0.68054
108	-4.8098	1.314	0.82967	0.53801	0.007891	2.5672	1.5651	0.001371	0.79894	0.11008
112	-3.2962	1.4794	0.5457	0.44401	0.44661	-0.06213	-0.28602	0.41182	-0.54211	0.019473
116	-2.9752	1.3568	0.48547	0.68534	-0.27962	-1.0766	0.63343	0.7336	-0.63986	0.089618
120	-1.91	0.17845	0.92327	-0.53265	-0.13336	-0.39902	0.51588	0.38874	0.22424	0.35736
124	-1.8166	1.18	0.17838	0.1197	0.046896	-0.88781	-0.47412	0.53201	-0.48953	-0.36586
128	0.12259	2.4156	0.5086	-0.63747	0.43517	-0.07349	-0.08311	-0.27307	1.0169	0.058111
130	1.0232	1.8466	-0.55109	-0.20187	-0.59657	-1.1376	0.45816	0.26576	0.12367	-0.20153
135	1.7633	2.8525	-2.2488	0.56955	0.0733	-0.02621	-0.37612	-0.07214	0.006463	-0.80209
145	0.73852	1.7387	-0.33902	-0.1058	0.3857	-0.3059	-0.68373	-1.1289	0.044291	0.089218
155	0.91913	-0.08817	0.96899	-0.9325	0.13627	0.036246	-0.19846	-0.27698	-0.00265	1.1722
165	2.3263	-1.0402	3.5244	0.4039	2.7498	0.69425	0.37318	-0.12878	-0.66157	-0.67915
175	1.3795	-0.03988	1.5435	1.4192	1.6043	-0.00023	0.095847	-0.67795	-0.2687	-0.08629
185	2.3064	-0.19057	2.858	3.7014	-3.0369	0.52805	-1.4651	0.44274	0.40073	0.23193
195	1.0394	-1.3507	-2.0316	0.8596	0.56361	0.40111	-0.29795	0.96433	0.39601	0.059449
205	1.4295	-0.77747	-2.5418	0.6407	0.84122	1.3851	-0.28059	1.3343	0.33053	0.070001

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10
215	0.86475	-0.31079	-0.5357	1.6041	1.1163	-0.30026	0.87015	-0.14764	-0.35195	0.36537
225	1.5384	-1.2123	0.060158	0.56289	0.23684	-0.94525	1.4681	-0.07273	0.46747	-0.35205
235	1.7451	-0.63696	-0.47863	0.71446	0.20313	-0.67455	1.6994	0.17462	0.18306	0.069908
245	0.77863	-0.54861	-0.27667	-0.5293	0.6263	-0.33834	-0.04232	0.29654	0.64061	0.51612
255	0.15909	-0.40168	-0.78569	0.60799	0.58497	-0.02448	-0.29175	0.31148	0.41412	0.044562
265	-1.6281	-2.6128	-0.26657	-0.46529	-0.46038	-0.20383	-0.1778	-0.85313	-0.02342	0.10358
275	-1.34	-1.5085	-0.46592	-0.07683	-0.12944	-0.03295	-0.45609	-1.1579	0.060474	0.10773
280	-0.98524	-2.2563	-0.85305	-0.02271	-0.03147	0.024878	-0.45189	-0.10423	-0.31178	0.041343
284	-1.0001	-0.26066	-1.3133	0.93622	0.55718	-0.10717	-0.4346	-0.93062	0.48844	0.051128
288	-1.7247	1.2799	-1.0236	1.7766	0.79418	-0.85337	-0.54591	-0.20573	-0.42604	0.64287
292	-0.72681	-2.4133	-0.99493	-0.10252	-0.68742	0.22057	-0.1389	-0.02773	-0.03202	-0.54997
296	-1.7872	-2.2782	0.17556	0.17802	-1.0457	-0.59483	0.17057	0.64542	-0.73371	-0.36297

