A Promethean Legacy:
Late Quaternary Vegetation History
of Southern Georgia, Caucasus

Simon Edward Connor

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School of Anthropology, Geography and Environmental Studies, and
School of Art History, Cinema, Classics and Archaeology,
University of Melbourne

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Abstract

This dissertation presents new data on the vegetation history of the Caucasus, a region of high biodiversity and ancient human occupation. The aim of the study is to determine the causes of vegetation changes in Southern Georgia over the past 14,000 years by comparing well-dated pollen and charcoal records to evidence of past climatic change and human activity in the region. Pollen data from semi-arid and mountainous environments are often very difficult to interpret, a consideration which has hampered previous research in Southern Georgia. In this thesis I present a novel method to overcome this problem to allow the reconstruction of past trends in rainfall, temperature, forest cover and land-use.

Reconstructed climatic parameters show that the study area’s climate was extremely arid and seasonally variable between 14,000 and 11,500 years ago. Precipitation increased slowly during the early Holocene, such that a rainfall pattern of more or less modern character was established in Georgia between 9000 and 8000 years ago. Conditions then became wetter and warmer during the mid Holocene, reverting to a cooler and drier climates during the late Holocene.

Often the vegetation of Southern Georgia did not respond to these climatic changes in an expected fashion. After the aridity of the last glacial period waned between 11,500 and 9,000 years ago, forest cover expanded throughout Georgia. Yet the vegetation of Southern Georgia remained without forest even though rainfall was increasing. It was not until much later, 5000 years ago, that trees began to expand in the highlands of Southern Georgia during what seems to have been a dry period. Charcoal records from the study sites indicate that fire was very common in Southern Georgian landscapes prior to 5000 years ago.

In the absence of any evidence for climatically driven fires, I argue that the delayed expansion of forest in Southern Georgia was caused by human activity, namely burning and grazing by Neolithic and Chalcolithic pastoralists. The expansion of forests 5000 years ago corresponds more to the adoption of Bronze Age metallurgy than any climatic event, and subsequent vegetation changes in Southern Georgia, although affected by climatic variations and the general aridity of the climate, were strongly influenced by human activity. Thus, humans have preserved the open landscapes of Southern Georgia since the early Holocene.
Declaration

This is to certify that,

1. The thesis comprises only my original work towards the PhD, except where indicated in the Preface,

2. Due acknowledgement has been made of in the text to all other material used,

3. The thesis is less than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.
Preface

This project on the environmental history of the Caucasus region originally arose from the University of Melbourne’s archaeological investigations at Sos Höyük in the Pasinler Valley, Eastern Anatolia, headed by Professor Antonio Sagona. Interest in the palaeoenvironments of the Pasinler Valley led Sarah Howell-Meurs to investigate prehistoric faunal exploitation and both Jennifer Newton and Catherine Longford to examine Bronze and Iron Age plant use. Dr Ian Thomas made the first attempts to find out about the broader vegetation history of the Pasinler Valley, but it became apparent at an early stage that palynological fieldwork in Eastern Anatolia was subject to considerable bureaucratic and logistic constraints.

For this reason, the late Dr Tamaz Kiguradze suggested coming to Georgia to help provide an environmental context to his important excavations of early agricultural sites. My first visit to Georgia took place in 2001, when I was fortunate to meet Dr Zaal Kikodze, Dr Eliso Kvavadze, Dr Henrikh Avakov, Dr Oleg Bendukidze, Dr Giorgi Arabuli and Dr Vakhtang Todria, all of whom also had an enormous input into my fieldwork and shaped many of my conceptions about Georgia’s environment.

In this collegial context, several publications have appeared prior to the submission of this thesis. The first was printed in *Review of Palaeobotany and Palynology* (Connor et al., 2004) and is incorporated into Chapter Four in a form that bears little resemblance to the published paper. A second publication appeared in the *Proceedings of the Georgian Academy of Sciences, Biological Series* (Connor and Kvavadze, 2005), and appears in much-changed form as part of Chapter Five. A further paper (Kvavadze and Connor, 2005) was also published in the *Review of Palaeobotany and Palynology*, but does not contribute to this thesis. Two more papers were in press at the time of writing. The first is co-authored with Prof. Sagona and is called “Environment and society in the late prehistory of southern Georgia, Caucasus”; it will appear in *Paléorient* and comprises parts of Chapters Six and Nine. The final paper will appear in volume 17 of *The Holocene* and is entitled “A 5600-year history of changing vegetation, sea levels and human impacts from the Black Sea coast of Georgia”, co-authored with Dr Thomas and Dr Kvavadze. It appears in more or less its published form in Chapter Seven.
Acknowledgements

It is with great fondness that I recall all those who have not only helped me with this project over the past few years, but have enriched my life with their friendship and forbearance.

My first debt of gratitude is owed to my three wonderful supervisors. Dr Ian Thomas has been an ever-present source of guidance and perspective, seeing the project from infancy to maturity, assisting with fieldwork and allowing its author the enormous privilege of academic freedom. Professor Antonio Sagona has shown tireless interest in my work and ensured from the outset that the whole endeavour would be a successful one. Dr Eliso Kvavadze has been an unfailing source of dialogue, information, assistance and extraordinary hospitality. It is no exaggeration to say that without her help this project could never have succeeded.

To the staff of the Institute of Palaeobiology in Tbilisi, I express my sincere appreciation. Especially to Dr Henrikh (Genia) Avakov and Dr Oleg Bendukidze, who on their weekend rambles in the hills about Tbilisi, introduced me to the extraordinary variety of the Georgian flora, not to mention the equal variety of Genia’s homemade vodka. Thanks also to Dr Guram Mchelidze for allowing me to undertake fieldwork at his institute’s invitation, and to Rosa, Nika, Nana, Tamuna, Tamriko, Giorgi, Slava, Siuri and Siala for enlivening my visits there.

I extend my most heartfelt thanks to my Georgian family, Dr Vakhtang Todria, Manana Chichinadze, Tamuna Todria and Nino Chantladze, who accepted me as one of their own and taught me so much more Georgian than I could have ever learnt at university. I thank Dr Maia Jejelava for looking after my all-too-frequent medical ailments with skill and patience and for doubling as a trusted companion, translator and fieldwork assistant. Thanks to Dr Eristo Kvavadze for teaching me all the worst Georgian words, and to my brilliant Georgian teacher, Nana Saganelidze, for helping me unlearn them.

Thanks are also due to Dr Giorgi Arabuli from the State Museum of Georgia for his botanical expertise; to Prof. Revaz Gagnidze and Dr Nino Margalitadze at the Botanical Institute for their kind interest; to Matthias Krebs and Dr Izo Matchutadze for fieldwork assistance in Western Georgia; and to my ever-patient drivers from the State Museum, Kako, Tariel and Sergo.
I would like to remember two very dear colleagues who passed away during the course of my PhD. Dr Tamaz Kiguradze first invited me to Georgia to undertake fieldwork and I am forever grateful for his gentle encouragement and eager assistance during the early stages of the project. Dr Zaal Kikodze is especially missed for his good humour, vivacity and enthusiasm. I am not alone in mourning the loss of this truly remarkable man, mountaineer, archaeologist, naturalist, humanitarian and friend.

It was through Zaliko that I met Prof. Brigitta Ammann from Bern University. I thank Brigitta for her kind hospitality, sage advice and constant interest in my project. I am especially grateful that Brigitta spent the first weeks of her hard-earned retirement on the unenviable task of reading drafts of this thesis! To her co-workers, Jacqueline van Leeuwen and Pim van der Knaap, I give thanks for their constant encouragement, for teaching me pollen morphology, reading my drafts, and for such memorable times botanising in the Alps and the Sierra Nevada.

This project would not have been possible without the considerable financial support given me by an Australian Postgraduate Award and fieldwork funding from my university departments and faculty. I acknowledge the Australian Institute of Nuclear Science and Engineering for a generous postgraduate research award, which enabled me to be involved directly in radiocarbon dating and introduced me to Drs D. Mather, G. Jacobsen, H. van der Gaast, Q. Hua, U. Zoppi and A. Williams.

I give thanks to my dear friends for their understanding and camaraderie. I am truly thankful to my fellow palynologists, Michael Fletcher, Christine Kenyon and Angus Tye, for their friendly companionship and, in Michael’s case, his much-appreciated fieldwork assistance on the other side of the globe. Thanks to biogeographers Libby Rumpff, Rob Hale, Jane Catford, Deb Thomas, Alana Burley and Marc Bellette, and to my favourite anthropologists, Nick Bainton, Tanya King, Fleur Smith and Gillian Tan. Cheers to Mark Ellaway, Dorothy Bugg, Kate Marks, Barb Hughes, Chandra Jayasuriya, Jianping Lin, Wayne Stephenson, Barb Downes, Brooke Macdonald, Geoff Vietz, Jenny Newton, Alex Gartrell, Elise King, Mat Carter, Ren Yi, Adam Jasinsky, Kathy Cook, Ben Walkenhorst, Katie Nichols, Ash Macqueen, Carmel McFarlane, Tasha Logan, Simon Collings and Jen Mathews.

Finally, my sincerest thanks go to my family, Keryn, Keith, Sally and Caroline, for their constant love. I dedicate this work to them.
TABLE OF CONTENTS

Abstract iii
Declaration iv
Preface v
Acknowledgements vi
Table of Contents viii
List of Figures xi
List of Tables xiii

Chapter One Introduction 1
  General aim 2
  Approach 2

Chapter Two Background 5
  Language and myth, agriculture and environment 5
  Georgia’s geography and vegetation 12
  Late Quaternary vegetation history of Georgia 19

Chapter Three Methods 33
  Site selection 33
  Vegetation surveys 35
  Sediment sampling 36
  Physical analyses 37
  Microscopic analyses 38
  Radiocarbon dating 40
  Numerical analyses 41
  Presentation of results 44

Chapter Four Modern pollen-vegetation relationships 47
  Introduction 47
  Study sites and their pollen-vegetation relationships 50
  Pollen representation 79
  Numerical analyses 82
Mesolithic (c. 8500 – 7000 BC) 269
Neolithic (c. 7000 – 4800 BC) 271
Chalcolithic (c. 4800 – 3000 BC) 278
Early and Middle Bronze Age (c. 3000 – 1500 BC) 280
Late Bronze and Iron Ages (c. 1500 – 400 BC) 284
Contacts with Greece and Rome (400 BC – 330 AD) 286
From Christianity to the Middle Ages (330 AD – 1400 AD) 290
Recent history (1400 AD – present) 293

Chapter Ten  Conclusions  295

References  297

Appendices  323
List of Figures

2.1. The spread of the Near Eastern crop assemblage in NW Eurasia. 6
2.2. Map of pollen sites in Western Asia. 8
2.3. Oak pollen curves from key sites in Western Asia. 9
2.4. Topographic map of the South Caucasus Region. 12
2.5. Vegetation belts in Georgia. 14
2.6. Maps of precipitation and temperature for Georgia. 15
2.7. Forest map of Georgia. 16
2.8. The Blytt-Sernander chronostratigraphic scheme. 21
2.9. Pollen sites in Georgia with radiocarbon dates. 25
2.10. Sukhumi-36 pollen diagram. 25
2.11. Supsa pollen diagram. 27
2.12. Gomnis Lake pollen diagram. 29
2.13. Kartsakhi pollen diagram. 30
2.14. Sagarejo pollen diagram. 31
3.1. Study sites in Georgia. 34
3.2. Method of vegetation cover comparison with pollen proportions. 35
3.3. Point-count estimation of charcoal abundance. 39
3.4. Comparison of numerical analyses: DCA and NMDS. 43
3.5. Pollen source-area variations under changing lake levels. 45
4.1. Graph of non-arboreal pollen versus landscape openness. 49
4.2. Study site locations and vegetation zones in Southern Georgia. 51
4.3. Diagrams of pollen percentages in relation to bioclimatic gradients. 52
4.4. Photograph of Sakhare Lake. 55
4.5. Exposures of Mio-Pliocene sedimentary units, Udabno region. 55
4.6. Geological cross-section, Udabno region. 57
4.7. Photograph of Lake Kumisi. 59
4.8. Oligocene-Miocene sediments near Lake Kumisi. 59
4.9. Photograph of Tsavkisi Wetland. 60
4.10. Belt-transect vegetation survey near Tsavkisi Wetland. 60
4.11. Map of Tsavkisi Wetland and its vegetation. 61
4.12. Cow grazing on sedges at Tsavkisi Wetland. 63
4.13. Photograph of Lake Cherepanov. 63
4.14. Photograph of Nadarbazevi ruins, near Lake Cherepanov. 64
4.15. Belt-transect vegetation survey at Lake Cherepanov. 65
4.16. Photograph of Trialeti Wetland. 68
4.17. Belt-transect vegetation survey, Chochiani Gorge, near Trialeti Wetland. 69
4.18. Belt-transect vegetation survey, Khrami Canyon, near Trialeti Wetland. 69
4.19. Map of Lake Imera, Tsalka Plateau. 71
4.20. Photograph of Lake Imera. 71
4.21. Photograph of Lake Bareti. 74
4.22. Photograph of Avchalagöl Mire, Javakheti Plateau. 74
4.23. Map of additional study sites. 77
4.24. Diagrams of pollen percentages from additional sites. 78
4.25. Comparison of tree cover abundance and pollen percentages. 80
4.26. Pollen representation of dominant tree species in the study area. 81
4.27. New TWINSPAN classification of pollen data. 84
4.28. DCA ordination of modern pollen data, axes 1 and 2. 87
4.29. DCA ordination of modern pollen data, axes 2 and 3. 87
5.1. Two photographs of Mtatsminda – 1905 and 2003 AD. 92
5.2. Map of the Tbilisi area, with lakes, forests and elevated land. 95
5.3. Climate diagram for Tbilisi. 95
5.4. The Sakhare Lake core. 98
5.5. The Lake Kumisi core. 99
5.6. Lake Kumisi pollen diagram. 102
5.7. Sakhare Lake pollen diagram. 105
5.8. Environmental changes at Sakhare Lake. 107
5.9. Environmental changes at Lake Kumisi. 107
5.10. Photograph of Lake Jvari. 109
8.17. Reconstructed July temperature patterns in Georgia for the last 12,000 years. 254
8.18. Modelled Holocene palaeoclimatic trends. 257
9.1. Holocene vegetation changes in Southern Georgia for selected periods. 267
9.2. Map of Southern Georgia showing palynological and archaeological sites. 270
9.3. Fire records from Southern Georgia. 274
9.4. Photograph of Neolithic stone tools from Southern Georgia. 275
9.5. The Roman baths at Bagineti. 290
9.6. A pollarded *Zelkova carpinifolia* tree, Eastern Georgia. 293

List of Tables

2.1. Georgian pollen site locations, ages and sources. 24
4.1. Site locations and associated environmental variables. 51
4.2. Modern pollen-vegetation relationships at Sakhare Lake. 56
4.3. Modern pollen-vegetation relationships at Tsavkisi Wetland. 62
4.4. Modern pollen-vegetation relationships at Lake Cherepanov. 66
4.5. Modern pollen-vegetation relationships at Trialeti Wetland. 70
4.6. Modern pollen-vegetation relationships at Lake Imera. 72
4.7. Additional site locations. 77
4.8. TWINSPLAN indicators. 83
4.9. Classification of additional pollen samples using TWINSPLAN indicators. 83
4.10. New TWINSPLAN indicators. 84
4.11. Classification of additional pollen samples using new TWINSPLAN indicators. 85
4.12. Pollen taxa correlated with DCA axes. 88
5.1. Sediment description of the Sakhare Lake core. 98
5.2. Sediment description of the Lake Kumisi core. 99
5.3. Sediment description of the Tsavkisi Wetland cores. 118
5.4. Wetland pollen taxa and microfossils correlated with DCA axes. 130
5.5. TWINSPLAN indicators for vegetation stages at Tsavkisi Wetland. 131
5.6. Stages of vegetation development, Tsavkisi Wetland. 133
6.1. Analysis of lake waters in Southern Georgia. 150
6.2. Sediment description of the 2002 Lake Imera core. 151
6.3. Sediment description of the 2003 Lake Imera core. 151
6.4. Stages in vegetation development, Lake Imera. 160
6.5. Modern pollen-vegetation relationships at Lake Aligol. 168
6.6. Sediment description of the Lake Aligol core. 170
6.7. Stages in vegetation development, Lake Aligol. 181
7.1. Sedimentology of the Ispani-II core. 197
7.2. Radiocarbon determinations, Ispani-II. 198
8.1. Location of pollen sites used in Georgian pollen dataset. 216
8.2. Pollen types that share a common history. 220
8.3. TWINSPLAN classification of pollen taxa. 241
8.4. Misclassified pollen-vegetation relationships. 243
8.5. Predictors used in the selected NPMR models. 250
CHAPTER ONE
INTRODUCTION

The history of vegetation is shaped by the myriad forces of environmental change. Perhaps the most important challenge for the study of vegetation dynamics is unearthing their causes, whether related to the climate change, soil formation, ecological succession, pathogen outbreaks or human impacts. Some of the most energetic and long standing debates in palaeoecology have revolved around the question of climatic or anthropogenic agency in the changes observed. Climate changes, rather than being a bland backdrop to cultural events, have impacted on the vegetation and hence shaped the way humans interacted with their environment in the past. Humans have also impacted on the environment directly; such that the task of disentangling the causes of past vegetation changes becomes an important one for understanding human history.

The Caucasus region, located at the crossroads of Europe, the Middle East, the Mediterranean and Central Asia, is home to a great diversity of plants including some that are numbered amongst history’s most important agricultural resources – the vine, wheat, barley, flax and several kinds of fruit tree. Humans have lived in the Caucasus for more than 30,000 years and region’s mountainous environment has allowed the evolution of many distinct cultural groups within a relatively small area, making this one of the richest ethno-linguistic areas in the world. In the Caucasus we find a diversity of cultures born of and contextualised by a complex and unique geography.

Archaeology and palaeoenvironmental research have a long history in the Caucasus region, but rarely have these two strands of knowledge been drawn together to provide a complete picture of prehistoric humans in their environment. Caucasian botanists have often argued that what are today treeless steppes and grasslands were once covered thickly in forest, which was destroyed by recent human activity. But evidence for if, when and how these forests were destroyed remains much more elusive. Part of the problem is the difficulty in interpreting palaeoenvironmental data from semi-arid areas where the dry climate can often distort or destroy the evidence. This constraint is often seen as an insurmountable barrier to the study of vegetation
history in dry environments, and yet it was in these same environments that agriculture and cities first emerged in Western Asia; hence their environmental history is of considerable interest.

**General aims**

This study aims to shed light on the causes of vegetation change in Southern Georgia during the last 14,000 years.

Drawing on evidence for past climatic changes, the long-term impacts of grazing and burning, and the archaeological record, the study will attempt to determine which of these forces made the greatest impression on Southern Georgia’s vegetation history.

In doing so, it is hoped to reveal the character of the vegetation during various archaeological periods; examine ecological consequences associated with the adoption of agriculture and subsequent agro-pastoral activities; determine the past occurrence and impact of fire in the vegetation; trace the changing extent of forests and grasslands; gauge the effects of changes in precipitation and temperature; and question current thinking on how Southern Georgia’s vegetation history has contributed to its rich biodiversity and varied landscapes.