PCA Scree plot w/broken stick



Lycopodium count



SG02

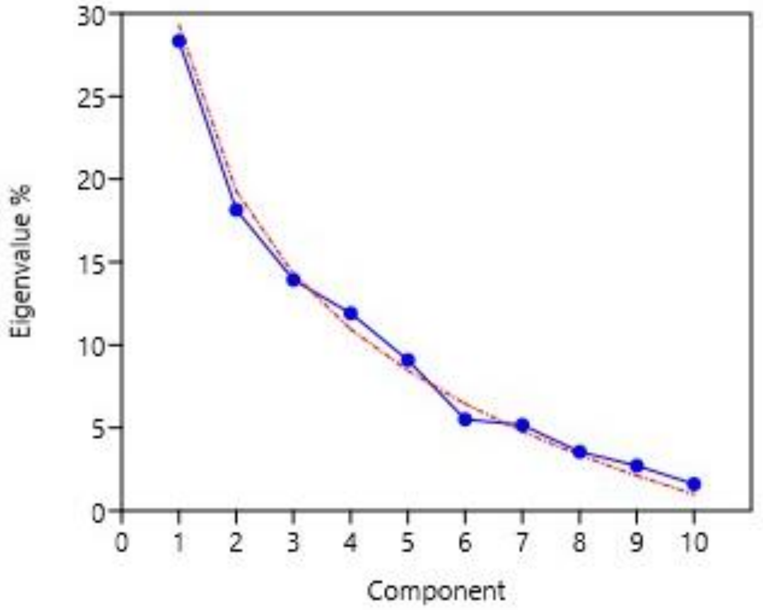
PCA Loadings

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9
Conifers	-0.13873	-0.27219	0.55416	-0.34787	0.58677	0.19673	0.000785	0.16191	-0.26333
Trees/Shrubs	-0.34891	0.4395	-0.1592	-0.23954	0.27589	0.029862	0.42157	-0.58947	-0.01315
Artemisia	-0.45464	0.28519	0.21501	-0.05562	0.063865	-0.19407	-0.12666	0.36037	0.6892
Poaceae	0.25873	-0.5621	-0.19585	0.065168	0.35417	-0.06624	0.28868	-0.18968	0.5704
Ferns	-0.41825	-0.26116	0.13272	0.29577	-0.35316	0.31788	0.62144	0.19318	-0.04995
Grazing	0.32287	0.3683	-0.37497	-0.05783	0.29504	0.3136	0.30526	0.58086	-0.01376
Char. Influx	0.3684	0.20847	0.40899	-0.08742	-0.23581	0.62919	-0.05598	-0.26387	0.34882
Spore influx	0.37975	0.10767	0.36462	-0.33082	-0.25459	-0.54281	0.4833	0.090945	-0.02248
Herbs	0.16209	0.2767	0.3529	0.77869	0.34334	-0.16866	0.082498	-0.08862	-0.07264

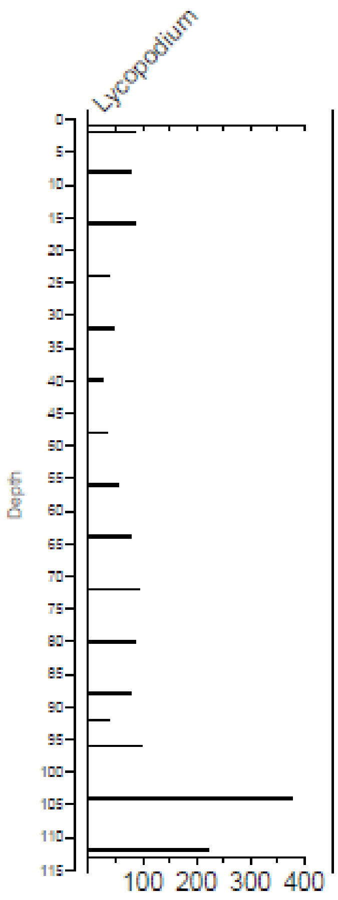
PCA Scores

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9
2	3.6705	0.19354	-1.0515	-0.27188	-0.06858	-0.17475	0.63763	0.54372	0.012131
8	1.3497	-1.2905	-1.3328	-1.0516	0.39681	0.44368	-0.46293	0.30613	0.19038
16	1.6777	-0.08131	-0.19032	0.67135	0.64282	-0.64474	-0.60783	-0.52596	0.27687
24	1.9097	0.9144	1.6986	0.99141	-0.09841	1.3545	0.17862	-0.26981	-0.0305
32	1.8335	-0.4469	1.6239	-0.63352	-0.12316	-0.77998	0.52021	-0.36811	-0.10982
40	-0.24067	0.9753	2.3141	-1.138	-0.64777	-0.40601	-0.25931	0.31101	0.003369
48	0.19551	0.85402	0.52492	-0.04992	-0.26435	0.41175	-0.73684	0.04548	-0.03856
56	-1.2494	0.16317	0.74375	0.77859	1.4031	-0.36773	-0.21567	0.13841	-0.27109
64	-2.0436	1.9554	-0.44096	0.84125	0.27763	-0.10454	0.2469	0.65755	0.10166
72	-2.152	2.4437	-1.663	-1.6578	0.19528	0.21744	0.29084	-0.56501	-0.00967
80	-0.59546	-0.03082	-1.2543	1.5588	-0.65543	-0.2564	0.51382	-0.25918	0.092115
88	0.45075	-1.773	-1.9218	-0.08334	-0.11322	0.18245	-0.14757	-0.06139	-0.35305
92	-1.8465	-0.83247	-0.36871	0.46484	-1.3002	-0.25391	-0.49489	0.038967	-0.02948
96	-2.9598	-3.0445	1.3181	-0.42018	0.35549	0.37824	0.53703	0.008201	0.16564