**Approach**

To achieve these aims, Chapter Two introduces the study area and some of the current debates and uncertainties regarding its human and environmental history; Chapter Three describes the method of pollen analysis adopted in satisfying the project aim and the numerical techniques to overcome problems associated with palaeoenvironmental data from semi-arid environments; Chapter Four analyses the relationships between the present-day vegetation and the pollen that it produces, as a means of reconstructing past environmental changes; Chapters Five, Six and Seven present new data on the vegetation history of three areas of Southern Georgia (the Tbilisi area, Tsalka Plateau and Black Sea coast) and, using the techniques developed in previous chapters, these chapters discuss the results in terms of past climate, forest cover and land-use; Chapter Eight places these results in a regional context by
attempting to reconstruct the past vegetation for the whole of Georgia using a large dataset of published work, and then uses the same data to estimate the past climate of different parts of Georgia through time; Chapter Nine compares the vegetation history of Southern Georgia to the palaeoclimatic estimates from the previous chapter and to the area’s archaeological record to make an informed judgement of the causes for past vegetation change; and finally, Chapter Ten outlines the significance of the project’s findings and proposes directions for future research.
CHAPTER TWO
BACKGROUND

“And at day-dawn they looked eastward, and midway between the sea and the sky they saw white snow-peaks hanging, glittering sharp and bright above the clouds. And they knew they were come to Caucasus, at the end of all the earth” (Charles Kingsley, The Argonauts, quoted in Allen, 1942, p. 228).

Language and myth, agriculture and environment

The Caucasus has long been a source of fear and fascination, myth and legend in Western consciousness, a rugged and diversified landscape where Europe and Asia collide in an explosion of language and culture.

It was to the distant Caucasus that Jason and his Argonauts sailed on their mythical quest for the Golden Fleece. Here Prometheus, the titan of Greek legend, was punished for stealing fire from the gods. Zeus, furious that his planned destruction of the human race had been thwarted thus, shackled Prometheus to the Caucasus where an eagle came daily to feed on his liver. By giving fire to humankind, Prometheus became revered as the great benefactor of farmers, artisans and metallurgists alike.

The Prometheus myth may indeed be an ancient Caucasian tale transmitted to the Greeks through early contacts (Braund, 1994; Lang, 1966). Variations on the tale are spread through the region, from Abkhazia to Armenia. In some local variants, Abrskil, a Promethean figure, helps humankind rid the soil of choking vines, brambles and bracken so that crops can be planted (Lang, 1966, p. 71). The parallels with fire as an agricultural tool are obvious.

The question of when farming originated in the Caucasus presents a challenge to theories of agricultural evolution and language dispersal in Western Asia. Renfrew (1992; 1996) has argued that that Indo-European languages disseminated throughout
Europe from the centres of agricultural development in Western Asia, a claim subsequently reinforced by genetic evidence for a ‘wave of advance’ (Figure 2.1) supplanting the pre-existing Pleistocene-age languages (Cavalli-Sforza, 1996; Cavalli-Sforza et al., 1994). The Caucasian languages, which are unrelated to the Indo-European group, seem to have survived or countered the Neolithic Indo-European agricultural diffusion. Renfrew (1992) provides two possible explanations for this linguistic resilience: 1) that a local agricultural system evolved independently in the Caucasus prior to or coeval with events in the Fertile Crescent; or 2) that the Caucasian people adopted the farming technology of the Indo-Europeans without the usual linguistic change.

Figure 2.1. Map of NW Eurasia with the spread of the Near Eastern Neolithic crop assemblage from Western Asia indicated by numbers and the genetic ‘wave of advance’ indicated by lines emanating from the southeast. Simplified from Zohary and Hopf (1993) and Cavalli-Sforza (1996). The Caucasus region is located between the Black and Caspian Seas.

In support of the first hypothesis, we might look to the great diversity and degree of endemism in the Caucasian flora (Dolukhanov, 1966; Gagnidze, 2005), which has undoubtedly been the source of many cultigens, particularly rosaceous fruits like apples, pears, plums and cherries (Menabde, 1961; Vavilov, 1992). The
Caucasus lies within the natural range of many endemic cereals and the wild grapevine (Lisitsyna and Prishchepenko, 1977; Zohary and Spiegel-Roy, 1975). Wine-making, in particular, has an ancient history in the Caucasus, and especially so in Georgia, where grape cultivation may have originated (Burney and Lang, 1971). Did the Caucasians stave off Indo-European colonisation by having a specialised proto-agricultural system emplaced? Or is linguistic stability here merely the result of rugged topography, which necessarily inhibits inter-cultural exchange?

Toward the second hypothesis, that the Caucasians adopted the Indo-European agricultural model without inheriting its language, the weight of archaeological evidence can be advanced. By and large, macrofossil remains of crops cultivated by the Neolithic people of the Caucasus were the same as those ‘founder’ crops of the Fertile Crescent and Levant (Chataigner, 1995; Lisitsyna and Prishchepenko, 1977; Zohary and Hopf, 1993). These included einkorn, emmer, bread wheat, barley, oats, rye, millet, grapes and various legumes (Chataigner, 1995). Purported finds of endemic wheat species (*Triticum carthlicicum* Nev. and *T. macha* Dec. et Men.) at early agricultural sites in Georgia (Yanushevich and Rusishvili, 1984) might suggest that Neolithic settlements in this region were sited to take advantage of wild cereal stands (Kiguradze and Sagona, 2003).

One of the most problematic aspects of archaeobotanical evidence is, however, the differential preservation of cereal grains and legumes compared to fruits, tubers and vegetables. The impact of this problem on archaeological interpretation and the question of agricultural origins cannot be underestimated, explaining as it does the ‘Levantine Primacy’ (Watson, 1995) in such discussions. It may be that an endemic Caucasian farming system, if it ever existed, was of an entirely different nature to that of the Fertile Crescent, inheriting its characteristic crop assemblage only through later cultural exchange. And, because cereal-based agriculture is often subsidiary to pastoralism in mountainous terrain (Newton, 2004), the earliest farming in the Caucasus may have taken place in the rangelands.

**Palynological research in Western Asia – a synopsis**

These broad questions of agricultural origins were the impetus for early pollen-based research efforts in Western Asia. The multidisciplinary archaeological
excavations at Jarmo, directed by R.J. Braidwood from the University of Chicago, challenged the idea that the traditional hearth of agriculture was situated in the Levant. Their work gave rise to the ‘hilly flanks’ theory: that cereal cultivation began in the rain-fed foothills of the Zagros and Taurus Mountains, better known as the Fertile Crescent (Braidwood and Howe, 1960). The complimentary pollen diagram from Lake Zeribar in Iran (Figure 2.2)(van Zeist and Wright, 1963) has remained pivotal in discussions of the vegetation history of Western Asia. Covering the last 22,000 years, it shows that the landscape of the Zagros prior to the terminal Pleistocene was one of treeless Artemisia-Chenopodiaceae steppe. Climate changes at the beginning of the Holocene triggered the slow expansion of oak woodland, reaching its fullest extent during the mid Holocene (Figure 2.3).

The same general pattern is observed in pollen diagrams from Lake Mirabad in southwestern Iran (van Zeist, 1967) and Lake Urmia in northwestern Iran (Bottema, 1986). That these climatic changes were broadly coincident with the emergence of cereal cultivation has raised questions about the element of ‘climatic determinism’ involved in this cultural event (Wright, 1970; Wright, 1993).

Figure 2.2. Map of Western Asia showing the pollen sites and mountain ranges mentioned in the text. Adapted from van Zeist and Bottema (1991).
In the Levant, the expansion of oak (*Quercus*) and terebinth (*Pistacia*) woodlands commenced earlier (Figure 2.3), during the late Pleistocene in the Ghab Valley and Lake Huleh sediments (Niklewski and van Zeist, 1970; van Zeist and Bottema, 1991; Yasuda et al., 2000). In addition, this expansion took place at a much greater rate than the Zagros sites, suggesting a wetter early Holocene climate in the coastal regions of the Eastern Mediterranean and Arabian Peninsula (Roberts and Wright, 1993). This can be related to the intensification of the African monsoon in these areas, compared to the seasonally droughty conditions prevalent in the Zagros and interiors of Anatolia during the early-mid Holocene (Roberts et al., 2001; Stevens et al., 2001).

Anatolia, of all of Western Asia, has been the most intensively studied palynologically (Figure 2.2). From eastern Turkey, whence palynological data are very scanty, the first record from Lake Van (van Zeist and Woldring, 1978) has long been plagued by dating problems arising from the use of varve counting (Bottema, 1986; Wick et al., 2003). The original dating model indicated that oak woodland progressively replaced steppe vegetation between 6400 and 3400 years ago, leading to the conclusion that the early-to-mid Holocene climate of eastern Anatolia was much drier than in Iran (van Zeist and Woldring, 1978).
Since then the chronology of the Lake Van pollen record has been revised considerably, firstly by the study of a neighbouring peat bog (Bottema, 1995) and more recently by a new pollen diagram and varve count from Lake Van itself (Wick et al., 2003). The new diagram shows that oak expansion took place between 10,460 and 6250 years ago (Wick et al., 2003), corresponding much better to the Zagros records (Figure 2.3). Even so, questions have been raised recently on whether the revised Lake Van varve ages are still somewhat young, and, more importantly, if the slow expansion of oak woodland during the early-mid Holocene was actually the result of Neolithic human impacts rather than climatic aridity alone (Roberts, 2002).

Pollen records of southern and southwestern Anatolia are of considerable interest from an archaeological perspective. Like the sequences discussed above, they exhibit an early Holocene *Quercus* expansion at the expense of *Artemisia*-Chenopodiaceae steppe (Bottema and Woldring, 1984; Bottema and Woldring, 1990; Eastwood et al., 1999; Roberts et al., 2001; van Zeist and Bottema, 1991; van Zeist et al., 1975; Vermoere et al., 2002). However, the subsequent appearance of distinct phases of human impact, indicated by *Plantago, Olea, Fraxinus, Juglans, Vitis, Cerealia*-type and other anthropogenic indicator pollen (Behre, 1990), provides a startling legacy of cyclical land-use and population change (Roberts, 1990). The cause of these vegetation changes was almost certainly political instability rather than climate change or volcanic activity (Roberts et al., 1997). Following these so-called ‘Beyşehir Occupation Phases’ (Bottema and Woldring, 1990), landscapes were often left deforested and eroded to the point that oak woodland was unable to return, especially under the rapacious grazing habits of goats, and instead pine forests became widespread around some sites (Roberts, 1990).

This trend is reflected in pollen diagrams from the northwestern Anatolian sites of Abant and Yeniçağa (Beug, 1967; Bottema and Woldring, 1990). A late Holocene pollen diagram from Pasinler in northeastern Anatolia likewise exhibits a strong anthropogenic signal that varies through time as populations waxed between sedentism and transhumance under the influence of political, population and environmental pressures (Thomas, 1999). The small scale of the basin from which the Pasinler pollen record was obtained contrasts starkly with Lake Van, which, although in the same geographic region, has a surface area of over 3500 km² and therefore
represents change on a much more regional scale, masking localised changes in land-use (sensu Jacobson and Bradshaw, 1981; Prentice, 1985; Sugita, 1993).

Far from the results of Western Asian pollen analyses seeming “disappointing” (Behre, 1990, p. 227), they have great potential to reveal the variety of human experience through time. Whilst the seminal records from Lakes Zeribar, Urmia, Van and Mirabad have set a general climatic backdrop for understanding agricultural innovation, they can tell us little about the environmental impacts of prehistoric cultures or those that dwelt in Western Asia more recently. The success of the southwestern Anatolian pollen analyses in this regard is to a large degree attributable to the comparatively small scale of the lake and wetland basins studied. The sheer number of sites analysed in southwestern Anatolia allows for differentiation of changes affecting one lake catchment from those exerting influence across a larger area.

If we accept that the emergence of an agricultural economy during the Neolithic was probably small in scale, with highly localised impacts on the soil, vegetation and fauna (Buitenhuis, 1990; Roberts, 1998, p. 153), then it is clear that these changes are unlikely to manifest themselves in pollen records from large lakes. It could be more enlightening to use a suite of locally representative records from small lakes and wetlands and correlate this with nearby archaeological sites where the source area or catchment scales of both are comparable (see Flannery, 1976; Roberts et al., 1997).

With the exception of southwestern Anatolia, knowledge of prehistoric human interactions with their local environment in this region is largely based on macrofossil evidence, which, as noted, is only representative of the surrounding vegetation in the most general sense (Wasylikowa, 1986). This leaves enormous scope for establishing a ‘footprint’ of prehistoric impact in vast areas of Anatolia, the Levant, Mesopotamia, Iran and the Caucasus. The latter is of interest because of the ethno-linguistic and agro-botanical aspects discussed earlier, and also because of its turbulent political history, resulting in boom and bust cycles that doubtless left a considerable palaeoenvironmental legacy. In the following section, I introduce Georgia’s present environment as a precursor to understanding its vegetation history.
Georgia’s geography and vegetation

For a country with an area comparable to Ireland, Georgia is remarkably diverse. Situated on the eastern shore of the Black Sea, the country forms a great dissected valley running from west to east between the anticlinal Main Caucasus Range (maximum elevation 5642 m at Mt Elbrus) to the north and the volcanic Armenian highlands to the south. Georgia is, and has historically been, subdivided into two major regions: Colchis (Western Georgia) and Iberia (Eastern Georgia). These two are separated by the Likhi Range, which also forms the watershed between Colchian rivers flowing westward to the Black Sea, and catchments draining eastward to the Caspian Sea via the Kura (or Mtkvari) Valley (Figure 2.4).

![Figure 2.4. Topographic map of the South Caucasus Region. Source: Атлас Грузинской ССР (AN GSSR, 1964).](image)

Botanically, the Caucasus sits at the junction of three major phytogeographical provinces: the Euro-Siberian, Irano-Turanian and Euxinian territories (Zohary, 1973). During the Oligocene, the Caucasus existed as a chain of islands in the Tethys Sea, a temporary isolation that had far-reaching effects on the subsequent development of the flora (Tumajanov, 1971) and goes some way toward explaining the Caucasus region’s great botanical diversity, which with 6350 species, is equivalent to the plant species diversity of the Iberian Peninsula or the Balkans (Dolukhanov,
Georgia is home to 4130 known species of vascular plants, of which 20% are endemic to the Caucasus region (Gagnidze, 2005; Gagnidze et al., 2002; Sakhokia, 1961). The country is particularly rich in Asteraceae (566 species, 44 endemic to Georgia), Poaceae (399 spp., no endemics), Fabaceae (317 spp., 34 endemics), Rosaceae (237 spp., 63 endemics), Brassicaceae (186 spp., 11 endemics) and Scrophulariaceae (181 spp., 14 endemics) (Gagnidze, 2005).

Georgia is a mountainous country and this determines, in concert with climate and soils, the general character of the vegetation. Of Georgia’s total area of 6,548,600 hectares, less than 25% is classed as lowlands and plains, and only 13% of the land area is between sea level and 200 metres (Ketskhoveli, 1959). The Main Caucasus Range shields Georgia from the continental climates of the southern Russian steppes, and intercepts rainfall from the dominant westerlies originating over the Black Sea.

An example of the interplay between topography and climate, and its effect on plant life, is the Alazani Valley in Eastern Georgia (see Figure 2.4). This valley carves its way south from the Main Caucasus Range and flows out to the southeast through the semideserts and steppes of Azerbaijan. The valley is warmer than much of Eastern Georgia, as it occupies the zone between mountains and semidesert, and the sheer wall of southwest-facing slopes promotes orographic rainfall. Climatic conditions are ideal for viticulture, and the Kakheti region is famous for its wines. The region is also known for its unusual forests, which contain thermophiles that are otherwise found only in proximity to the Black and Caspian Seas. Tertiary-relict trees, such as *Zelkova carpinifolia* and *Pterocarya fraxinifolia*, grow in forests that are more typical of humid western Georgia or the moist mountain slopes of northern Iran than of a region with less than 800 mm annual rainfall. The Alazani forests are also the only ones in Eastern Georgia to contain forests of yew (*Taxus baccata*) and chestnut (*Castanea sativa*).

Aspect is an important influence on vegetation composition in a mountainous terrain. Vegetation composition can vary dramatically from north- to south-facing slopes. On the mountains around Tbilisi, south-facing slopes are often treeless, whereas shaded northern slopes may be clothed in dense forest. Ketskhoveli (1959) notes that, amongst herbaceous plants, north-facing slopes generally have a prevalence of mesophytes with palmate leaves (e.g. *Anemone*, *Trollius*, *Geranium*), while graminoids prevail on south-facing slopes. Amongst the conifers, pine (*Pinus*)...
has a preference for southern aspects; fir (*Abies nordmanniana*) and spruce (*Picea orientalis*) prefer more sheltered northern slopes. Beech (*Fagus orientalis*) likewise prefers the moister conditions on north-facing slopes, leaving sunnier slopes for oak-hornbeam associations (Ketskhoveli, 1959). Figure 2.5 shows some examples of the altitudinal distribution of important taxa in relation to aspect in Georgia.

![Figure 2.5. Schematic representation of vegetation zones in Western and Eastern Georgia in relation to altitude and aspect. Redrawn and simplified from Nakhutsrishvili (1999).](image-url)
Figure 2.6. Maps of average annual precipitation (a), and average temperatures for January (b) and July (c) in Georgia. Adapted from *Атлас Грузинской ССР* (AN GSSR, 1964). Projection: World Geodetic Survey 1984.
The major climatic and topographic division in Georgia, however, is the Likhi Range – the 950 m-high granitic massif that links the Greater Caucasus Range to the Anticaucasus Mountains of Southern Georgia. Together, these mountains create an orographic rain shadow over Eastern Georgia. Western Georgia is a land of subtropical rains, dark coniferous forests, alder swamps, liana-festooned trees, giant sphagnum bogs and rivers flowing into the Black Sea. In Eastern Georgia the rivers drain into the Caspian Sea, and salt lakes, semideserts, xerophytic shrublands and hot, dry summers are more characteristic.

The humid, warm-temperate climate of Colchis led Soviet scholars to term this a ‘subtropical’ region (Berg, 1950). Areas close to the Black Sea coast, such as the coastal resort of Batumi, receive approximately 2500 mm of annual precipitation (Figure 2.6) (AN GSSR, 1964). Average temperatures in lowland Colchis vary between 5 and 7 ºC in winter, with rare frosts, and around 22-23 ºC in summer (Tatashidze, 2000). The Colchis lowland is a large, often swampy plain formed by fluvio-glacial sediments eroded from the surrounding mountains and the effects of sea level rise during the Holocene (Dzhanelidze, 1980). Small mountain glaciers are distributed on the western parts of the Main Caucasus Range, in Svaneti and Abkhazia, but their past extent is as yet poorly understood due to a lack of systematic, well-dated studies (Serebryanny, 1984; Serebryanny and Orlov, 1993).

Colchis is regarded as a glacial refugium for thermophilous plants (Denk et al., 2001; Röhrig, 1991), hence the presence of *Vaccinium myrtillus*, *Viburnum orientale*,...
Laurocerasus officinalis, Rhododendron ponticum, Ilex spp., Hedera colchica, Quercus pontica, Betula medwedewii, Corylus colchica and other species in lowland Colchic forests (Dolukhanov, 1966; Nakhutsrishvili, 1999). Many other species were present during the early Pleistocene; thermophiles such as Aesculus, Juglans, Tsuga, Sequoia, Carya and Liquidambar were forced into extinction during the succession of Pleistocene glacial periods (Chochieva and Mamatsashvili, 1996; Shatilo va, 1984; Shatilova and Mchedlishvili, 1980; Shatilova et al., 2003; Shatilova et al., 2002; Shatilova and Stuchlik, 1996; Tumajanov, 1971). A handful of Mediterranean plants are also found in Colchis forests, such as the strawberry tree (Arbutus andrachne) and box (Buxus colchica).

Vegetation in Western Georgia is arranged in altitudinal belts. In the lowlands, Alnus barbata and the Tertiary-relict Pterocarya fraxinifolia form dense swamp forests tangled with lianas (Denk et al., 2001; Ketskhoveli, 1959). In better-drained locations and with increasing elevation, Quercus-Carpinus, Quercus-Castanea and Fagus-Carpinus associations occur. Fagus orientalis becomes the dominant tree in forests above elevations of 600-700 metres (Figure 2.7). Higher still, at 1200-1400 metres, beech gives way to coniferous forests of Picea orientalis and Abies nordmanniana and these prevail until the upper tree line around 2000 m, where subalpine herbaceous meadows or krummholz thickets of Betula, Sorbus, Acer and other species appear (Dolukhanov, 1966; Ketskhoveli, 1959; Nakhutsrishvili, 1999; Walter, 1974). Human impact in the subalpine zone is intense, under the combined effects of livestock grazing, hay-making and wood cutting (Badenkov et al., 1990; Bock et al., 1995; Dolukhanov, 1978).

The landscape of Eastern Georgia (Iberia) is entirely different, with large areas of steppe and semidesert vegetation maintained by a rain shadow cast by the Anticaucasus (or Lesser Caucasus) Mountains, which intercept the prevailing westerly storm tracks. Annual precipitation in the lowland steppe zone amounts to less than 400 mm, average winter temperatures are just below freezing and around 25 °C in summer (Figure 2.6)(AN GSSR, 1964; Tatashidze, 2000). The Georgian capital, Tbilisi, is located at the northwestern corner of the lowland steppe zone, at the foot of the Trialeti Range. The soils of Eastern Georgia are generally chernozems and saline kastanozems in the semidesert and steppe zone, brown earths in the forest belt and peaty soils in the subalpine and alpine zones (Urushadze, 1999). Chernozems also
occur on the volcanic plateaux of the South Georgian Uplands where the vegetation is predominantly steppic grassland.

The vegetation of Eastern Georgia falls broadly into the Irano-Turanian group (Zohary, 1973), widespread through the steppes and arid woodlands of Iran, Eastern Anatolia and Central Asia. Oak-hornbeam forests of *Quercus iberica*, *Carpinus betulus* and *C. orientalis* are common in the foothill zone, replaced by *Fagus orientalis* or mixed forests at higher altitudes. On sunny slopes, *Quercus macranthera* grows from 1400 m elevation up into the subalpine zone. *Picea orientalis* and *Abies nordmanniana* forests are common only in the westernmost part of Southern Georgia (Akhaltsikhe Basin), and disjunct pockets of pine forest exist in rocky gorges and on steep, eroded slopes. At the lower tree line, xeric communities known as *shibliak* and *phrygana* are common (Dolukhanov, 1966). These correspond to the Mediterranean vegetation groups called *maquis* or *garrigue*, and are regarded by many Caucasian botanists as the result of forest degradation (Badenkov et al., 1990; Ketskhoveli, 1959; Sakhokia, 1961).

Large areas of the lowland steppe and semidesert zone have been appropriated for irrigated agriculture, but vegetation associations dominated by various chenopods, *Artemisia* species and *Bothriochloa ischaemum* are widespread. More restricted are areas of arid woodland, composed of *Pistacia mutica*, *Pyrus salicifolia*, *Juniperus foetidissima*, *J. polycarpos*, *Celtis caucasica*, *Quercus iberica* and *Carpinus orientalis* (Arabuli, 2003; Dolukhanov, 1966). Gallery forests dominated by *Quercus pedunculiflora*, *Populus canescens* and *P. hybrida* occur alongside some rivers in Eastern Georgia, accompanied by large numbers of lianas (Ketskhoveli, 1959; NACRES, 2005).

It must be remembered that although the Caucasus today tends to be synonymous with Russia and the former Soviet Union, its environment has always existed within the regional sphere of Western Asia, so great a barrier did the Main Caucasus Range present to human and biotic migration (e.g. Seddon et al., 2002). Thus we can regard Eastern Georgia, Armenia, Azerbaijan and Eastern Anatolia as being a varied yet distinct mountainous geographical unit.
Late Quaternary vegetation history of Georgia

To understand the present-day complexity of Georgia’s vegetation, it is necessary to look to the past to determine the causes of vegetation change. The final section of this chapter aims to introduce some of the debates and uncertainties that surround Georgia’s vegetation history during the Late-glacial and Holocene periods. It is not an attempt to describe the results of previous studies in detail (covered in Chapter Eight and Appendix A), but a discussion of the theoretical issues associated with interpretation of these results, with particular emphasis on causation.

Botanical debate on Georgia’s vegetation history

For many years, botanists have argued that highland grassland, lowland steppe, shibliak scrub and phrygana vegetation have appeared in the Georgian landscape as a result of late Holocene deforestation (Badenkov et al., 1990; Ketskhoveli, 1959; Nakhutsrishvili, 1999; Sakhokia, 1961; Sosnovskii, 1915; Tumajanov, 1971). As one prominent writer recently stated, “during the Holocene, when climatic conditions were similar to nowadays, the entire territory of Georgia was occupied by forests” (Nakhutsrishvili, 1999, sect. 6).

Around 40 percent of Georgia’s territory is currently classified as forest (Figure 2.7) (Papava, 2000), making it by far the most forested nation in the South Caucasus. Almost everything that has been written on the forest vegetation of this region is prefaced by a statement such as “these forests have also suffered from the agricultural activities of man” (Nakhutsrishvili, 1999, sect. 6.6), ‘woodland was degraded to shrubby vegetation or completely destroyed as a result of excessive wood-cutting and grazing’ (Walter, 1974, p. 381), ‘profoundly modified as a result of human impact’ (Gulisashvili, 1964, p. 159), or ‘strongly disturbed by felling’ (Sakhokia, 1961, p. 17). Some have suggested that this widespread deforestation took place during the last few centuries in Eastern Georgia (Ketskhoveli, 1959; Matcharashvili et al., 2004; Tumajanov, 1971) and even more recently in Western Georgia (Badenkov et al., 1990; Dzhanelidze, 1980).

Evidence for these past forests comes in several forms. One is the presence of isolated forest trees in steppe landscapes, thought to represent remnants of a formerly continuous forest cover (Grossgeim, 1948; Ketskhoveli, 1959; Matcharashvili et al.,
Another is the climatic and edaphic similarity between forested and non-forested areas, which suggest that steppe or scrub prevails where forest is capable of growing (Gulisashvili, 1964; Ketskhoveli, 1959). Others have looked to the historical record to find reference to the nature of the vegetation in the past (Dzhanelidze, 1980; Ketskhoveli, 1959; Maruashvili, 1956; Matcharashvili et al., 2004; Sosnovskii, 1915).

The weight of opinion therefore supports the contention that forests were formerly much more widespread than at present. But Avakov (1982) has questioned whether Eastern Georgia’s highly diverse xeric scrub and steppe communities could have arisen as recently as other botanists contend. He argues that steppe and scrub have a longer history that is intertwined with disturbances such as fire and grazing. Avakov supports this view with reference to the antiquity of farming in Georgia, as well as early drawings and photographs of Tbilisi that show a city surrounded by bare hills (e.g. Tournefort, 1718). Steppe fauna were present in parts of Eastern Georgia during the early-mid Holocene (Bendukidze, 1979), and this indirect evidence lends support to Avakov’s belief that the region’s xerophilous vegetation has a very considerable ancestry indeed.

The question of if and when Georgia’s steppe and scrub landscapes were forested is a critical one for understanding the present-day complexity of Georgia’s vegetation, for determining how the biodiversity of xeric plant communities came about, for setting in context the events of history and prehistory, and for deciding how best to direct vegetation conservation and management efforts today. Pollen analysis, as a means of reconstructing past vegetation, is perhaps the most appropriate means of resolving this problem. As we shall see, however, the palynological literature is not without certain problems of its own.

**General comments on the palynological literature**

The majority of Georgia’s pollen diagrams were prepared during the Soviet period. Perhaps the most conspicuous aspect of Soviet palynology was the almost universal use of the Blytt-Sernander scheme to define chronological subdivisions for the Holocene (Figure 2.8). The timing of these subdivisions was based on peat stratigraphical changes observed in Northern European raised bogs (see Roberts,
1998, p. 118), and the scheme’s application relies on the assumption that vegetation shifts were driven exclusively by climate changes, synchronous across Europe. The picture that has emerged with the widespread adoption of radiocarbon dating is far more complex than the Blytt-Sernander scheme would suggest (Mangerud et al., 1982). Indeed, temperature variations in southeastern Europe during the Holocene may follow an entirely different trend to the northern regions where the Blytt-Sernander scheme was developed (Davis et al., 2003). And, in supposed glacial refugia such as Colchis, the clear break between the Pleistocene and Holocene may not be obvious in pollen stratigraphy, let alone assumed differences between the early and mid Holocene climate (Mangerud et al., 1982). Independent dating is therefore of paramount importance.

The vast majority of pollen diagrams from the former Soviet Union are unsupported by radiocarbon ages (Grichuk, 1984). Even in regional syntheses, where considerable effort has been expended in gathering dated pollen records, undated sections represent 20-30% and poorly dated diagrams are in the majority (Khotinskiy, 1984; Tarasov et al., 2000; Tarasov et al., 1998). Where sediments are typically low in organic content, such as in the Caucasus region, conventional $^{14}$C dates may not be obtainable in any case. This explains why, amongst the 233 sites included in a comprehensive study by Tarasov et al. (1998), Caucasian sites averaged less than two
dates per diagram, compared to twice that number across the former Soviet Union generally.

A second important aspect of palynology in Georgia, particularly in regions where peat accumulation is negligible, is the widespread use of soils and archaeological deposits as palaeovegetation archives. Exposed river terraces have often been used for palaeoenvironmental reconstruction (e.g. Bortenschlager, 1987; Gogichaishvili, 1984b; Gogichaishvili et al., 1977; Kvavadze, 1978), but the pollen in these sediments is often carried fluvially from upstream vegetation, making the source of the pollen difficult to define. The continuity of these largely alluvial deposits may be also questioned; in the absence of strict dating control, it is unclear whether these deposits are affected by pollen redeposition and hiatuses in sedimentation.

Pollen analysis of archaeological strata (e.g. Kalandadze et al., 1977; Kvavadze et al., 2004; Kvavadze and Todria, 1992; Martín Sánchez et al., 1999) presents some difficulties for reconstructing vegetation because the source of the pollen varies through time, depending on the form and use of the site’s structures (van Zeist and Bottema, 1991). Cereal pollen, for example, is rarely found in archaeological contexts due to its delicate structure, but on former grain-threshing floors it occurs in great abundance (Behre, 1986). The construction of dwellings from mud bricks introduces secondary and aquatic pollen (Bottema, 1992), and additional pollen may be incorporated during the occupation, destruction and reworking of the site (Tomescu, 2000). Pollen taphonomy in these sites often leads to an over-representation of Asteraceae compared to fragile pollen types (Bottema, 1975; Havinga, 1964; Havinga, 1967). These considerable biases make interpretation of archaeological pollen spectra inherently difficult, somewhat subjective, and unsuitable for the reconstruction of past vegetation on any more than a local scale.

Thirdly, the identification of anthropogenic indicators in pollen diagrams (Behre, 1986) would seem to be of prime importance in a landscape so heavily indebted to human activity as Georgia (Gogichaishvili, 1990). However, as Kvavadze and Gabashvili (1998) note, this has rarely been the case. Only a handful of diagrams make any distinction between cereal and grass pollen. The differentiation of the various diagnostic Plantago species is even less common. Many diagrams ignore herbaceous pollen entirely, presenting only data for arboreal taxa and some shrubs.
(Kvavadze and Connor, 2005). In these circumstances it is very difficult to disqualify human impact as a cause of vegetation change.

A final point relates to the interpretation of pollen data. The almost ubiquitous use of the Blytt-Sernander scheme introduces an element of climatic determinism and argument circularity into any interpretation of vegetation change. The elm decline, for instance, which occurred in Europe with surprising synchronicity around 5800 BP, is usually attributed to climate change in Soviet-era publications (Wright and Barnosky, 1984). This view was shared by Western European scholars some decades ago (e.g. Tauber, 1965), but more recent thought posits that the catastrophic nature of the elm decline was probably caused by an outbreak of Dutch Elm Disease, perhaps related to Neolithic forest disturbance (Girling and Greig, 1985; Peglar and Birks, 1993). In the Georgian palynological literature, the impacts of disease, human activity, soil weathering and fire are seldom considered to have played a more significant role than climate in governing the timing and direction of past vegetation change.

**Palynological studies in Georgia**

The first palynological studies in the Caucasus region were conducted by Russian scientists in the early 1930s (Dokturovskii, 1931; Dokturovskii, 1936). Dokturovskii’s work in the peatlands of lowland Colchis and the highland bogs of Bakuriani to a large extent dictated the future direction of Holocene palynological research in Georgia, allowing Neishtadt (1957) to enumerate his influential, tripartite scheme of vegetation change in Colchis (see Chapter Seven). In recognition of the interpretive problems associated with undated pollen diagrams, the following discussion will focus on records with at least one radiocarbon date (Table 2.1, Figure 2.9).¹

As Figure 2.9 shows, there are many more dated pollen diagrams from humid Western Georgia compared to the semi-arid east. The greatest concentration of these is in the autonomous region of Abkhazia, the mountainous strip of land between the

¹ A detailed overview of all palynological research in the Caucasus and Central Asia from 1931 to 1975 has been published in Russian: Pakhomov and Klopotovskaya (1980).
Main Caucasus Range and the Black Sea in northwestern Georgia. Interestingly, since this area is considered to have been a glacial refugium for trees, its lowland pollen diagrams are characterised by consistently high arboreal pollen proportions during the Late Pleistocene.

Table 2.1. Details of Georgian pollen sites shown in Figure 2.9.

<table>
<thead>
<tr>
<th>No</th>
<th>Site name</th>
<th>Sub-region</th>
<th>Lat.</th>
<th>Long.</th>
<th>Elev.</th>
<th>14C</th>
<th>From</th>
<th>To</th>
<th>Source</th>
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<td>(Kvavadze and Rukhadze, 1989)</td>
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<td>41.28</td>
<td>1830</td>
<td>2</td>
<td>2000</td>
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<td>(Kvavadze and Rukhadze, 1989)</td>
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<td>0</td>
<td>(Serebryannyi et al., 1984)</td>
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<td>40.53</td>
<td>2490</td>
<td>2</td>
<td>5000</td>
<td>0</td>
<td>(Kvavadze and Efremov, 1994)</td>
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<td>E Georgia</td>
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<td>44.68</td>
<td>875</td>
<td>1</td>
<td>3000</td>
<td>0</td>
<td>(Kvavadze and Connor, 2005)</td>
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<td>41.03</td>
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<td>(Margalitadze and Ramishvili, 1972a)</td>
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<td>43.63</td>
<td>41.12</td>
<td>2726</td>
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<td>6000</td>
<td>0</td>
<td>(Kvavadze and Efremov, 1996)</td>
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<tr>
<td>19</td>
<td>Lashkhrashi</td>
<td>Svaneti</td>
<td>43.13</td>
<td>42.43</td>
<td>2000</td>
<td>1</td>
<td>3000</td>
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<td>(Margalitadze and Kimeridze, 1985)</td>
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<td>2</td>
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<td>45.35</td>
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<td>41.00</td>
<td>0</td>
<td>1</td>
<td>20000</td>
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<td>41.00</td>
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<td>4</td>
<td>10000</td>
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<td>Supsa</td>
<td>Colchis</td>
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<td>41.85</td>
<td>8</td>
<td>4</td>
<td>8000</td>
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<td>(Kvavadze and Rukhadze, 1982)</td>
</tr>
<tr>
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<td>Colchis</td>
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<td>41.83</td>
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<td>2000</td>
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<tr>
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<td>S Georgia</td>
<td>41.77</td>
<td>43.35</td>
<td>1920</td>
<td>2</td>
<td>6000</td>
<td>0</td>
<td>(Margalitadze, 1967)</td>
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</table>

Key to abbreviations: Central C. – Central Caucasus; Lat. – latitude (decimal degrees); Long. – longitude (decimal degrees); 14C – number of radiocarbon dates (v – varve ages); From – basal age in 14C yr BP; To – most recent sample age (0 = modern).
Figure 2.9. Location map of radiocarbon-dated palynological sites in Georgia. See Table 2.1 for site names and other details. Filled circles indicate published pollen data; open circles represent unpublished data. Dashed line indicates the approximate bioclimatic boundary between Western and Eastern Georgia (after AN GSSR, 1964, map 98).

Figure 2.10. The Sukhumi-36 pollen diagram from lowland Abkhazia, Western Georgia. Radiocarbon date is $6425\pm 60$ $^{14}$C yr BP. Redrawn and simplified from Kvavadze and Rukhadze (1989, p. 66).

The longest such record is the Sukhumi-36 core (Figure 2.10), collected from the Black Sea coast near the Abkhazian capital of Sukhumi. Although the 45-m core has only one radiocarbon date of $6425\pm 60$ $^{14}$C BP at a depth of 10 m, it dates back
well into the Late Pleistocene (possibly more than 40 kya), as indicated by the pollen of now-extinct Tsuga, Carya, Cedrus and Taxodiaceae in the lowermost zones. Late Pleistocene spectra are dominated by Abies, Pinus and Carpinus amongst arboreal types, and Poaceae, Asteraceae and Polypodiaceae in the non-arboreal group. Abies declines during the early Holocene and Alnus becomes dominant. The mid Holocene has increased proportions of Fagus, Castanea and Quercus, leading the authors to conclude that this was the time of climatic optimum (Kvavadze and Rukhadze, 1989, p. 67). Inferred late Holocene spectra have an increase in Pinus, thought to indicate a climatic deterioration (Kvavadze and Rukhadze, 1989).

Similar patterns are evident in the Sukhumi-721 and Sukhumi-723 records, collected nearby. These well-dated cores have high proportions of Alnus pollen in the early stages of the Holocene, increased proportions of Abies, Fagus and Tilia in the early-mid Holocene, and a prevalence of Castanea from the mid to late Holocene. At both Sukhumi and Gagra, increasing Alnus and Cyperaceae proportions in the last 4000 years are explained by climatic deterioration and human impact (Kvavadze and Rukhadze, 1989). Geomorphic evidence, however, suggests an elevated sea level around that time (Chepalyga, 1984; Dzhanelidze, 1980; Tvalchrelidze et al., 2004).

In the mountains of Abkhazia, the temporal record of vegetation change is considerably shorter than in the lowlands, as highland peat deposits seem to have begun forming from the mid Holocene onwards. The longest of these records is from Luganskoe, situated at an altitude of 2428 metres in the alpine zone. Pollen spectra from the mid Holocene contain elevated proportions of herbaceous taxa, including Chenopodiaceae, Cirsium, Apiaceae and Caryophyllaceae, which the authors think represents a rich herbaceous vegetation developed under humid climatic conditions (Kvavadze and Efremov, 1996). Pollen data from Kvartsevoe, Bathing Chamois and Adange also have an increased representation of herbaceous pollen during the mid Holocene (Kvavadze and Efremov, 1994; Kvavadze and Efremov, 1996; Kvavadze and Rukhadze, 1989). The interpretation of these taxa as indicative of greater humidity and warmth seems difficult to reconcile with the ecology of the plants, which are mostly herbs of dry environments. Since these increases in herbaceous pollen correlate with lithological changes (from minerogenic to organic sediment), it is possible that the herbaceous component is derived from plants growing in the local vegetation.
Opinion is divided on the causes of late Holocene vegetation change in highland Abkhazia. Some have interpreted rapid changes in pollen assemblages as evidence of tree line shifts in response to climatic events such as the ‘Little Ice Age’ (Kvavadze and Rukhadze, 1989). For others, these excursive and often asynchronous changes could have been initiated by human activities, especially grazing and deforestation (Yazvenko, 1994). The most problematic of these changes is the recent increase in *Abies* and *Picea* at many sites in highland Western Georgia (e.g. Luganskoie, Bathing Chamois, Lashkhrashi, Adange and Chamlukh); the varied timing and rapid rate at which this conifer ingress took place seems difficult to explain adequately in climatic terms alone.