PCA Scree plot w/broken stick



Lycopodium count



TM01

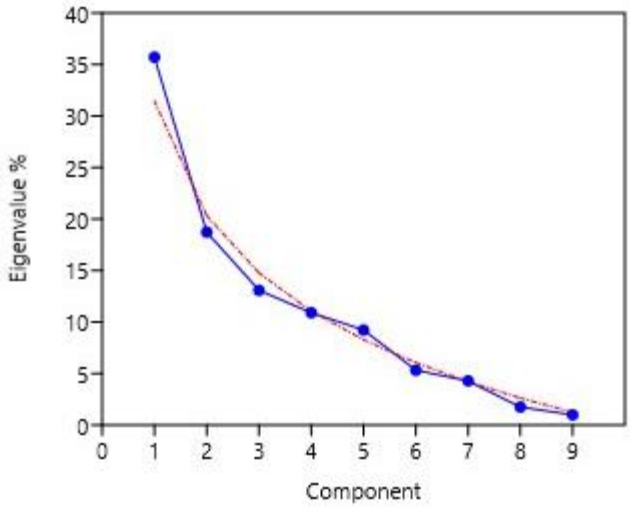
PCA Loadings

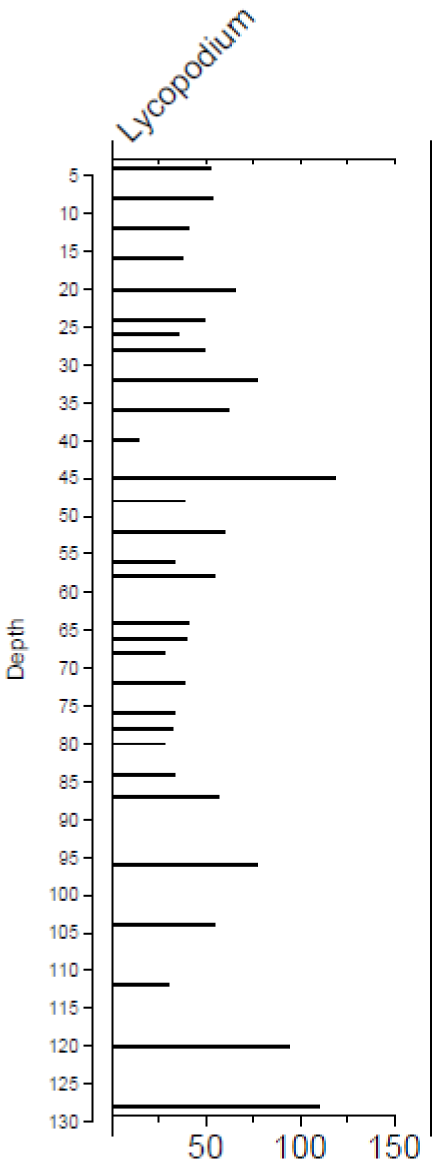
	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9
Conifers	-0.04849	-0.13639	0.60383	0.7223	0.018135	-0.10411	-0.12277	-0.19876	-0.16424
Trees/shrubs	-0.41379	-0.17116	0.13068	-0.05038	0.43491	0.37054	0.61103	-0.23263	0.16108
Artemisia	-0.46704	-0.20169	0.030518	0.006624	0.3119	-0.27811	-0.41261	0.39174	0.49181
Poaceae	0.42358	0.077333	0.37882	-0.11106	0.42668	0.11206	0.13976	0.63984	-0.18769
Herbs	-0.03499	0.65239	-0.09078	0.26463	0.058121	-0.50269	0.42954	0.065097	0.22378
Grazing	0.49831	0.022359	0.31141	-0.13577	-0.04424	0.092151	-0.06459	-0.29917	0.72915
Ferns	-0.14841	0.60677	-0.077	0.20224	0.13751	0.62609	-0.38678	0.003308	0.049672
Spore influx	0.3205	-0.08528	-0.39324	0.12249	0.69758	-0.19364	-0.19972	-0.37351	-0.12981
Char influx	0.23369	-0.32233	-0.45617	0.5648	-0.14255	0.26697	0.20886	0.33206	0.26253

PCA Scores

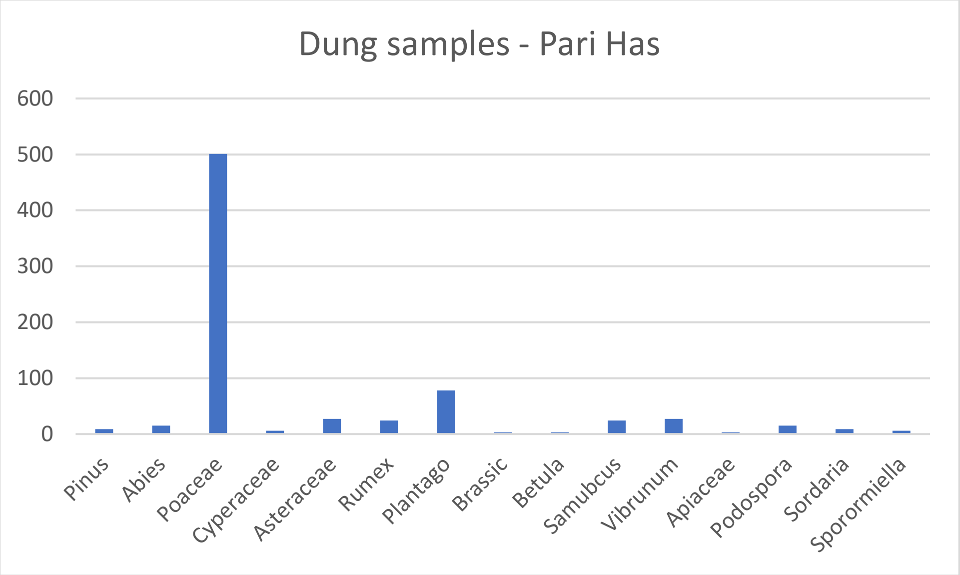
	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9
4	3.0165	0.32484	1.1751	0.028642	0.87947	0.37935	-0.09477	-0.06729	0.24562
8	2.5185	-0.45454	0.8961	-0.37876	-0.44132	-0.28295	0.37507	0.10948	0.091948
12	2.2129	-0.72476	-0.23532	-0.0324	-0.40627	0.8031	-0.45515	0.18096	-0.05365
16	0.84915	-0.40551	-0.6659	-1.9273	-1.5417	-0.00062	-0.46116	0.019759	-0.27442
20	2.756	-1.0672	1.4949	-0.59128	-0.3389	0.73738	-0.28751	-0.15343	0.14724
24	1.7115	0.34066	0.48035	-0.44042	-0.96179	-0.11683	-0.6384	-0.86822	-0.01942
26	1.2384	2.5039	1.3493	0.45652	0.54407	0.96051	-0.38666	0.53162	-0.09364
28	0.9263	1.6043	0.91258	-0.48376	-0.24031	-1.8042	1.2738	0.54197	0.40295
32	-0.73558	4.1717	-1.1641	0.51463	-0.86373	0.44277	-0.47099	0.38958	0.16607
36	-1.2084	0.086666	-0.12949	-0.24461	-1.0298	-0.1475	0.25461	-0.69245	0.13383
40	0.28181	-0.60407	-1.9979	-0.95957	0.42596	-0.26348	-0.05262	0.29807	-0.34308
45	-1.4369	-0.37312	0.50354	3.0405	-1.0047	-0.30379	0.43103	-0.32773	0.10086
48	-2.3832	0.25158	0.9074	0.58702	-0.27278	-0.36274	-0.5498	-0.45079	-0.29982
52	2.4489	-2.1051	-1.3056	1.9248	-0.6311	-0.03736	0.29206	0.15661	-0.14237
56	2.2071	1.665	-2.3712	0.64653	2.43	-0.65527	0.032019	-0.76514	-0.0653
58	-1.0553	0.2359	-0.69219	-0.32865	-0.50514	0.50923	0.12702	0.21678	-0.01455
64	-2.521	-0.97737	0.63411	0.56993	1.5187	-0.04203	-1.695	0.27159	0.15649
66	-1.8485	-0.40615	0.37906	0.48881	-0.40361	-0.45565	-0.3011	0.31854	-0.20062
68	-1.733	-0.28351	-0.67506	-0.44347	-0.48608	-0.48911	-0.47568	0.3547	0.096319
72	0.40683	-1.7075	-1.8826	0.71299	0.027526	0.46307	0.15378	0.36862	0.42544
76	-0.21048	-1.1407	0.71042	-1.0586	1.5052	-1.0599	-0.05183	0.2108	-0.30378
78	-1.486	-0.81569	-0.11581	-0.27722	0.073952	0.059753	0.70729	0.36208	-0.08717
80	0.10589	-0.09298	1.7785	0.79025	0.53579	-0.30907	0.38582	-0.00052	-0.50011
84	-1.8934	-0.40855	-0.0394	-1.2374	0.069207	-0.43726	-0.25111	-0.4837	0.79908
87	-2.4717	-0.56907	0.43423	-0.5081	1.3198	1.785	1.2982	-0.17104	0.25325
90	-1.6963	0.95121	-0.38096	-0.84905	-0.20239	0.6276	0.84107	-0.35085	-0.62116