**Figure 2.11.** Pollen diagram from Supsa, coastal Western Georgia. Redrawn from Kvavadze (1982).

Another group of sites is clustered in the swampy lowlands of Colchis. The longest record (Figure 2.11) was obtained from exposed alluvial deposits along the Supsa River, between the towns of Poti and Kobuleti (Kvavadze, 1982). The early Holocene phase is distinguished by its representation of coniferous taxa (*Picea-Pinus-Abies*). From approximately 7500 BP, *Picea* and *Abies* decline and herbaceous pollen increases dramatically. Kvavadze (1982) interprets this as a temperature decrease. Around 6000 years ago, Tertiary-relict *Pterocarya* became very important in pollen spectra, indicating an increase in gallery forest on this floodplain and possibly a
warmer, wetter climate. The disappearance of *Pterocarya* during the mid-late Holocene is thought to indicate a cooling climate and the intensification of human activity since the 4th century AD (Kvavadze, 1982).

The next closest site is Imnati, approximately 10 km north of Supsa and part of the extensive *Sphagnum* mires of Central Colchis. In contrast to other diagrams, where *Castanea* becomes prevalent in the mid or mid-late Holocene, at Imnati this taxon declines around 6650 BP to be replaced by *Alnus* (Botch and Masing, 1983; Neishtadt et al., 1965). Another lowland diagram comes from Anaklia, at the mouth of the Inguri River (Serebryannyi et al., 1984). The seven-metre core dates back 6500-7000 years and has five radiocarbon dates. The most outstanding feature of the Anaklia diagram is the decline in *Alnus* and coincident increase in *Pinus, Picea, Abies, Carpinus, Fagus, Quercus, Ulmus, Castanea, Corylus* and herbaceous types such as Asteraceae. Dated from 5500-3300 BP, this event follows a period of rapid sediment accumulation, and is thought to relate to the reactivation of glaciers on the Main Caucasus and the subsequent depression of tree lines (Margalitadze, 1995). The problem with this interpretation is that most pollen diagrams from Western Georgia show no evidence for such a change, and it seems strange for tree line depression to manifest at the coast rather than in the mountains.

Moving now to Eastern Georgia, we can see that dated pollen diagrams are particularly lacking (Figure 2.9). This is because the climatic conditions are largely unfavourable for peat formation. Seven radiocarbon-dated diagrams are available, of which five are published. The Gomnis Tba and Tseros Tbis diagrams are both derived from lake-wetland sediments cored on the Dabadzveli Plateau, on the western flank of the Trialeti Range above the spa resort of Borjomi. The climate of this section of the Trialeti Range is wetter than most parts of Eastern Georgia, due to its interception of moist westerly air currents originating over the Black Sea (Margalitadze, 1998).

Gomnis Tba is a small lake of volcanic origin set in a herb meadow and surrounded by *Picea orientalis*-dominated forest (Margalitadze, 1967). The 9.5 metre core consists of sedge peat in the upper four metres, with a black silt layer at 4.0-4.25 m and underlain by lake clays (Figure 2.12). Pollen analysis revealed an early Holocene landscape dominated by herbaceous taxa, although the high proportions of Asteraceae could also suggest post-depositional changes to the pollen assemblage.
Pinus and Abies were the most abundant arboreal taxa. Margalitadze (1971) has argued that the landscape of that time was rendered treeless by volcanic activity in tandem with a cooler climate. A more recent, unpublished diagram from the same site indicates that these levels date to the early Holocene prior to 9500 BP (E. Gobet, unpubl. data). In the subsequent period, mixed deciduous forests expanded up the surrounding mountain slopes, changing into monodominant Fagus orientalis forest approximately 6000 years ago. In both diagrams there is a rapid reduction in beech pollen and an increase in conifers around 2000 years ago. This shift from deciduous to coniferous is thought to indicate cooler, drier conditions (Margalitadze, 1971).

Figure 2.12. Pollen diagram from Gomnis Lake, Dabadzveli Plateau, Southern Georgia. Plus (+) symbol denotes trace proportions. Redrawn from Neustadt (1971).

Tseros Tbis is located near Gomnis Tba in the same volcanic terrain. It is a small, mesotrophic Sphagnum bog surrounded by woodlands of Pinus and Betula. Like the Gomnis core, the sediments were peat underlain by silty sediments with low arboreal pollen percentages. Two radiocarbon dates suggest the 11.5 metres of sediment accumulated during the last 7000 years. The palynological changes are similar to those in the Gomnis record and their interpretation is likewise in climatic terms (Margalitadze, 1995).

Lake Kartsakhi is located near the Turkish border on the treeless Javakheti Plateau of Southern Georgia. An 8.25-metre core was taken from the lake margins in
a *Carex dichoandra-Equisetum fluviatile* wetland association (Margalitadze, 1995). Sediments of the early-mid Holocene have low arboreal pollen counts and are dominated by Asteraceae, while the more organic sediments in the upper four metres have more arboreal pollen and an increasing proportion of sedge pollen (Figure 2.13). Much of the tree pollen at this site could have come from long-distance pollen transport, and thus the authors interpret the Kartsakhi record as evidence for persistent open landscapes in the South Georgian Uplands during the Holocene (Gagnidze and Margalitadze, 1998; Margalitadze, 1977; Margalitadze and Ramishvili, 1972b). However, the interpretation of these three diagrams (Gomnis, Tseros and Kartsakhi) is influenced by sediment hiatuses and changes in the depositional environment, as reflected in the non-arboreal pollen component (Dr N. Margalitadze, Botanical Institute, Tbilisi, pers. comm., 2003).

![Figure 2.13.](image)

The only lowland pollen diagram from Eastern Georgia comes from alluvial terraces at Manavi, near the town of Sagarejo in the Iori Valley. The local vegetation at the site was gallery forest, but much of the surrounding vegetation is xerophytic scrub or agricultural land, heavily human-impacted (Gogichaishvili, 1990; Tumajanov and Gogichaishvili, 1969). The pollen diagram (Figure 2.14) contains a record spanning the last 17,000 years. The lowermost levels of the Sagarejo diagram have high proportions of herbaceous pollen and *Pinus*. The landscape of the lowland Iori
Valley at the last glacial maximum was inferred as treeless steppe with pines sheltering in less exposed areas (Gogichaishvili, 1984a).

An interesting aspect of the Late Pleistocene levels from Sagarejo is the presence of *Juglans* and *Pterocarya* pollen. These two thermophilous, Tertiary-relict trees must have survived the cold and aridity of the glacial period on the lowland floodplains of glacier-fed rivers, becoming locally extinct in these habitats during the early Holocene. Mesophilic tree species expanded during the early Holocene, with a pronounced reduction in forest cover during the mid Holocene that the author interpreted as the result of Neolithic human activities and a ‘xerothermic’ (hot, dry) climate (Gogichaishvili, 1984a; Gogichaishvili, 1990). Human impacts are thought to have further intensified during the mid-late Holocene throughout Eastern Georgia, maintaining the open, steppic character of the landscape from 3500 years ago until the present-day (Gogichaishvili, 1984b).

**Figure 2.14.** Pollen diagram from Sagarejo, lowland Eastern Georgia. Redrawn and simplified from Gogichaishvili (1984b).

Hence the pollen evidence from Eastern Georgia contradicts the dominant botanical paradigm that Georgia was entirely forested until recently: Margalitadze (1977) concluded that the highland landscapes of Southern Georgia remained open and grassy throughout the Holocene, and Gogichaishvili (1984a) argued for an expansion of xerophilous plants coinciding with the adoption of agriculture in the
lowlands of Eastern Georgia (approx. 7800 to 6600 cal. yr BP). These interpretations support Avakov’s (1982) suggestion that non-forest plant communities have a considerable history in Georgia. However, the evidence is not altogether conclusive. Gogichaishvili’s argument is based on floodplain sediments and it is difficult to define the source of the pollen or to exclude the possibility that older pollen has been brought in by erosion. It would be preferable to use lake sediments as a means of avoiding these issues. On the other hand, Margalitadze’s pollen diagrams from the highland lakes of Southern Georgia seem to be affected by different sedimentation processes, such that herb and grass pollen always prevail in minerogenic sediments, while tree pollen is dominant in peaty sediments. Some form of correction is required to ensure that the apparent lack of trees is not simply the result of differential pollen degradation or changing pollen source-area due to lake level variations.

In conclusion, there is much to be learned about the history of Georgia’s vegetation, not least of all in the open landscapes of the semi-arid regions. The aim of this thesis is to examine the causes of vegetation change in Southern Georgia during the last 14,000 years. Currently, opinion is divided over whether climatic change has been the dominant cause of Holocene vegetation changes (Kvavadze and Rukhadze, 1989; Margalitadze, 1995), or whether human impacts in fact overrode these climatic influences (Gogichaishvili, 1984b; Gogichaishvili, 1990). Reconciling these divergent causes rests on obtaining carefully dated pollen data with a greater attention to anthropogenic indicators, and, more specifically, formulating an objective method for reconstructing changes in climate, forest cover and land-use. These tasks are described in the following chapter.
CHAPTER THREE

METHODS

A complete study of vegetation history through pollen analysis is a multifaceted endeavour, involving diverse techniques that complement the elementary method of identifying pollen grains freed from sediment.

Attention must be paid to the selection of sites, as this determines the spatial scale of the investigation (Davis, 2000; Jacobson and Bradshaw, 1981). The vegetation growing in and around the study site should be recorded in a way that can be usefully compared to the pollen currently being deposited there (Andersen, 1970; Sugita, 1994, and references therein). The sediments containing fossilised pollen must be carefully gathered so as not to disturb or contaminate them, and the physical properties of these sediments may reveal important changes in the sedimentary environment through time (Birks and Birks, 1980).

Once pollen has been isolated, identified and counted, the development of the vegetation can only be interpreted in an historical sense with the aid of absolute ages, in the form of radiocarbon dates, marker horizons or other indicators (Olsson, 1986; Roberts, 1998). Finally, underlying patterns in the data can be teased out using statistical analysis and the results presented in a standard format (Bennett, 2002; Moore et al., 1991). Each of these stages for the present study is detailed in the sections that follow.

Site selection

Sites were selected to represent a variety of vegetation units, including semidesert-steppes, coastal swamps, broadleaf forests, tree lines and upland grasslands. The sites are located along a transect running through Southern Georgia, from the high-rainfall coast of the Black Sea to the arid lowlands of Eastern Georgia (Figure 3.1). This transect of sites is designed to give a spatial dimension to the study that furthermore allows local phenomena to be differentiated from a background of regional change: “Experience has proved, what a priori considerations should have
foreseen, that few problems can be adequately resolved by the investigation of a single site” (Walker, 1971, p. 93).

**Figure 3.1.** Study sites on a topographic map of Georgia. Sites numbered thus – 1: Ispani; 2: Avchalagöl; 3: Khachalgora; 4: Lake Aligol; 5: Lake Baretì; 6: Lake Imera; 7: Trialeti Wetland; 8: Lake Cherepanov; 9: Tsavkisi Wetland; 10: Chili Lake; 11: Lake Jvari; 12: Patara Gldani Lake; 13: Lake Kumisi; 14: Sakhare Lake.

While site selection was limited to the sedimentary basins occurring in the landscape, the aim of studying vegetation change on a scale comparable to the archaeological record necessitated the selection of small lakes and wetlands (sensu Jacobson and Bradshaw, 1981; Prentice, 1985; Sugita, 1993; Sugita, 1994). Where possible, closed basins (i.e. without inflowing streams) were used because their pollen and sediment source-area is greatly simplified (Dearing and Foster, 1986). Sites with shallow standing water (0.5 to 1.5 m) were thus favoured, except when a boat or other water craft was available, and sites with very steep basin topography or those that were difficult of access were avoided.

Small lakes and wetlands with the appropriate characteristics were identified from 1:200,000 topographic maps; we then made a field expedition to each site to determine the suitability of its sediments for coring. At the same time, each basin’s morphometry was recorded using a Global Positioning System (GPS) receiver. Where appropriate, lake terraces and other obvious geomorphic features were recorded and measured using a clinometer and tape measure.
Vegetation surveys

To satisfy the aim of comparing pollen and vegetation composition, the local vegetation of each site was described in some detail, because existing data on the study area’s vegetation composition is particularly scanty (Prof. R. Gagnidze, Botanical Institute, pers. comm.). Dr Giorgi Arabuli of the State Museum of Georgia and Dr Henrikh Avakov of the Palaeobiology Institute described the vegetation and identified plants according to standard nomenclature (Czerepanov, 1995). Percentage cover of the most common species was estimated subjectively using the ten-point Domin scale (Kent and Coker, 1992), a variant of the Braun-Blanquet scale. The pollen source-area model of Sugita (1993) was applied to define the area of dryland vegetation described on a palynologically meaningful scale. I found it useful to approximate the model by defining the 50% source area of most common pollen types as ten-times the lake basin radius. Thus for a lake 100 m in radius, the 50% pollen source-area encompasses a radius of 1 km (cf. Sugita et al., 1999). The area of vegetation described was consequently larger for larger lakes and wetlands.

Separate cover abundance estimates were produced for aquatic, wetland, ground layer and forest canopy plants, producing total cover abundances in excess of 100% where forest was present. These percentages were then converted to a single total by calculating percentage forest area within each site’s 50% pollen source-area

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from 1:100,000 topographic maps (Figure 3.2). In several forested places we also undertook short belt transect surveys (Kent and Coker, 1992) to characterise the forest’s composition and age structure.

Surveying vegetation for pollen-based studies in a heterogeneous landscape presents particular challenges (Sugita, 1994). Though the study’s environmental gradient passes from lowland semidesert-steppes through the forest belt to mountain grasslands, in reality each of these vegetation types may occur within the pollen ‘catchment’ of any and all of the sites. In the forest belt, for instance, it is not uncommon to encounter considerable grassy clearings and patches of xerophytic vegetation. Cover abundance values are therefore compositional estimates for ‘vegetation areas’ (sensu Malmer and Regnell, 1986) in the 50% pollen source-area (Figure 3.2). This approach was considered the most appropriate and practical solution to the problem of semi-quantitatively relating heterogeneous vegetation to pollen spectra at an equivalent spatial scale.

Sediment sampling

Heterogeneity of sedimentary environments in the study area necessitated sampling with a variety of hand-held coring equipment. Peats and organic-rich lake sediments were collected with a stainless-steel Russian D-section corer (Jowsey, 1966) with an internal diameter of 5 cm and a barrel 50 cm long. Where this was insufficient to penetrate consolidated silty sediments, a ‘sticky-clay’ auger (Dormer Engineering, Australia) was used instead. My Swiss colleagues collected one core (Lake Bareti) using their own piston corer, constructed of a rigid perspex tube 1.2 m in length. Surface sediments were collected either by hand or, where the water depth was too great, using the D-section corer. To avoid sampling bias, each surface sample was an aggregation of several sub-samples collected over a 5 × 5 metre area.

Each type of coring device has its characteristic advantages and disadvantages (Faegri and Iversen, 1989). The D-section corer is invaluable because it removes stratigraphically intact sections of sediment with minimal disturbance and contamination, but the corer is limited to soft sediments. The ‘sticky-clay’ auger penetrates the hardest sediments with ease, but disturbs their stratigraphy and may introduce contamination from younger sediments. Piston corers fall somewhere between the two extremes of the D-section corer and the auger, allowing for the
preservation of stratigraphy, but compacting the sediment and introducing the possibility of contamination by repeatedly coring down the same hole (Aaby and Digerfeldt, 1986; Birks and Birks, 1980; Wright, 1980).

Cores were collected with a 10-cm overlap when the D-section corer was used. In hard sediments it was unfeasible to obtain such an overlap, so contiguous cores were gathered from the same hole. Great care was taken to avoid contamination during fieldwork. Samples, once collected, were immediately wrapped in plastic film or placed in plastic sample bags, labelled and stored in a cool, dark place until they could be transferred to refrigerated storage in Melbourne. Duplicate samples of 1 cm$^3$ for physical and microscopic analyses were initially taken from each core at a relatively coarse interval, which was later refined. But since this study is primarily concerned with changing small-scale spatial patterns within a larger geographic region, rather than the detailed vegetation history of a single lake or mire, a compromise had to be reached between spatial and temporal resolution.

**Physical analyses**

The physical structure of sediments reveals much about their genesis and the environments in which they formed (Dearing and Foster, 1986). Sediment colour was defined using Munsell colour charts and sediment description followed the standard system developed by Troels-Smith (1955). This widely-adopted scheme classifies sediments into a number of types based on physical characteristics, degree of humification and sediment composition (Birks and Birks, 1980).

In addition to these descriptive data, the moisture and organic content of the sediments was determined using the method of Bengtsson and Enell (1986), based on overnight drying at 100 °C and ignition for 2 hours at 550 °C. The magnetic susceptibility of 10 cm$^3$ sediment aliquots from several cores was measured using a Bartington Magnetic Susceptibility Meter (Bartington Instruments MS-2). Unfortunately, this equipment developed a fault before all the cores could be analysed, so magnetic susceptibility profiles are lacking from some sites. Where carbonates were present in the sediment, this was recorded semi-quantitatively based on their reaction to the addition of 10% hydrochloric acid (HCl).
Microscopic analyses

Before chemical pretreatment for microscopy, two Lycopodium marker spores (University of Lund, batch 938934, n=10,679) were added to each 1 cm³ sediment sample for the calculation of pollen concentrations (see Moore et al., 1991).

Most of the samples collected for this study contained a high proportion of silt and other inorganic particles. Hydrofluoric acid digestion of samples for pollen analysis (Faegri and Iversen, 1989) was quickly abandoned because of violent reactions upon addition of HF to some samples. Instead, gravity separation was performed on all samples, using sodium polytungstate (3Na₃WO₄.9WO₃.H₂O) solution with a specific gravity of 2.0 (Hart, 1988). Also, boiling samples with low organic content in a 10% solution of potassium hydroxide (KOH) proved to be unnecessary and damaging to fragile pollen preserved in compact, silty sediments. Silts and clays were instead deflocculated overnight in a 3-5% solution of sodium hexametaphosphate (Na₂P₂O₇). See Appendix C for the complete method.

Samples were subjected to standard acetolysis, stained with safranin and mounted in glycerol. I identified all pollen and spores at a magnification of 400× on an Olympus binocular microscope. My primary source for identifications was the excellent pollen key of Moore et al. (1991), supported by the collection of Caucasian type material housed in the Palynology Laboratory at the University of Melbourne and several published pollen atlases (Beug, 2004; Bobrov et al., 1983; Chester and Raine, 2001; Gogichaishvili et al., 1975; Kuprianova and Aleshina, 1972; Kuprianova and Aleshina, 1978; van Zeist and Bottema, 1977). In some cases, difficult pollen grains were referred to Dr Eliso Kvavadze (in Georgia) or Jacqueline van Leeuwen (in Switzerland) for identification. An average of 1100 pollen grains were identified in each sample, but this figure varied considerably depending on differences in pollen preservation and concentration from core to core.