Scree plot w/broken stick



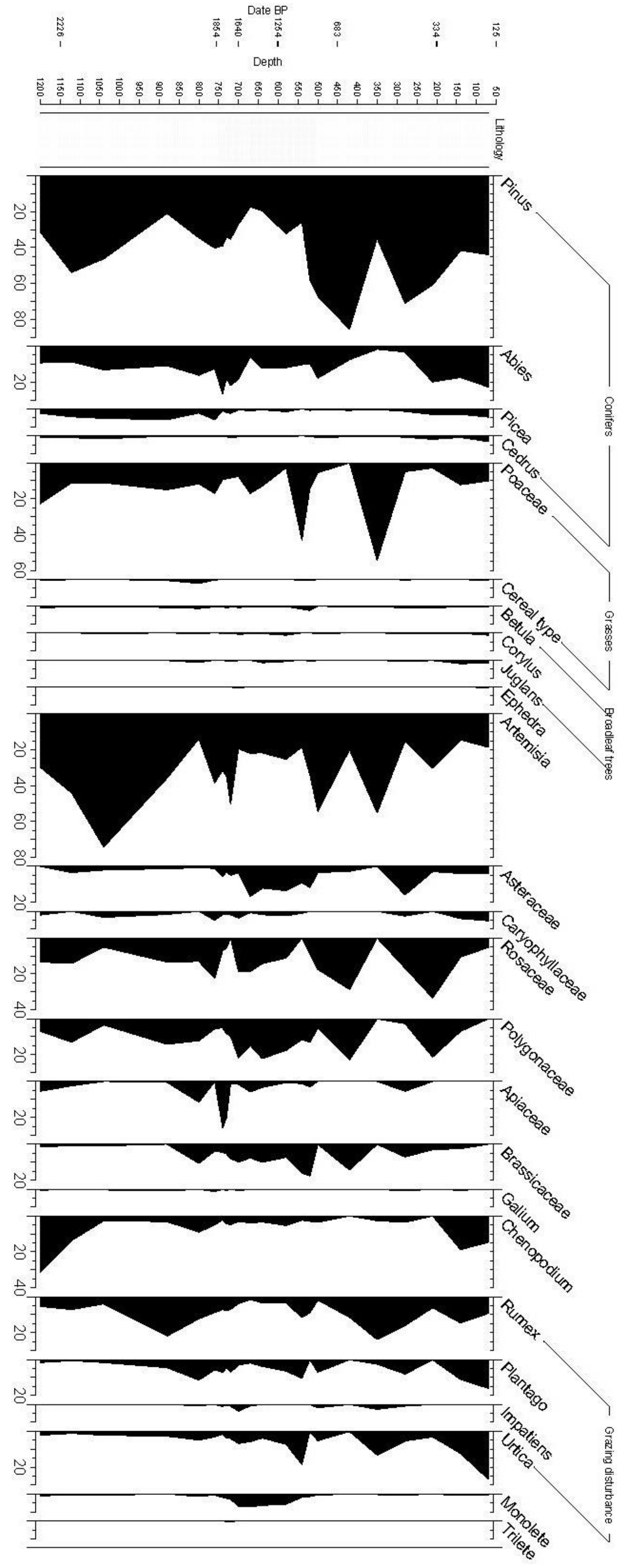


Palynomorph Counts – Dung samples



Appendix C – Preliminary PH01 data (superseded)