In addition to pollen, microscopic charred particles encountered on pollen slides were quantified by the point-count method (Clark, 1982). This method provides a probability-based estimate of the area of charcoal in the sediment sample and is a proxy for fire. Fire history has received little or no attention in palynological literature from the Caucasus and consequently almost nothing is known of the palaeoecological importance and successional effects of fire, even though fire clearly
is commonplace in steppe landscapes in the Caucasus today (Connor et al., 2004). Methods for quantifying sedimentary charcoal are many and their selection depends on the questions being asked of the data (Innes et al., 2004; Patterson et al., 1987, and references therein; Rhodes, 1998). Point-count estimation is distinguished from other methods (e.g. Tinner and Hu, 2003) in that it rapidly quantifies the area rather than number of charred particles on a pollen slide (Figure 3.3). Hence it is not biased by the fragmentation of charred particles that occurs during pollen extraction or through sediment diagenesis (Clark, 1982). During counting, microscopic charcoal were grouped into size classes of 5-20, 20-40, 40-60, 60-80 and >80 μm, as charcoal size broadly reflects a fire’s proximity to the site of deposition (Blackford, 2000).

![Figure 3.3. Simulated pollen slides with charcoal particles (black). Point-count estimation using the grid gives a result of 33 points for the left-hand graph and 31 points for the right (out of a possible 121 points). In contrast, charcoal counts are vastly different (36 versus 12), even though the charcoal area on both slides is the same. While charcoal counts and charcoal area are positively-correlated (Tinner and Hu, 2003), point-count estimation retains many theoretical and practical advantages over raw charcoal counts.](image)

Other microscopic plant and animal remains were identified from the descriptions and microphotographs provided by van Geel and co-workers (van Geel, 1978; van Geel and Aptroot, 2006; van Geel et al., 1981; van Geel et al., 2003). Not surprisingly, the identity of many such remains in Caucasian deposits could not be found in the published literature, so only common taxa were recorded, and only those taxa that could be confidently identified and have well-defined ecological significance are presented in pollen diagrams. These remains include coprophilous fungi (Sporormiella and Podospora), thermophilous members of the Zygnemataceae (Penium, Spirogyra and Mougeotia), green algae (Botryococcus), Ceratophyllum leaf

**Radiocarbon dating**

All of the radiocarbon dates presented in this study were determined through accelerator-mass-spectrometry (AMS). Prior to pre-treatment, samples were picked over for contaminating rootlets and silt-rich samples were gravity separated (see above) to remove excess inorganic material. Most samples were pre-treated using the standard acid-base-acid (ABA) method, which involves carbonate removal with 2 M HCl, then repeated humic acid removal with increasing concentrations of sodium hydroxide (NaOH), followed by a final HCl treatment (see Appendix D).

A few samples were not prepared in this way, and were pre-treated to isolate only the pollen fraction of the sediment (Brown et al., 1989) or using only hydrochloric acid washes (Beta Analytic). Pretreatment for dating of pollen concentrate involves repeated bleaching and sulphuric acid treatment to remove organic detritus and chitin from the sample (Brown et al., 1989, see Appendix D), although the absolute ages produced from this method have not always been consistent with those produced by dating macroscopic plant remains (Kilian et al., 2002). Repeated hydrochloric acid washes are the simplest method and are particularly effective in carbonate-rich sediments, but can render ages that are too recent on account of humic acid infiltration from higher stratigraphic levels (Olsson, 1986). As such, sample pre-treatment has a strong bearing on the resulting age determination.

Once pre-treated, the samples were combusted to convert the remaining organic carbon to carbon dioxide. This process liberates the carbon from its contaminants and is followed by graphitisation (conversion to a graphite target) for dating by AMS (Hua et al., 2001). Samples preceded by codes OZG and OZH were dated at the Australian Nuclear Science and Technology Organisation AMS facility, Lucas Heights, Sydney.

All dates reported in this study are given in calendar years before 1950 (BP), determined by calibrating conventional dates to the tree-ring dataset in the computer.
Numerical analyses

Several numerical analyses have been employed in this study and are discussed at greater length in the sections in which they are presented. The principal methods are all multivariate analyses and have been used to identify the prevailing trend or trends in spatial and temporal data.

Detrended Correspondence Analysis (DCA) (Hill and Gauch, 1980), an indirect gradient analysis, has frequently found application in ecological and palaeoecological research because it assumes unimodal species response to environmental gradients (ter Braak and Prentice, 1988), sample scores represent species-compositional turnover (β-diversity) (Gauch, 1982) and, perhaps most attractively, it “works well in practice with real-life data” (Birks et al., 2004, p. 537). It is a variant of Correspondence Analysis (CA) that uses detrending-by-segments to remove the ‘arch effect’ (curvilinear distortion) and axis compression associated with CA, PCA and other methods (Hill and Gauch, 1980; Kent and Coker, 1992).

Following its introduction, several ecologists and statisticians seriously questioned the robustness of DCA as an ordination method. Criticisms revolved around its sensitivity to rare species, possible distortions introduced by detrending, poor results associated with the second and higher-order gradients, and unstable results depending on sample input order (Dargie, 1986; Minchin, 1987; Tausch et al., 1995; ter Braak, 1995; van Groenewoud, 1992; Wartenburg et al., 1987). At least some of these problems were solved more recently by Oksanen and Minchin (1997), who identified the software bug that caused sample order to bear heavily on the ordination results, causing instability in the second and third ordination axes.

Oksanen and Minchin’s (1997) de-bugged ‘super-strict’ version of DCA was used in this study to analyse percentage pollen data, through the statistical software package, PC-ORD 4.25 (McCune and Mefford, 1999). Rare species were down-weighted and axes were rescaled to represent species turnover. The resulting trends can be compared ecologically to climatic, topographic, anthropogenic, edaphic and
other data to determine the dominant controls on pollen composition now and in the past. The selection of an indirect ordination technique is important where the major environmental controls on species compositional change are unknown or poorly understood (ter Braak and Prentice, 1988).

A second method employed in this study, Two-Way Indicator Species Analysis (TWINSPLAN) (Hill, 1979), is a divisive classification method which produces a hierarchy of dichotomies based on weighted averaging ordination similar to DCA. PC-ORD’s de-bugged version (McCune and Mefford, 1999) was used to classify samples in this study. TWINSPLAN works by splitting the entire set of samples into two groups at each division, according to each sample’s position on the ordination axis. At each split, the ‘pseudospecies’ (a quantitative measure of presence/absence) that best differentiates the two groups is given as an indicator for that group. These indicators can greatly assist the ecological interpretation of the resulting groups. They also allow samples that were not included in the original dataset to be classified when, as in this study, the ordination is performed on untransformed data.

Because both DCA and TWINSPLAN are based on the chi-squared ($\chi^2$) dissimilarity coefficient, these two methods have often been criticized for their greater sensitivity to rare species compared to other methods such as Canonical Correspondence Analysis (CCA), Principal Components Analysis (PCA) and Non-metric Multidimensional Scaling (NMS) (see discussions in Clark, 1993; Minchin, 1987; Peet et al., 1988; Wartenburg et al., 1987). The chi-squared dissimilarity coefficient’s sensitivity to rare species can be reduced in DCA by down-weighting and in TWINSPLAN by selecting cut-levels that give preference to more common taxa (Vermeersch et al., 2003). There are also several a priori reasons for favouring signal-to-noise dissimilarity coefficients such as chi-squared over others in palaeoecological applications (Jackson and Williams, 2004; Overpeck et al., 1985; Prentice, 1980; Prentice, 1986).

---

3 CCA is not considered appropriate for ordination of data in this study because there are no a priori grounds to assume that known environmental variables exert direct control over pollen composition at different sites. PCA can also be dismissed, as there is no evidence that pollen taxa respond to environmental gradients in a linear fashion. The appropriateness of NMS is discussed later.
Unlike living organisms, palaeoecological data is a fossilised ‘death assemblage’ that represents the community of living organisms in a way heavily distorted by factors such as the sedimentary environment, fossilization processes, fossil production and dispersion (Birks and Birks, 1980). One of the most significant distortions in any pollen data-set is the background ‘noise’ created by regional pollen, which effectively obscures changes on a more local scale (Davis, 2000; Jacobson and Bradshaw, 1981). The chi-squared dissimilarity coefficient has a noise-reducing capability that helps to isolate a ‘signal’ that may otherwise be obscured by regional pollen rain (cf. Jackson and Williams, 2004; Overpeck et al., 1985; Prentice, 1980).

To demonstrate this capacity, Figure 3.4 presents the results of NMS and DCA applied to the same pollen dataset and related to environmental gradients. DCA extracted strong gradients on both axes and ordered samples in an ecologically interpretable way, whereas NMS produced only one climatic gradient, with a much noisier sample scatter that is poorly related to biogeographical patterns and much more susceptible to the presence or absence of rare species. Although it has been argued that “DCA is not a statistically elegant technique” (Peet et al., 1988, p. 924), it may perform better when faced with noisy or highly heterogenous data (Ejrnæs and Bruun, 2000; Prentice, 1986) and appears to be quite robust even when its assumption of unimodal response to environmental gradients is violated (Ejrnæs, 2000).
Most palaeoecological applications of multivariate analyses are, by definition, heuristic, since we have no way of directly measuring the environmental gradients that species were responding to in the past. Indeed, the reason that multivariate analyses are used in this study is to reconstruct past environmental changes from changing species abundances. Circular arguments in interpretation are easily avoided by referring to the present-day ecological tolerances of the species in question and, applying uniformitarian principles, making the assumption that these tolerances were much the same in the past as they are now.

The idea that the ‘present is the key to the past’ is a theme carried through all the numerical analyses in this study. In Chapter Four, DCA is used to identify the prevailing environmental gradients that shape the composition of pollen samples in the study area presently. Each pollen taxon has a specific relationship to each of these gradients; the stronger the relationship between a pollen taxon and a gradient, the more heavily ‘weighted’ it will be (though this will also depend on its ubiquity – more common taxa require less weight than rare taxa to have the same effect.) In subsequent chapters these weights are applied to fossil pollen data through Weighted Averaging (Whittaker, 1967), allowing environmental gradients to be reconstructed for the past, firmly anchored to present bioclimatic patterns. If particular pollen assemblages in the past have no modern analogue (Anderson et al., 1989; Birks, 1973; Webb, 1980), Weighted Averaging may still reconstruct meaningful, albeit distorted, trends, as it places each sample at the “centre of gravity” (Prentice, 1986, p. 783) of the species in the ordination space. It stands to reason that a comprehensive modern dataset will produce reconstructions of greater certainty.

**Presentation of results**

Pollen data are conventionally calculated and graphed as percentages of a sum that includes all trees, shrubs and terrestrial herbs, forbs and grasses (Faegri and Iversen, 1989; Wright and Patten, 1963). Pollen of wetland and aquatic plants are excluded because these plants often become incorporated into the sediment itself, and hence their pollen is over-represented. For deep lakes and perennially-wet bogs, the calculation of the pollen sum presents no particular problem. In shallow lakes and wetlands prone to desiccation, however, it is possible that terrestrial plants grew very
near to or on the sediment surface itself at various times. Taphonomic processes associated with semi-arid environments can lead to pollen degradation and a further distortion of the death assemblage (Havinga, 1964; Havinga, 1967; Horowitz, 1992; Moore and Stevenson, 1982).

**Figure 3.5.** A model of pollen behaviour under changing lake levels. In this example (Figure 3.2), when the lake is full (A) the 50% pollen source-area contains 60% forest and 40% open landscapes. A lake regression shrinks the source-area (B), which is now dominated by open land. The effect of this change is shown (C). The contracted lake is theoretically more sensitive to changes in local pollen than the full lake (Sugita, 1994). Local pollen may also be contributed by vegetation growing on the exposed lake bed (LB), constituting an ephemeral source of non-arboreal pollen (NAP). Graphs at right compare source-area openness to pollen composition. AP:NAP ratios simulated for southern Sweden (Figure 4.1) can be applied to predict that arboreal pollen (AP) will decline at this site as the lake level drops. Observed values (Chapter Four) may indicate that the lake-bed component (LB) is an important pollen source in seasonally fluctuating lakes.

Basin size also plays a very important part: small basins have a pollen assemblage dominated by locally produced pollen, while larger basins contain a more regional assemblage (Jacobson and Bradshaw, 1981; Prentice, 1985; Sugita, 1993). According to the model of Jacobsen and Bradshaw (1981), regional pollen prevails at sites with a diameter of 300 m or more; extra-local pollen dominates sites around 200 m in diameter; local pollen is most prevalent in sites less than 100 m in diameter. Sugita’s (1994) simulations of pollen representation in heterogenous vegetation suggest that small lakes (radius 50 m) are dominated by a local signal, which is not apparent in larger lakes (radius 750 m). This means that the entire pollen assemblage
may be strongly affected by lake level variations related to hydrological change, a process illustrated in Figure 3.5.

Because the study area is largely semi-arid, and probably was so in the past (Wick et al., 2003), sums for pollen diagrams have been calculated in a variety of ways. Where there appears to have been major pollen source-area or post-depositional changes due to lake level variations recorded lithologically, percentages have been calculated from separate arboreal and non-arboreal sums. Where no significant changes in source area have been detected, the pollen sum is calculated conventionally. The particular sum used is reported alongside the results from each site. These adjusted pollen sums are only for the purposes of displaying the data and were not used in Weighted Averaging.

Pollen diagrams were all drawn using Psimpoll (Bennett, 2002). The pollen diagrams have been subdivided stratigraphically into pollen assemblage zones based on optimal splitting by information content (Bennett, 1996; Birks and Gordon, 1985). The number of zones was determined by the reduction in variance produced by each split, where the variance reduction exceeded that anticipated by the ‘broken stick’ statistical model (Bennett, 1996). This means that the placement and number of pollen assemblage zones has a robust statistical basis, independent of any regional stratigraphic, palaeoclimatic or chronological schemes. Palaeoecological research in the study area must move beyond such schemes if it is to truly analyse past vegetation changes in an objective manner.
CHAPTER FOUR
MODERN POLLEN-VEGETATION RELATIONSHIPS

“Know the changes of the times, remember the proverbs, and liken the future to the past” (The Georgian Chronicles: Thomson, 1996, pp. 341-342).

Introduction

The aim of palaeoecology is to reconstruct past ecosystems. As in many of the natural sciences, this aim can only be fulfilled by making certain assumptions in relation to the physical environment, assumptions collectively known as uniformitarian principles. In part, these state that natural processes are governed by the laws of physics, which do not change with the passing of time, even though the processes themselves and the rate at which they occur may vary (Birks and Birks, 1980). On this premise, palaeoecological data represent past ecology in the same way that equivalent data collected today represent the ecology of organisms living (or dying) now.

To reconstruct the environmental conditions that led to certain assemblages of organisms existing in the past, it is most feasible to infer these conditions from a solid knowledge of how they operate on the same organisms in the present-day. Furthermore, because of processes that shape and distort fossil assemblages, the abundance of fossils in a sedimentary deposit does not represent the organisms that produced them in any simple, straightforward manner (Birks and Birks, 1980).

Pollen analysis is used to reconstruct the composition and character of plant communities in the past. With a firm understanding of the ecology of the vegetation in the present-day and the pollen it produces, past pollen assemblages may be matched to modern analogues, lending greater certainty to the reconstruction (Anderson et al., 1989; Birks, 1995; Jackson and Williams, 2004; Overpeck et al., 1985; Wright, 1967). The environmental conditions of the past can be inferred if the conditions associated with this assemblage are known in the present. And while there
are errors inherent in this process, a study of modern pollen-vegetation relationships is a necessary prelude to the interpretation of fossil pollen data.

Traditionally, studies of how modern pollen is represented in sediments have made use of moss cushion or surface soil samples and related these to the surrounding vegetation (e.g. Bradshaw, 1981; Bunting, 2002; Davis, 1980; Elliot, 1999; Gajewski et al., 2002; Islebe and Hooghiemstra, 1995; Paez et al., 2001; Tinsley and Smith, 1974; Wright et al., 1967). Several such studies have been previously undertaken in the Caucasus region, using soil or moss samples collected over long altitudinal transects (e.g. Klopotovskaya, 1973; Kvavadze, 1993; Kvavadze, 1999a; Kvavadze and Stuchlik, 1990; Kvavadze and Stuchlik, 1991; Kvavadze and Stuchlik, 1993; Peterson, 1983; Stuchlik and Kvavadze, 1993; Stuchlik and Kvavadze, 1998; Yazvenko, 1991). While they reveal important broad-scale changes in pollen composition, the application of these studies to the interpretation of fossil pollen is limited. This is because few lake and wetland sites usually used in palaeoenvironmental reconstructions have a pollen source area that is comparable to soil or moss samples (Hicks, 2001; Kvavadze and Efremov, 1995; Seppä and Bennett, 2003). Indicator pollen types derived from soils and mosses cannot be strictly applied to the interpretation of pollen spectra in lake and wetland sediments.

The pollen source-area of soils, mosses, wetlands and lakes can be strikingly different. Moss ‘polsters’ beneath forest canopies are dominated by pollen originating in the surrounding 20-30 m; small forest openings by pollen from the surrounding 50-100 m; while sediments in the centre of a large lake are typically dominated by a regional component with a source area of many hundreds of kilometres (Andersen, 1970; Calcote, 1995; Jacobson and Bradshaw, 1981; Janssen, 1966; Janssen, 1986; Prentice, 1985; Sugita, 1993).

These source-area concepts are based on conditions in Northern Hemisphere temperate forests and their applicability to areas where semidesert-steppes, scrub, savanna and mountain grasslands are characteristic vegetation types may be questioned (Davies and Fall, 2001). Sites in open vegetation have a greater potential source area than sites in forest, due to the removal of the ‘trunk space’ (Tauber, 1965) or ‘gravity’ component (Jacobson and Bradshaw, 1981) and the absence of filtration by arboreal vegetation (Tauber, 1967).
Highland sites are often dominated by arboreal pollen generated by forests growing at lower altitudes (Fall, 1992; Frei, 1997; Haberle and Bennett, 2001; Islebe and Hooghiemstra, 1995; Markgraf, 1980), so determining the position of tree lines palynologically is difficult and potentially flawed (Birks and Birks, 2000). In mountain environments, joint analyses of conifer stomata and pollen have shown that arboreal pollen percentages and influx rates increase as forests advance toward a study site, but often decline once forests are present in situ (Ammann and Wick, 1993; David, 1997; Pisaric et al., 2000). Human-induced forest disturbance can also cause a greater influx of tree pollen, increasing arboreal pollen percentages, paradoxically, during deforestation events (Aaby, 1988).

![Figure 4.1](image)

**Figure 4.1.** Non-arboreal pollen (NAP) percentages plotted against the percentage of open land within a kilometre of a one-hectare lake. A: observed relationship; B: simulated relationship; dashed line: direct linear relationship (simplified from Sugita et al., 1999).

The relationship between arboreal pollen abundance and forest abundance is therefore non-linear (Figure 4.1), influenced heavily by how pollen disperses in various environments and the density and composition of the vegetation itself.

In the semi-arid parts of the mountainous Caucasus region, accurate differentiation of open versus forested landscapes from pollen data is crucial for reconstructing past vegetation, contextualising a rich archaeological record and developing a model of Holocene palaeoclimatic fluctuations. Hence the aims of this chapter are:

1. To study the relationships between the present-day vegetation of the study area and the pollen that it produces, by comparing vegetation survey data with modern pollen spectra from lakes and wetlands.
2. To determine whether treeless and forested environments can be differentiated using pollen data, and if there are pollen indicator taxa specific to certain vegetation types.

3. To examine statistical relationships between environmental gradients and pollen spectra that may assist interpretation of palaeoecological data in terms of past climate and land-use.

My approach to satisfying these aims is both descriptive and experimental. Much of the following chapter is descriptive, in terms of data presentation and statistical analyses. The experimental part is essentially a model-testing exercise, in which a classification of the pollen data is validated using additional data. The results are then synthesised into a discussion on pollen representation and environmental gradients.

**Study sites and their pollen-vegetation relationships**

The study sites are located along an altitudinal transect through Southern Georgia and include places surrounded semidesert-steppe, xerophytic scrub, oak-hornbeam forest and mountain grassland vegetation (Figure 4.2). This transect does not attempt to capture the full range of vegetation types in Georgia since these are discussed in Chapter Eight. Instead, it is a small-scale exploration of pollen-vegetation relationships within the specific study area based on original data.

From the outset it must be said that the vegetation that surrounds each of the study sites is and has been heavily influenced by human activities. So, while the aim of analysing surface samples is to obtain modern analogues for past pollen spectra, this aim cannot always be fulfilled with precision in the present-day vegetation.

Eight sites were initially chosen for study. Their locations are shown in Figure 4.2, and some associated characteristics are provided in Table 4.1. Forest area was calculated using the method described in Chapter Three. Forest area data in Table 4.1 represent forest cover within each site’s 50% pollen source-area.

Pollen data from each of the eight sites is shown in Figure 4.3 along with major altitudinal, temperature and precipitation gradients. It is immediately apparent that these gradients have a profound influence on pollen spectra. In the hot, dry
In the lowlands of the eastern part of the transect, Chenopodiaceae pollen is absolutely dominant. This changes as one moves upslope, where the pollen of various deciduous trees (Quercus, Carpinus, Fagus) and grasses (Poaceae) become important. Finally, in the westernmost part of the transect, pine (Pinus) pollen prevails over the deciduous types.

Each of the study sites is discussed in more detail in the following sections, beginning with the lowland semidesert-steppe area.

![Figure 4.2. Study site locations on a map of principal vegetation zones in the study area. Site names given in Table 4.1. Adapted from Ketskhoveli (1959) and 'Landscape Map' in AN GSSR (1964).](image)

### Table 4.1. Site locations and associated environmental variables. See Chapter Three for an explanation of forest area calculations. Type: L- lake site, W- wetland site.

<table>
<thead>
<tr>
<th>Site code</th>
<th>Site name</th>
<th>Type</th>
<th>Location (Lat.; Long.)</th>
<th>Elevation (m a.s.l.)</th>
<th>Basin avg. radius (m)</th>
<th>Forest area (%)</th>
<th>Vegetation type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>Sakhare</td>
<td>W/L</td>
<td>41°35’N; 45°19’E</td>
<td>800</td>
<td>190</td>
<td>0</td>
<td>Semidesert-steppe</td>
</tr>
<tr>
<td>KU</td>
<td>Kumisi</td>
<td>L</td>
<td>41°35’N; 44°50’E</td>
<td>469</td>
<td>1070</td>
<td>&lt;1</td>
<td>Semidesert-steppe</td>
</tr>
<tr>
<td>TS</td>
<td>Tsavkisi</td>
<td>W</td>
<td>41°41’N; 44°45’E</td>
<td>1100</td>
<td>100</td>
<td>60</td>
<td>Steppe-forest</td>
</tr>
<tr>
<td>CHE</td>
<td>Cherepanov</td>
<td>L/W</td>
<td>41°34’N; 44°22’E</td>
<td>1400</td>
<td>210</td>
<td>70</td>
<td>Oak forest</td>
</tr>
<tr>
<td>TR</td>
<td>Trialeti</td>
<td>W</td>
<td>41°32’N; 44°07’E</td>
<td>1520</td>
<td>140</td>
<td>45</td>
<td>Upper tree-line</td>
</tr>
<tr>
<td>IM</td>
<td>Imera</td>
<td>L/W</td>
<td>41°39’N; 44°12’E</td>
<td>1610</td>
<td>140</td>
<td>0</td>
<td>Mountain grassland</td>
</tr>
<tr>
<td>BA</td>
<td>Bareti</td>
<td>L/W</td>
<td>41°39’N; 44°10’E</td>
<td>1630</td>
<td>620</td>
<td>&lt;5</td>
<td>Mountain grassland</td>
</tr>
<tr>
<td>AV</td>
<td>Avchalagöl</td>
<td>W</td>
<td>41°20’N; 43°42’E</td>
<td>2050</td>
<td>417</td>
<td>&lt;1</td>
<td>Mountain grassland</td>
</tr>
</tbody>
</table>
Figure 4.3 (A). Diagram of altitudinal and climatic gradients, AP-to-NAP ratios and percentages of selected AP taxa, calculated from the dryland pollen sum. Taxa are ordered according to TWINSPLAN ordination. Climatic data from AN G SSR (1964). See Appendix E for the complete data-set.
Figure 4.3 (B). Diagram of selected NAP percentages. Pollen and charcoal concentrations, as well as the TWINSPLAN result, are shown at the top of the diagram. TWINSPLAN indicators are given in Table 4.8.
Sakhare Lake

Sakhare Lake is a small, saline wetland situated on the Iveria Plateau of Eastern Georgia (Figure 4.4). The wetland is one of several salt lakes nestled in the striking, ‘cuesta-like’ folds of the Udabno-Gareji landscape (Kvavadze and Todria, 1992) (Figure 4.5). Its basin is around 600 m long and 200 m wide, but the lake’s size varies according to the seasons. Geologically, the area is predominantly Mio-Pliocene sediment that has been tilted and subsequently heavily eroded (Tsereteli, 1971). Lake basins have formed through preferential erosion of soft, sandy strata interbedded between more resistant conglomerates (Figure 4.6).

The wetland surface, when it is not seasonally inundated, is mainly vegetated with *Salicornia europaea* and *Phragmites australis*. Dense swathes of *Bolboschoenus maritimus* occur around the wetland margins along with other semidesert plants. The surrounding landscape is covered with semidesert-steppe vegetation, dominated by *Festuca valesiaca*, *Stipa pulcherrima*, *Artemisia lerchiana* and *Salsola nodulosa*. In describing the Udabno-Gareji landscape in the early 18th century, the Georgian geographer Prince Vakhushti Bagrationi observed that, ‘there is no forest, if we do not count the Christ-thorn [*Paliurus*], sumac and suchlike; no rivers flow, and springs and lakes are rare, besides being hard and salty. Grassy even in winter…the summer is oppressively hot’ (Maruashvili, 1956, p. 74). His description is as valid today as it was then.

A comparison of the site’s vegetation composition and pollen spectra (Table 4.2) demonstrates that Chenopodiaceae pollen are over-represented palynologically, that Poaceae pollen are well-represented, whereas many other herbaceous plants are severely under-represented, including *Artemisia*. Consistent with the predominantly treeless landscape, arboreal pollen is represented only in tiny proportions. *Polygonum aviculare*-type and unidentified Polygonaceae pollen occur frequently in the Sakhare Lake pollen spectra, even though no source plants were identified in our surveys. A previous botanical description of this site records the presence of the halophytic annual, *Polygonum argyrocoleum*, along with various Chenopodiaceae (Ketskhoveli, 1959, p. 297).
The lands around Sakhare Lake are used predominantly as winter pasture. Cattle, goats and fat-tailed sheep graze here and their herders periodically burn the vegetation to promote fresh growth for their stock. The high charcoal concentrations in the Sakhare Lake sediments probably reflect this practice (Figure 4.3).

Figure 4.4. Photograph of Sakhare Lake in the Udabno region of Eastern Georgia (May 2002).

Figure 4.5. Exposures of Mio-Pliocene sedimentary rock strata near the Davit Gareji Monastery.
Table 4.2. Comparison of plant community composition and pollen spectra at Sakhare Lake. The table compares cover abundance (‘% cover’) of plant species to the abundance of corresponding pollen types (‘% pollen’), the values indicated by shading (see legend below). Pollen percentages are a mean value for the four samples studied.

<table>
<thead>
<tr>
<th>Herbaceous plants:</th>
<th>% cover</th>
<th>% pollen</th>
<th>Pollen type represented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achillea micrantha</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Artemisia fragrans</td>
<td>-</td>
<td>-</td>
<td>Artemisia</td>
</tr>
<tr>
<td>Carduus albidus</td>
<td>-</td>
<td>-</td>
<td>Aster-type</td>
</tr>
<tr>
<td>Carduus seminudus</td>
<td>-</td>
<td>-</td>
<td>Aster-type</td>
</tr>
<tr>
<td>Cousinia macroptera</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cousinia orientalis</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Onopordum acanthium</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Senecio vernalis</td>
<td>-</td>
<td>-</td>
<td>Aster-type</td>
</tr>
<tr>
<td>Anchosus italicca</td>
<td>-</td>
<td>-</td>
<td>Boraginaceae undiff.</td>
</tr>
<tr>
<td>Camelina microcarpa</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rorippa prostrata</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thlaspi arvense</td>
<td>-</td>
<td>-</td>
<td>Hornungio-type</td>
</tr>
<tr>
<td>Chenopodium album</td>
<td>-</td>
<td>-</td>
<td>Chenopodiaceae undiff.</td>
</tr>
<tr>
<td>Salsola nodulosa</td>
<td>-</td>
<td>-</td>
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<td>Reseda lutea</td>
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<td>Phragmites australis</td>
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Legend for Tables 4.2 to 4.6

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<td>34-75%</td>
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<td>76-100%</td>
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</table>
Lake Kumisi

Lake Kumisi is also situated in the semidesert-steppe area, but it is a much larger lake than Sakhare Lake, with a maximum diameter of 2.6 km (Figure 4.7). Kumisi is a salt lake impounded by the tectonic uplift of the surrounding Teleti and Yagluja Ranges and the suffosion of gypseous strata in the underlying sedimentary strata of Oligocene-Miocene age (Janelidze, 1955; Tsereteli, 1971) (Figure 4.8). Because the lake has no outlet and is fed only by intermittent streams, its water level fluctuates considerably from year to year. In the last two decades the lake water has been supplemented with water diverted from the Iori River, such that the water depth in the centre of the lake is now about 3 metres (Kvavadze and Connor, 2005). Local villagers recall the lake being much smaller and salt flats much more extensive prior to this irrigation scheme.

*Ruppia spiralis* grows in the saline water and *Phragmites australis* beds are scattered round the lake margins. The surrounding steppes are ‘without forest and without water’ (Vakhushti, in Maruashvili, 1956, p. 59). This site and Sakhare Lake are notable for the extensive representation of halophytic semidesert plants on the saline soils (solonchaks) that surround both basins (Ketskhoveli, 1959, pp. 296-7). These soils are given over to pastures while more elevated, less salty soils are used for irrigated agriculture. The only trees in the catchment are a few planted pines (*Pinus eldarica*) and poplars, though oak-hornbeam forests grow in the upper reaches of the Nagubi Creek, the main tributary of Lake Kumisi.

It proved impossible to survey the vegetation of so large a pollen source area as Lake Kumisi’s. Nevertheless, several points may be made about the relationship
between its pollen spectra and the surrounding vegetation. Chenopodiaceae are dominant, but not quite as prevalent as at Sakhare Lake. This deficit is counteracted by higher levels of *Artemisia* and Poaceae at Lake Kumisi. Arboreal pollen is also more important, and especially so in surface samples gathered from the lake centre where the pollen source area is greatest. Samples from the centre contain 23% arboreal pollen compared to just 2% in samples taken nearer the lake edge. Most of this arboreal pollen must arrive as long-distance-transported pollen from trees growing outside the lake basin, though some of the *Pinus, Quercus* and *Juniperus* pollen could come from more local sources. The Lake Kumisi pollen spectra demonstrate with clarity the strong influence of lake area and water depth on pollen source area in semi-arid lakes.

**Tsavkisi Wetland**

Tsavkisi Wetland is an infilled lake situated at 1110 m elevation in the rugged foothills above the Georgian capital, Tbilisi (Figure 4.9). The wetland is around 400 m long and 100 m wide, contained within a steep-sided basin composed of Upper Eocene sedimentary rocks, which have been warped and folded into a series of abrupt ridges and steep ravines. Preferential weathering of anticlines, occurrence of landslips and suffosion of gypsum layers within the sedimentary units have led to the formation of a number of closed lake basins near Tbilisi, occupied by spring-fed, alkaline lakes (Dzhanelidze, 1980; Tsereteli, 1971).

Tsavkisi Wetland is located at the very border of forest and steppe. Forests of *Quercus iberica* and *Carpinus orientalis* occur extensively to the north and west of the wetland (Figure 4.10), while scrub vegetation, steppe and phrygana occur in various associations to the south and east. Plantations of pine (*Pinus kochiana*), apple (*Malus domestica*) and walnut (*Juglans regia*) occupy some of the site’s catchment (Figure 4.11). The wetland itself is densely clothed with *Phragmites australis* and *Typha latifolia*, and fringed with sedges (*Carex vesicaria*).
Figure 4.7. Lake Kumisi in the semidesert-steppe lowlands. Dr Maia Jejelava at left (May 2002).

Figure 4.8. Exposed sediments of Oligocene-Miocene age on the shores of Lake Kumisi (May 2002).
Figure 4.9. Tsavkisi Wetland, between the villages of Tsqneti and Tsavkisi, looking eastward (August 2003).

Figure 4.10. Belt transect survey through *Quercus iberica* - *Carpinus orientalis* woodland at the western end of Tsavkisi Wetland (see Figure 4.11). Taller trees grow on the north-facing slope, more xeric species on the south-facing slope.
Vegetation survey data are compared to pollen spectra from the wetland edge and wetland centre in Table 4.3. In general, the agreement between the three sets of data is good. Amongst the arboreal species, pollen from shrubs is much under-represented compared to tree pollen. This is especially the case for shrubs in the Rosaceae family, which are palynologically ‘silent’ because their pollen are insect-dispersed.

Although *Quercus iberica* and *Carpinus orientalis* are the most common trees in the catchment, this is not reflected in pollen spectra from the wetland edge, where *Pinus* pollen from the adjacent plantation prevails. *Carpinus orientalis* is very much under-represented in pollen spectra; oak is better represented. Spectra from the lake centre better reflect the surrounding forest composition, but fail to adequately represent the substantial areas of steppe and shibliak vegetation nearby. Again, this is the result of poor pollen production and dispersion amongst most steppe herbs, with the notable exception of Chenopodiaceae, Poaceae and *Plantago* species.

The Tsavkisi area is mainly used as rough pasture for cattle, as is the wetland’s sedge vegetation (Figure 4.12). High proportions of *Plantago lanceolata* pollen are probably indicative of this activity (cf. Behre, 1986).

**Figure 4.11.** Map of Tsavkisi Wetland, showing principal vegetation units. Compiled from aerial photographs, topographic maps and ground surveys.
Table 4.3. Comparison of plant community composition and pollen spectra at Tsavkisi Wetland. See Table 4.2 for explanation and legend. Asterisks (*) denote plantations.

<table>
<thead>
<tr>
<th>Trees and shrubs:</th>
<th>% cover</th>
<th>% edge</th>
<th>% centre</th>
<th>Pollen type represented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acer lactum</td>
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<td><em>Acer</em></td>
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<td>Lonicera caucasica</td>
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<tr>
<td>Viburnum lantana</td>
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<td><em>Viburnum</em></td>
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<td>Cornus mas</td>
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<td><em>Cornus</em></td>
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<tr>
<td>Carpinus orientalis</td>
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<td><em>Ostrya-type</em></td>
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<tr>
<td>Fagus orientalis</td>
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<td><em>Fagus</em></td>
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<tr>
<td>Quercus iberica</td>
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<td><em>Quercus</em></td>
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<td>Juglans regia*</td>
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<td><em>Juglans</em></td>
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<td>Fraxinus excelsior</td>
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<td><em>Fraxinus</em></td>
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<td>Ligustrum vulgare</td>
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<td><em>Ligustrum</em></td>
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<td>Pinus kochiana*</td>
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<td><em>Pinus</em></td>
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<tr>
<td>Malus domestica*</td>
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<tr>
<td>Malus orientalis</td>
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<td>Prunus spinosa</td>
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<td>Rosa canina</td>
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<tr>
<td>Rubus caesius</td>
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<td><em>Rubus-type</em></td>
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<tr>
<td>Populus canadenstis*</td>
<td></td>
<td></td>
<td></td>
<td><em>Populus</em></td>
</tr>
</tbody>
</table>

Herbaceous plants:

| Ailisma arcuatum |         |        |          |                         |
| Crepis micrantha |         |        |          | *Cichorium-type*        |
| Senecio vernalis |         |        |          | *Aster-type*            |
| Lappula barbata  |         |        |          |                         |
| Hesperis matronalis |     |        |          | *Brassicaceae undiff.*  |
| Campanula collina|         |        |          | Campanula               |
| Silene viscosa    |         |        |          |                         |
| Eupatorium helioscosia | |        |          |                         |
| Astragalus victorius |      |        |          |                         |
| Onobrychis transcaucasica | |        |          |                         |
| Scutellaria galericulata | |        |          | *Lamiaceae undiff.*    |
| Aegilops cylindrica|         |        |          | Poaceae undiff.         |
| Bromopsis riparia |         |        |          | Poaceae undiff.         |
| Koeleria cristata |         |        |          | Poaceae undiff.         |
| Melica picata     |         |        |          | Poaceae undiff.         |
| Melica taurica    |         |        |          | Poaceae undiff.         |
| Nardus krausei    |         |        |          | Poaceae undiff.         |
| Rumex acetosella  |         |        |          | Rumex                   |
| Asplenium trichomanes |     |        |          | *Polypodiaceae undiff.* |
| Polypodium vulgare |         |        |          | *Polypodiaceae undiff.* |
| Polystichum braunii|         |        |          | *Polypodiaceae undiff.* |
| Trollus ranunculatus |      |        |          |                         |
| Geum urbanum      |         |        |          |                         |
| Asperula arvensis |         |        |          | *Galiun-type*           |
| Digitalis ferruginea |      |        |          |                         |
| Veronica jacquinii|         |        |          |                         |
| Veronica serpyllifolia |     |        |          |                         |
| Hyoscyamus niger  |         |        |          |                         |

Wetland plants:

| Carex vesicaria |         |        |          | *Cyperacea undiff.*     |
| Phragmites australis |     |        |          | Poaceae undiff.         |
| Typha latifolia  |         |        |          | Typha                   |
Figure 4.12. A cow grazing on sedges (*Carex vesicaria*) at the edge of Tsavkisi Wetland (July 2005).

Figure 4.13. Dr Henrikh Avakov poses beside an oak (*Quercus iberica*) at Lake Cherepanov, Southern Georgia. Oak trees in the background can be distinguished by colour – the oaks appear olive green because their leaves were just appearing (May 2002), while other trees (*Carpinus betulus*, *Pyrus caucasica* etc.) were already in full leaf.
Lake Cherepanov

Lake Cherepanov is a small lake situated in the Nadarbazevi Basin, approximately 8 km WNW of the township of Tetri Tsqaro (Figure 4.13; Figure 3.2). The relief here is muted on account of the basin’s volcanic origin. Both Cainozoic and Plio-Pleistocene basalts occur in the lake’s catchment (Maruashvili, 1971) and a small-scale quarry operates near the south side of the lake. The basalt was previously mined in the Mediaeval Period for the construction Queen Tamar’s summer residence, now ruined (Figure 4.14). The water depth in the sections of open water was only 1-2 m; numerous dams and dykes have been built to artificially elevate the water level, which fluctuates from year to year (Dr Eristo Kvavadze, Zoological Institute, Georgian Academy of Sciences, pers. comm.).