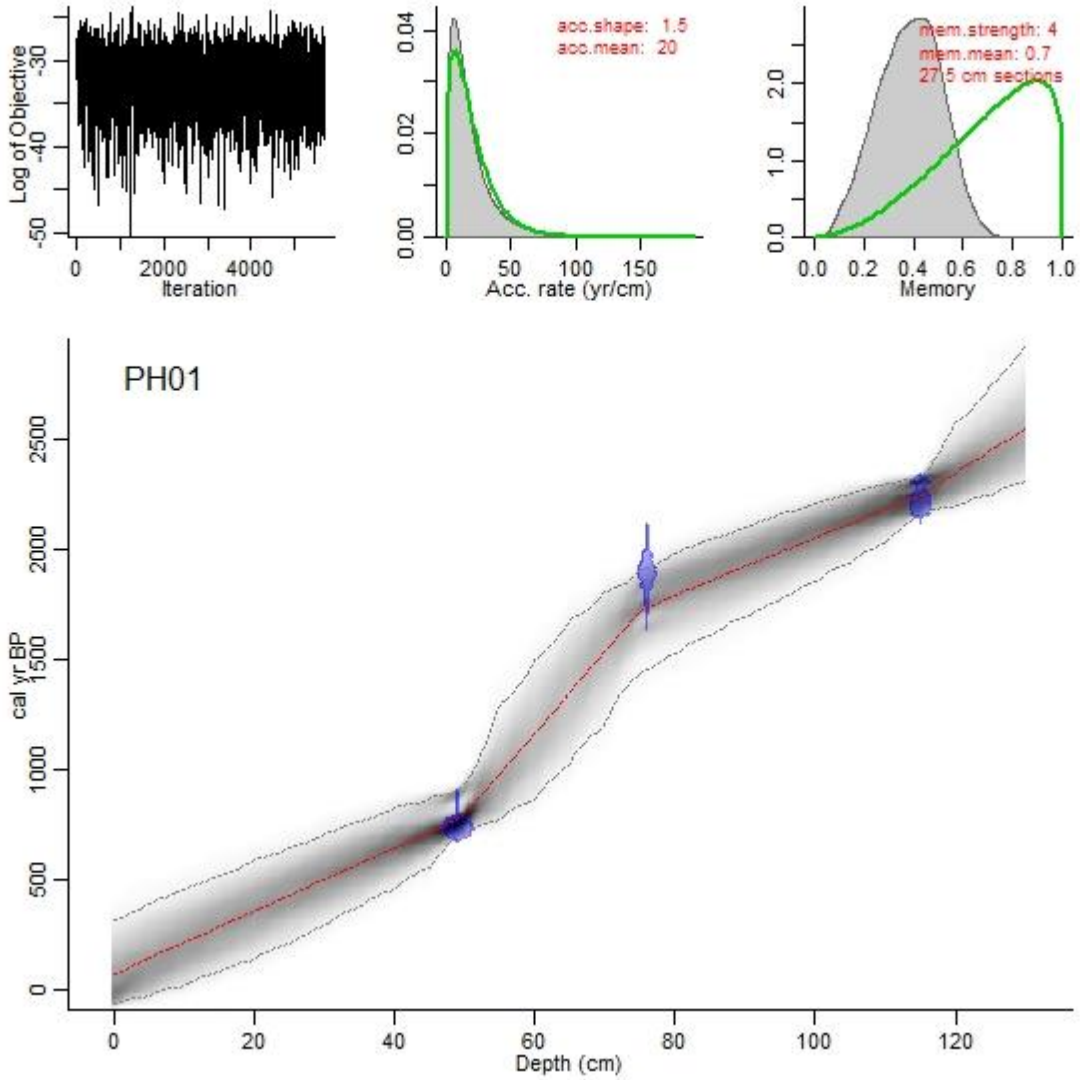
PH01 Pollen plot



PH01 AMS dates

Code	Lab code	Material	Age (BP)	Error	Depth
PH01-A1	D-AMS 023859	Bulk organic	832	26	490
PH01-C1	D-AMS 023860	Bulk organic	1948	49	760
PH01-C2	D-AMS 023861	Bulk organic	2223	23	1150

PH01 Age model



Preliminary logging photos