Lake Cherepanov is located in the forest belt proper. *Quercus iberica* and *Carpinus betulus* are the most common forest trees, with an understorey of rosaceous shrubs (Table 4.4; Figure 4.15). In this part of Georgia, wild pears (*Pyrus caucasica*) often form part of the forest canopy or occur solitary in park-like landscapes (Ketskhoveli, 1959). Small fragments of pure beech forest (*Fagus orientalis*) are found on moist, north-facing slopes. Another feature of this region is the occurrence
of polydominant forests, in which, along with the above species, Acer campestre, A. laetum, Carpinus orientalis, Cerasus avium, Crataegus curvisepala, C. pentagyna, Fraxinus excelsior, Pyrus caucasica, Ulmus glabra and other trees are admixed more-or-less equally. In clearings, such as the lake terrace of Lake Cherepanov (Figure 4.13), meadow vegetation occurs, dominated by Agrostis planifolia and other grasses. Lake Cherepanov’s wetland has extensive stands of Phragmites australis, Typha latifolia and Carex vesicaria, whilst Nymphaea candida, Potamogeton lucens and Lemna trisulca grow in the water itself.

Figure 4.15. Belt transect survey through the forest beside Lake Cherepanov. The large Fagus orientalis was the only beech tree observed in the vicinity and appears be an old field pollard. South-facing slope.
Table 4.4. Comparison of plant community composition and pollen spectra at Lake Cherepanov. Pollen samples from lake sediments (‘% pollen’), moss polsters (‘% moss’) and soil samples (‘% soil’). See Table 4.2 for further explanation and legend.

<table>
<thead>
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<th>Trees and shrubs:</th>
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<th>% pollen</th>
<th>% moss</th>
<th>% soil</th>
<th>Pollen type represented</th>
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<td>Rosa canina</td>
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<td>Pedicularis comosa</td>
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<tr>
<td>Veronica beccabunga</td>
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<thead>
<tr>
<th>Wetland plants:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carex vesicaria</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cyperaceae undiff.</td>
</tr>
<tr>
<td>Phragmites australis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Poaceae undiff.</td>
</tr>
<tr>
<td>Typha latifolia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Typha</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aquatic plants:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lemna trisulca</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Nymphaea candida</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Potamogeton lucens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Potamogeton-type</td>
</tr>
</tbody>
</table>

Table 4.4 shows the relationship between vegetation composition and the pollen spectra from Lake Cherepanov, moss polsters from the oak forest floor and soil samples from the same forest. Rosaceae are all but absent in all three pollen spectra even though they are very important in the vegetation. Pollen spectra from lake sediments are dominated by Poaceae and Quercus (arboreal pollen: 35%), the moss polsters by Quercus, Carpinus betulus and Pinus (AP: 67%), and the soil samples by
Pinus, Chenopodiaceae and Quercus (AP: 43%). These significant differences in pollen composition highlight the difficulties in using soil samples and moss polsters as modern analogues for pollen records based on lake sediments.

**Trialeti Wetland**

Trialeti Wetland is located 1 km south of the town of the same name on what is known to geomorphologists as the Chochiani Plateau. The Plateau is composed of Upper Pliocene andesite-basalts and is punctuated by a number of small, shallow lake basins. These depressions are thought to have formed at the same time as the lava flows through the subsidence of the underlying rocks (Maruashvili, 1971).

The wetland is approximately 300 metres in diameter with a water depth of around 1 metre (Figure 4.16). It is situated on a residual andesite-basalt cap directly above the Khrami River Canyon and the Chochiani Gorge. The steep slopes of the river gorges are densely forested, while the basalt plateau is treeless. This site is where the narrow forest belt of Southern Georgia yields to extensive mountain grasslands. On the southern slope immediately adjacent the wetland is an oak forest of *Quercus macranthera* and *Q. iberica* (Figure 4.17). On the northern slope is a secondary woodland dominated by *Corylus avellana*, *Carpinus betulus* and *Fraxinus excelsior* (Figure 4.18). Grassy steppic meadows prevail to the west and around the lake, which is vegetated with *Phragmites australis*, *Equisetum palustre*, *Juncus articulatus* and *Potamogeton nodosus*.

Arboreal pollen is poorly represented in the surface sediments from this site, masked by overwhelming proportions of Poaceae (Table 4.5). *Corylus* is particularly under-represented, even though dominant in the secondary woodland canopy. Grasses and herbs are much better represented palynologically than the trees. This could be a source-area effect related to the small size of Trialeti Wetland, or over-representation due to the abundance of Poaceae in the wetland flora. It is also possible that the site’s topography and its location at the forest margin cause tree pollen to be carried away by strong wind updraughts. Price and Moore (1984) showed that pollen spectra in steep-sided uplands were influenced by anabatic winds, and it is not uncommon for tree line situations in the Caucasus Mountains to have low arboreal pollen percentages (Kvavadze and Rukhadze, 1989) probably for this reason.
Like Lake Cherepanov, herders have attempted to manipulate the water level of Trialeti Wetland by building small dams around it, perhaps to encourage sedges for cattle. The wetland vegetation has been burnt in the past, leaving a few hummocks of the former peat surface protruding from the water. Charred particles are thus well represented in samples from this site.

Figure 4.16. Trialeti Wetland at the oak forest border. Boulders of andesite-basalt visible in the foreground; the forested slopes of the Chochiani Gorge and snow-capped mountains the Javakheti Range are seen in the background (May 2002).
Figure 4.17. Belt transect through oak woodlands on the side of the Chochiani Gorge, near Trialeti Wetland. South-facing slope.

Figure 4.18. Belt transect through secondary woodlands on the edge of the Khrami Canyon, near Trialeti Wetland. North-facing slope.
### Table 4.5.
Comparison of plant community composition and pollen spectra at Trialeti Wetland. Cover abundance and pollen spectra from lake sediments (‘% pollen’) and moss polsters from a mixed deciduous forest (‘% moss 1’) and a *Fagus*-dominated forest (‘% moss 2’) in the nearby Khrami Canyon are compared. See Table 4.2 for legend.

<table>
<thead>
<tr>
<th>Trees and shrubs:</th>
<th>% cover</th>
<th>% pollen</th>
<th>% moss 1</th>
<th>% moss 2</th>
<th>Pollen type represented</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Lonicera caucasica</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Lonicera steveniana</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Carpinus betulus</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><em>Carpinus betulus</em></td>
</tr>
<tr>
<td><em>Carpinus orientalis</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><em>Ostrya</em>-type</td>
</tr>
<tr>
<td><em>Corylus avellana</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><em>Corylus</em></td>
</tr>
<tr>
<td><em>Corylus colurna</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><em>Corylus</em></td>
</tr>
<tr>
<td><em>Quercus iberica</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><em>Quercus</em></td>
</tr>
<tr>
<td><em>Quercus macranthera</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><em>Quercus</em></td>
</tr>
<tr>
<td><em>Fagus orientalis</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><em>Fagus</em></td>
</tr>
<tr>
<td><em>Fraxinus excelsior</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><em>Fraxinus</em></td>
</tr>
<tr>
<td><em>Rhamnus catharticus</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Crataegus curvistipula</em></td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td><em>Rosa canina</em></td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td><em>Sorbus boissierii</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><em>Sorbus</em>-type</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Herbaceous plants:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sonchus palustris</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Pulmonaria dactica</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Capsella bursa-pastoris</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Scleranthus annuus</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Marrubium goktschaicum</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Phlomis pungens</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Asphodeline lutea</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Polygonatum verticillatum</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Alopecurus sericeus</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Bromopsis riparia</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Dryopteris filix-mas</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Trollius ranunculinus</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Alchemilla valdehirsuta</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Asperula taurina</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Veronica arvensis</em></td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wetland plants:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Equisetum palustre</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Juncus articulatus</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Phragmites australis</em></td>
<td>-</td>
</tr>
<tr>
<td><em>Potamogeton nodosus</em></td>
<td>-</td>
</tr>
</tbody>
</table>

**Lake Imera**

Lake Imera is situated on the Tsalka Plateau at an elevation of 1610 m. It occupies a small synclinal depression in Plio-Pleistocene basalt, andesite and dolerite substrate, formed more recently than Trialeti Wetland, but in much the same way (Maruashvili, 1971). The 12-hectare lake has a closed basin and is quite shallow. Its water depth depends heavily on atmospheric precipitation: in May 2002, after a dry spell, the water depth at the coring site (Figure 4.19) was 0.5 m, while in August 2003 it was over 2 metres, dropping to 1.5 m a month later. Villagers observed that the lake level was often low in spring and early summer, but was usually full by mid-summer.
Figure 4.19. Map of Lake Imera, Tsalka Plateau, showing major wetland vegetation units. Coring location is shown by a star. Map constructed by GPS-referenced ground survey.

Figure 4.20. Photograph from the edge of Lake Imera looking northward. The light-coloured plants in the very foreground are *Calamagrostis neglecta*, followed by the lake’s floating sedge mat, and areas of open water colonised by *Nymphaea candida* (May 2002).
Table 4.6. Comparison of plant community composition and pollen spectra at Lake Imera.

<table>
<thead>
<tr>
<th>Herbaceous plants:</th>
<th>% cover</th>
<th>% pollen</th>
<th>Pollen type represented</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Achillea setacea</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Arctium lappa</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Centaurea salicifolia</em></td>
<td></td>
<td></td>
<td><em>Centaurea</em></td>
</tr>
<tr>
<td><em>Cichorium intybus</em></td>
<td></td>
<td></td>
<td><em>Cichorium</em>-type</td>
</tr>
<tr>
<td><em>Grossheimia macrocephala</em></td>
<td></td>
<td></td>
<td><em>Centaurea phrygia</em>-type</td>
</tr>
<tr>
<td><em>Inula aspera</em></td>
<td></td>
<td></td>
<td><em>Aster</em>-type</td>
</tr>
<tr>
<td><em>Taraxacum pratense</em></td>
<td></td>
<td></td>
<td><em>Cichorium</em>-type</td>
</tr>
<tr>
<td><em>Anchusa gmelenii</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Capsella bursa-pastoris</em></td>
<td></td>
<td></td>
<td><em>Horium</em>-type</td>
</tr>
<tr>
<td><em>Clypeola jonchlaspi</em></td>
<td></td>
<td></td>
<td>Brassicaceae undiff.</td>
</tr>
<tr>
<td><em>Erophila verna</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Scleranthus annuus</em></td>
<td></td>
<td></td>
<td>Caryophyllaceae undiff.</td>
</tr>
<tr>
<td><em>Cephalaria gigantea</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Euphorbia villosa</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Trifolium pratense</em></td>
<td></td>
<td></td>
<td><em>Trifolium</em>-type</td>
</tr>
<tr>
<td><em>Vicia purpurea</em></td>
<td></td>
<td></td>
<td>Fabaceae undiff.</td>
</tr>
<tr>
<td><em>Vicia variabilis</em></td>
<td></td>
<td></td>
<td>Fabaceae undiff.</td>
</tr>
<tr>
<td><em>Gentiana gelida</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Agrostis planifolia</em></td>
<td></td>
<td></td>
<td>Poaceae undiff.</td>
</tr>
<tr>
<td><em>Phleum phleoides</em></td>
<td></td>
<td></td>
<td>Poaceae undiff.</td>
</tr>
<tr>
<td><em>Phleum pratense</em></td>
<td></td>
<td></td>
<td>Poaceae undiff.</td>
</tr>
<tr>
<td><em>Dactylis glomerata</em></td>
<td></td>
<td></td>
<td>Poaceae undiff.</td>
</tr>
<tr>
<td><em>Deschampsia parviflora</em></td>
<td></td>
<td></td>
<td>Poaceae undiff.</td>
</tr>
<tr>
<td><em>Poa pratensis</em></td>
<td></td>
<td></td>
<td>Poaceae undiff.</td>
</tr>
<tr>
<td><em>Alopecurus aequalis</em></td>
<td></td>
<td></td>
<td>Poaceae undiff.</td>
</tr>
<tr>
<td><em>Polygala transcaucasia</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Botrychium matricarioides</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rumex acetosella</em></td>
<td></td>
<td></td>
<td>Rumex</td>
</tr>
<tr>
<td><em>Trollius ranunculinus</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Alchemilla erythropoda</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sanguisorba officinalis</em></td>
<td></td>
<td></td>
<td><em>S. officinalis</em></td>
</tr>
<tr>
<td><em>Asperula Caucasica</em></td>
<td></td>
<td></td>
<td><em>Galium</em>-type</td>
</tr>
<tr>
<td><em>Galega officinalis</em></td>
<td></td>
<td></td>
<td><em>Galium</em>-type</td>
</tr>
<tr>
<td><em>Rhaphiolepis indica</em></td>
<td></td>
<td></td>
<td><em>Galium</em>-type</td>
</tr>
<tr>
<td><em>Digitalis ferruginea</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pedicularis comosa</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pedicularis condensata</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rynchospora arvensis</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Veronica anagallis-aquatica</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Viola montana</em></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Wetland plants:

| *Alismoides plantago-aquatica* |          |          |                         |
| *Sagittaria sagittifolia*      |          |          |                         |
| *Carex dichroandra*            |          |          | *Cyperaceae* undiff.    |
| *Scirpus lacustris*            |          |          | *Cyperaceae* undiff.    |
| *Carex vesicaria*              |          |          | *Cyperaceae* undiff.    |
| *Juncus pannonicus*            |          |          | *Cyperaceae* undiff.    |
| *Juncus effusus*               |          |          |                         |
| *Mentha arvensis*              |          |          | *Mentha*-type           |
| *Stachys palustris*            |          |          | Lamiaceae undiff.       |
| *Epilobium hirsutum*           |          |          |                         |
| *Phragmites australis*         |          |          | Poaceae undiff.         |
| *Scolochloa festuacea*         |          |          | Poaceae undiff.         |
| *Calamagrostis neglecta*       |          |          | Poaceae undiff.         |
| *Poa palustris*                |          |          | Poaceae undiff.         |
| *Typha latifolia*              |          |          | *Typha*                 |

Aquatic plants:

| *Myriophyllum spicatum*        |          |          | *Myriophyllum*          |
| *Nymphaea candida*             |          |          | *Nymphaea alba*-type    |
| *Polygonum amphibium*          |          |          | *P. amphibium*          |
| *Potamogeton gramineus*        |          |          | *Potamogeton*-type      |
| *Potamogeton lucens*           |          |          | *Potamogeton*-type      |
| *Potamogeton natans*           |          |          | *Potamogeton*-type      |
| *Sparganium minimum*           |          |          | *Sparganium*            |
| *Sparganium neglectum*         |          |          | *Sparganium*            |
The lake has a distinct wave-cut terrace on its eastern side, positioned about 2 metres above the wetland’s floating sedge mat (Figure 4.20). Behind the terrace is a low, rounded, lunette-like feature composed of fine sediments that may have been built by deflation of the wetland sediments during low lake level phases.

The vegetation of the Tsalka Plateau is treeless mountain steppe. Although situated above the present tree line, these grasslands are not regarded as truly subalpine (Nakhutsrishvili, 1999). Ketskhoveli (1959) argues that these plains were once forested. Their characteristic species are Stipa tirs, Festuca valesiaca, F. ovina, Falcaria vulgaris, Filipendula vulgaris and others (Ketskhoveli, 1959). Around Lake Imera, the dominant grassland species are Agrostis planifolia (60-70%), Phleum phleoides (40-50%) and P. pratense. Many other species were encountered in the survey, and are listed in Table 4.6. Most of the plants are represented in pollen spectra, with the exception of some of the insect-pollinated herbs, such as Polygala, Cephalaria, Gentiana and the various Scrophulariaceae.

Large numbers of Poaceae in the wetland flora of Imera Lake (Scolochloa festucacea, Phragmites australis, Calamagrostis neglecta, Poa palustris) present a special problem for interpretation of fossil pollen spectra. Grasses are dominant in both the wetland and the mountain steppes that surround it. Any change in either steppe or wetland vegetation will affect Poaceae pollen percentages, so interpretation of landscape openness in the fossil context must rest on other subalpine herbs and forbs.

Pinus is the most abundant arboreal pollen type encountered in surface sediments from Lake Imera. The nearest sources of Pinus pollen are pine plantations established in the 1950s approximately 3 km from the site. Most of the pine pollen, however, must come from more extensive forests bordering the Tsalka Plateau. The same is true of taxa such as Pterocarya, Buxus, Olea europaea, Zelkova, Pistacia and Picea, which do not currently occur on the Plateau, but are nevertheless represented in pollen spectra. Quercus, Fagus, Carpinus, Corylus and Betula do grow on the Plateau, but have such a restricted distribution there that much of their pollen must also be carried by the wind from more extensive forests at lower altitudes.
Figure 4.21. Lake Bareti on the Tsalka Plateau. In the foreground (beneath the fishing boat) is *Equisetum palustre*, while the brown reeds in the middle ground are *Phragmites australis*. The rounded hill to the left is Mt Elibaba and the snow-capped peaks in the background are part of the Trialeti Range.

Figure 4.22. Avchalagöl Mire on the Javakheti Plateau, looking southwards. The darker areas on the wetland surface are fire scars. The fearsome Caucasian Sheepdog in the foreground proved to be friendly, and his owner, an Armenian shepherd, told how the wetland had been burnt the previous October (Photo: May 2002).
Lake Bareti

Lake Bareti (or Bashkoi) is situated only 3 km WNW of Imera Lake in a synclinal depression (Maruashvili, 1971). The terrain here is also Plio-Pleistocene volcanics, but is slightly hillier on account of E-W anticlinal ridges running north and south of the lake (Mt Bareti and Mt Elibaba). Lake Bareti is a freshwater lake of moderate size, approximately 1300 m in diameter with a water depth of 1.5 metres (Figure 4.21).

Lake Bareti is surrounded by mountain steppic grassland vegetation, similar in composition to the Lake Imera flora (Table 4.6). Wetland vegetation at Lake Bareti is also diverse. Areas of open water are populated by *Myriophyllum* and *Potamogeton* spp. A thick sward of *Phragmites australis* borders the open water. Between the *Phragmites* beds and the lake shoreline grow various associations of *Sparganium, Typha, Phragmites, Carex, Scirpus, Equisetum*, wet meadow plants and a few *Salix caprea* shrubs. Not surprisingly, the pollen spectra of Lake Bareti are very similar to those from Lake Imera (Figure 4.3). *Pinus* pollen percentages are slightly higher, perhaps because of the pine plantation nearby on the slopes of Mt Bareti. The basin’s larger pollen source area could also account for this difference. Again, the diversity of grasses in the wetland and grassland flora makes interpretation of Poaceae pollen difficult.

Avchalagöl Mire

Avchalagöl is situated on the Javakheti Plateau at the foot of Mt Patara Abuli (2800 m), the southernmost volcanic cone in the Samsari Range. The mire is large (1.25 km across) and occupies a basin impounded by Upper Pliocene andesite-basalt hills. Despite such extensive vulcanism, the mire is situated in a graben that runs from Avchalagöl through Lake Saghamo to Lake Madatapa in the south, so a tectonic genesis cannot be discounted.

The mire is vegetated with sedges growing in small hummocks, except for small sections of open water. Its surrounds are steppic grasslands, with a few shrubs growing on steep, rocky slopes on the north side of the basin. These shrubs include *Viburnum lantana, Rosa spinossisima* and *Rubus*, species most often associated with deciduous woodlands (Ketskhoveli, 1959). Recent pine plantations also occur nearby.
Pinus and Poaceae dominate pollen spectra from this site. Arboreal pollen percentages are higher in samples from this site than at any of the sites described above, despite the nearest forests being some 50 kilometres away.

The Avchalagöl sediments are exceedingly rich in charred particles. A significant area of this shallow, Carex-dominated wetland appeared burnt in late 2001 (Figure 4.22). A local shepherd told of how the entire landscape of this area, including the wetland and surrounding slopes, had been burnt the previous October. This is an annual event, he said, deliberately lit by herders to boost spring grass growth when flocks and herds return to the highland pastures. High charcoal concentrations in sediments are therefore a good indication of local fires.
Other sites

Several other sites were added to the original eight: Lake Patara Gldani on the outskirts of Tbilisi, Lake Jvari near the old Georgian capital of Mtskheta, Chili Lake in the oak-forested mountains south of Mtskheta, Lake Aligol on the western part of the Tsalka Plateau, and the Khachalgori Wetlands on the Javakheti Range (Table 4.7; Figure 4.23).

Data from these sites are given in Figure 4.24 and will be used to test the statistical model developed in a later section.

Table 4.7. Additional site locations and associated environmental variables. See text for an explanation of forest area calculations. Type: L- lake site, W- wetland site. Sites marked with an asterisk (*) are discussed in greater detail in subsequent chapters.

<table>
<thead>
<tr>
<th>Site code</th>
<th>Site name</th>
<th>Type</th>
<th>Location (Lat.; Long.)</th>
<th>Elevation (m a.s.l.)</th>
<th>Basin avg. radius (m)</th>
<th>Forest area (%)</th>
<th>Vegetation type</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG</td>
<td>Patara Gldani</td>
<td>W/L</td>
<td>41°48'N; 44°50'E</td>
<td>535</td>
<td>100</td>
<td>5</td>
<td>Agricultural land</td>
</tr>
<tr>
<td>JV</td>
<td>Jvari*</td>
<td>L</td>
<td>41°50'N; 44°44'E</td>
<td>570</td>
<td>100</td>
<td>50</td>
<td>Xerophyte scrub</td>
</tr>
<tr>
<td>CHI</td>
<td>Chili</td>
<td>L/W</td>
<td>41°48'N; 44°40'E</td>
<td>1120</td>
<td>150</td>
<td>90</td>
<td>Oak forest</td>
</tr>
<tr>
<td>AL</td>
<td>Aligol*</td>
<td>L/W</td>
<td>41°38'N; 44°01'E</td>
<td>1540</td>
<td>100</td>
<td>1</td>
<td>Mountain grassland</td>
</tr>
<tr>
<td>KH</td>
<td>Khachalgori</td>
<td>W</td>
<td>41°18'N; 43°56'E</td>
<td>2650</td>
<td>20</td>
<td>0</td>
<td>Mountain grassland</td>
</tr>
</tbody>
</table>

Figure 4.23. Locations of additional study sites (in black). See Table 4.7 for site names. Vegetation units are the same as those in Figure 4.2.
Figure 4.24 (A). Percentage arboreal pollen data from the additional sites listed in Table 4.7, shown in relation to the altitudinal gradient from Figure 4.3. See Appendix E for the complete data-set.
Figure 4.24 (B). Percentages of non-arboreal pollen and charcoal concentrations from additional sites listed in Table 4.7. Taxa displayed are the same as those in Figure 4.3.

Pollen representation

The relationship between the vegetation and pollen spectra of the study sites (Tables 4.2-4.6, above) permits some discussion of the different pollen productivities of various plants. According to these data, Pinus and Quercus are abundant pollen producers and are always well represented in pollen spectra. Pinus pollen, because of its aerodynamic characteristics, is transported far from source trees so that it is dominant in treeless environments. Fagus and Carpinus betulus are moderate pollen producers, occurring in all spectra but in subordinate abundance to Pinus and
Quercus, a reflection of their subordinate role in the forest vegetation of the transect. Carpinus orientalis and Corylus appear to be poor pollen producers, and Fraxinus and the various Rosaceae are very poor (Figure 4.25). These observations are in accord with the representation factors calculated by Andersen (1970).

The pollen representation of herbaceous plants seems to depend largely on their pollination strategy. Wind-pollinated genera, such as the Poaceae, Brassicaceae and Polypodiaceae, are well-represented, whereas insect-pollinated Scrophulariaceae, Boraginaceae, Caryophyllaceae and Fabaceae are generally under-represented. Others, including the Chenopodiaceae, Plantaginaceae and Polygonaceae, are clearly over-represented, occurring in all pollen spectra but in few vegetation surveys.

Since the use of the arboreal to non-arboreal pollen (AP:NAP) ratio is unsuitable for differentiating forested from open vegetation types in this study, the ‘background’ pollen level must be estimated (cf. Sugita et al., 1999). This is illustrated in Figure 4.26, which shows proportions of selected tree pollen along the altitudinal transect. In general, Pinus pollen comprises up to 35% of the arboreal pollen sum even when it is absent from the extra-local vegetation, 35-50% when it occurs nearby, and over 50% when present and locally abundant. In treeless environments outside the forest belt, however, Pinus percentages may be elevated above 50% by long-distance pollen transport.

Figure 4.25. Comparison of tree cover abundance versus pollen percentages at Lake Cherepanov and Trialeti Wetland.
Further difficulties arise deriving similar thresholds for *Quercus*, *Fagus*, *Carpinus betulus*, *Ostrya*-type, *Corylus* and *Juniperus*. When oaks are present in the surrounding vegetation, *Quercus* pollen percentages vary between 5 and 50%, but in the forest belt proper the figure is consistently above 15%. It can be seen from Figure 4.26 that the relationship between source plants and pollen percentages is exceedingly complex. This pattern perhaps suggests that pollen production is influenced by factors other than the proximity and abundance of source plants in the surrounding vegetation. Factors such as pollen aerodynamics, the velocity and direction of wind, local variations in the vegetation mosaic, the pollen source area of individual study sites and even the use of percentage calculations themselves can all influence pollen percentages.
Pollen production is another factor that may vary in relation to environmental gradients. Different species of plants have “unique ecological responses to the multivariate environment” (Jackson and Williams, 2004, p. 522), pollen production being one such response. In Figure 4.26, for instance, *Quercus* constitutes less of the tree pollen percentage at the upper and lower limits of its distribution. At the lower tree line, *Quercus* percentages are diluted by *Pinus* and *Juniperus* pollen, even though pine and juniper trees are considerably less abundant in the vegetation here than *Quercus iberica*. A similar *Quercus* dilution occurs at the upper tree line where *Quercus macranthera* trees grow. As a second example, *Ostrya*-type pollen appears to be almost inversely related to the occurrence of its source (*Carpinus orientalis*) in the vegetation. *Carpinus orientalis* trees are co-dominants at the lower tree line, but the pollen data reflect this very poorly (Figure 4.26). Some other factor apart from vegetation cover abundance is influencing pollen representation in the study area; it is possible that individual species’ pollen productivity and cover abundance respond to climatic gradients in slightly different ways.

The foregoing shows that pollen representation is influenced by pollination strategies, vegetation cover abundance and environmental gradients. The latter stands as an impediment to determining the background pollen level, since this level changes according to environmental factors. Multivariate numerical analyses may be more useful than simple pollen thresholds in determining which environmental gradients have the greatest bearing on pollen data.

**Numerical analyses**

**Classification**

In a recent paper, Connor *et al.* (2004) presented an analysis of the pollen data from the eight original sites. TWINSPAN was used to classify the data into two main groups – a semidesert-steppe group and a forest-upland group – on the basis of the greater abundance of *Pinus* and *Quercus* pollen in forest and upland spectra. The forest and upland group could be further subdivided into ‘subalpine’, ‘treeline’, ‘oak forest’ and ‘forest-steppe’ classes since *Picea* pollen is most prevalent (on this transect) in treeless grasslands, *Cerealia*-type pollen in mixed oak forest, and Chenopodiaceae pollen at the border between forest and steppe (Connor *et al.*, 2004). Because each
TWINSPLAN division is based on the presence and abundance of these indicator species, it is possible to use them to classify samples that were not included in the original analysis, and in doing so, test the original classification.

Samples from Lake Kumisi, Lake Patara Gldani, Lake Jvari, Chili Lake, Tsavkisi Wetland, Lake Bareti, Lake Aligol and Khachalgora Wetlands (Figure 4.23) were classified according to the TWINSPLAN classification shown in Figure 4.3 and the accompanying indicators in Table 4.8. The results are shown in Table 4.9.

Table 4.8. Positive ‘perfect’ indicators for TWINSPLAN groups in Figure 4.3. Each indicator occurs in that group at the stipulated level. Groups not listed have no indicators.

<table>
<thead>
<tr>
<th>Group hierarchy</th>
<th>Vegetation (inferred)</th>
<th>TWINSPLAN indicators and cut levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Forest and upland</td>
<td>Quercus 1%; Pinus 2-3%</td>
</tr>
<tr>
<td>5</td>
<td>Steppe-forest</td>
<td>Chenopodiaceae 10%; Populus (presence)</td>
</tr>
<tr>
<td>6</td>
<td>Lowland steppe</td>
<td>Artemisia 2%; Aster-t. 0.5%; Lamiaceae 2%; Juglans (presence)</td>
</tr>
<tr>
<td>7</td>
<td>Semidesert-steppe</td>
<td>Polygonaceae 1.5%</td>
</tr>
<tr>
<td>8</td>
<td>Subalpine (burnt)</td>
<td>Fraxinus 2%</td>
</tr>
<tr>
<td>9</td>
<td>Subalpine and forest</td>
<td>Ranunculus (presence)</td>
</tr>
<tr>
<td>11</td>
<td>Steppe-forest</td>
<td>Cedrus (presence); Pinus 5%; Picea 0.5%; Poaceae 10%; Plantago lanceolata-t. 0-1%</td>
</tr>
<tr>
<td>18</td>
<td>Subalpine steppe</td>
<td>Picea 1.5%</td>
</tr>
<tr>
<td>37</td>
<td>Subalpine steppe</td>
<td>Fagus 5%; Quercus 5%; Carpinus betulus 5%</td>
</tr>
<tr>
<td>38</td>
<td>Upper tree line</td>
<td>Polygonum aviculare-t. 0-1%; Hornungia-t. (presence)</td>
</tr>
<tr>
<td>39</td>
<td>Oak forest</td>
<td>Cerealia-t. 2%</td>
</tr>
</tbody>
</table>

Table 4.9. Classification of additional surface pollen spectra using the TWINSPLAN indicators presented in Table 4.8 and the groups in Figure 4.3. Sample names followed by a zero are core-top samples from the initial group of sites.

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Actual vegetation</th>
<th>TWINSPLAN group (No.)</th>
<th>Goodness-of-fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kumisi 0</td>
<td>Semidesert-steppe</td>
<td>‘Forest-steppe’ (10)</td>
<td>+</td>
</tr>
<tr>
<td>Patara Gldani</td>
<td>Lowland agricultural</td>
<td>‘Forest-steppe’ (10)</td>
<td>++</td>
</tr>
<tr>
<td>Jvari 0</td>
<td>Oak-xerophyte scrub</td>
<td>None – poor fit</td>
<td>–</td>
</tr>
<tr>
<td>Jvari 1</td>
<td>Oak-xerophyte scrub</td>
<td>‘Forest-steppe’ (10)</td>
<td>+++</td>
</tr>
<tr>
<td>Chili 1</td>
<td>Oak forest</td>
<td>‘Upper tree line’ (38)</td>
<td>–</td>
</tr>
<tr>
<td>Chili 2</td>
<td>Oak forest</td>
<td>‘Forest-steppe’ (10/11)</td>
<td>–</td>
</tr>
<tr>
<td>Chili 3</td>
<td>Oak forest</td>
<td>‘Upper tree line’ (38)</td>
<td>–</td>
</tr>
<tr>
<td>Tsavkisi 0</td>
<td>Forest-steppe</td>
<td>‘Forest-steppe’ (11)</td>
<td>+++</td>
</tr>
<tr>
<td>Bareti 0</td>
<td>Mountain grassland</td>
<td>‘Forest-steppe’ (11)</td>
<td>–</td>
</tr>
<tr>
<td>Aligol 1</td>
<td>Mountain grassland</td>
<td>‘Subalpine steppe’ (36)</td>
<td>+++</td>
</tr>
<tr>
<td>Aligol 2</td>
<td>Mountain grassland</td>
<td>‘Upper tree line’ (38)</td>
<td>–</td>
</tr>
<tr>
<td>Aligol 3</td>
<td>Mountain grassland</td>
<td>‘Upper tree-line’ (38)</td>
<td>–</td>
</tr>
<tr>
<td>Khachalgori 1</td>
<td>Mountain grassland</td>
<td>‘Forest-steppe’ (11)</td>
<td>–</td>
</tr>
<tr>
<td>Khachalgori 2</td>
<td>Mountain grassland</td>
<td>‘Subalpine steppe’ (36)</td>
<td>+++</td>
</tr>
<tr>
<td>Khachalgori 3</td>
<td>Mountain grassland</td>
<td>‘Forest-steppe’ (11)</td>
<td>–</td>
</tr>
<tr>
<td>Khachalgori E</td>
<td>Mountain grassland</td>
<td>‘Forest-steppe’ (11)</td>
<td>–</td>
</tr>
<tr>
<td>Khachalgori W</td>
<td>Mountain grassland</td>
<td>‘Forest-steppe’ (11)</td>
<td>–</td>
</tr>
</tbody>
</table>
Of the 17 additional samples, only 6 were correctly classified. Although the TWINSPAN classification presented in Connor et al. (2004) is consistent with biogeographical patterns, the model is susceptible to the over-representation of Poaceae pollen in some samples, no doubt due to grass species being dominant in both wetland and terrestrial vegetation at some sites (i.e. Lake Imera, Lake Bareti, Trialeti Wetland). To correct for this, Poaceae was excluded and the ordination repeated. The results are essentially the same as the previous classification (Figure 4.3), although samples from the upper tree line and mountain grasslands are intermixed (Figure 4.27). TWINSPAN indicators are also slightly different (Table 4.10) and the new result has the advantage of being simpler than the original.

When the additional samples are run through this classification, a much better fit is obtained (Table 4.11). Only two samples were incorrectly classified and both of these from lower tree line sites where the vegetation has been greatly modified by agricultural activities and the establishment of pine plantations (which, in the lowlands, mimic the effect of long-distance pollen transport in upland environments).

![New TWINSPAN classification of pollen data from the eight original sites with Poaceae excluded. Indicator species for each group are given below in Table 4.10.](image)

**Figure 4.27.** New TWINSPAN classification of pollen data from the eight original sites with Poaceae excluded. Indicator species for each group are given below in Table 4.10.

<table>
<thead>
<tr>
<th>Group hierarchy</th>
<th>Vegetation (inferred)</th>
<th>TWINSPAN indicators and cut levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Forest and upland</td>
<td><em>Pinus</em> 2%</td>
</tr>
<tr>
<td>5</td>
<td>Forest-steppe</td>
<td>Chenopodiaceae 20%</td>
</tr>
<tr>
<td>6</td>
<td><em>Artemisia</em> steppe</td>
<td><em>Artemisia</em> 2%</td>
</tr>
<tr>
<td>8</td>
<td>Mountain grassland</td>
<td><em>Pinus</em> 10% + <em>Picea</em> 2% – group 9 indicators</td>
</tr>
<tr>
<td>9</td>
<td>Grassland and forest</td>
<td><em>Plantago maritima</em>-t. 2% + <em>Cichorium</em>-t. 3% – group 8 indicators</td>
</tr>
<tr>
<td>10</td>
<td>Forest-steppe</td>
<td><em>Fagus</em> 1%</td>
</tr>
<tr>
<td>19</td>
<td>Oak forest</td>
<td><em>Quercus</em> 10%</td>
</tr>
</tbody>
</table>
Table 4.11. Classification of additional surface pollen spectra using the new TWINSPAN indicators presented in Table 4.10 and the groups in Figure 4.27.

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Actual vegetation</th>
<th>New TWINSPAN group</th>
<th>Goodness-of-fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kumisi 0</td>
<td>Semidesert-steppe</td>
<td>Semidesert-steppe +</td>
<td>+++</td>
</tr>
<tr>
<td>Patara Gldani 0</td>
<td>Agricultural/urban</td>
<td>Tree line / mountain grassland –</td>
<td>–</td>
</tr>
<tr>
<td>Jvari 0</td>
<td>Oak-xerophyte scrub</td>
<td>Oak forest</td>
<td>+</td>
</tr>
<tr>
<td>Jvari 1</td>
<td>Oak-xerophyte scrub</td>
<td>Tree line / mountain grassland –</td>
<td>–</td>
</tr>
<tr>
<td>Chili 1</td>
<td>Oak forest</td>
<td>Oak forest</td>
<td>+++</td>
</tr>
<tr>
<td>Chili 2</td>
<td>Oak forest</td>
<td>Oak forest</td>
<td>+++</td>
</tr>
<tr>
<td>Chili 3</td>
<td>Oak forest</td>
<td>Oak forest</td>
<td>+++</td>
</tr>
<tr>
<td>Tsavkisi 0</td>
<td>Forest-steppe</td>
<td>Forest-steppe</td>
<td>+++</td>
</tr>
<tr>
<td>Bareti 0</td>
<td>Mountain grassland</td>
<td>Mountain grassland</td>
<td>+++</td>
</tr>
<tr>
<td>Aligol 1</td>
<td>Mountain grassland</td>
<td>Mountain grassland</td>
<td>+++</td>
</tr>
<tr>
<td>Aligol 2</td>
<td>Mountain grassland</td>
<td>Mountain grassland</td>
<td>+++</td>
</tr>
<tr>
<td>Aligol 3</td>
<td>Mountain grassland</td>
<td>Mountain grassland</td>
<td>+++</td>
</tr>
<tr>
<td>Khachalgori 1</td>
<td>Mountain grassland</td>
<td>Tree line / mountain grassland ++</td>
<td>++</td>
</tr>
<tr>
<td>Khachalgori 2</td>
<td>Mountain grassland</td>
<td>Mountain grassland</td>
<td>+++</td>
</tr>
<tr>
<td>Khachalgori 3</td>
<td>Mountain grassland</td>
<td>Tree line / mountain grassland ++</td>
<td>++</td>
</tr>
<tr>
<td>Khachalgori E</td>
<td>Mountain grassland</td>
<td>Tree line / mountain grassland ++</td>
<td>++</td>
</tr>
<tr>
<td>Khachalgori W</td>
<td>Mountain grassland</td>
<td>Tree line / mountain grassland ++</td>
<td>++</td>
</tr>
</tbody>
</table>

This second TWINSPAN classification suggests that the various vegetation types encountered along the altitudinal transect in Southern Georgia can be differentiated with relative confidence based on palynospectra. Semidesert-steppes are differentiated from the forests and highlands by the paucity of tree pollen in their sediments. Forest-steppe at the lower tree line can be distinguished from mid-alpine forests and the treeless highlands by an abundance of Chenopodiaceae pollen. Highland sites dominated by long-distance-transported pollen have higher proportions of *Pinus* and *Picea* than sites with a more local pollen signal, including oak forests, in which *Quercus* is the dominant arboreal pollen type. Although the result differs slightly from the one presented in Connor *et al.* (2004), the major biogeographical patterns revealed by both analyses are the same.

**Environmental gradients**

Major trends in the pollen data were identified using Detrended Correspondence Analysis (DCA) and the full surface pollen data set of eight original and five additional sites. DCA assumes no direct relationship between the data and its associated environmental variables. Where there is a relationship, however, this is identified indirectly by correlation. The resulting ordination is presented in Figure 4.28 with vector lines representing correlations with a matrix of environmental variables.
The prevailing trend in the pollen data is, judging from these correlations, a rainfall gradient from the arid semidesert-steppes to the moister forests and mountains (DCA axis 1). The strongest correlation of this axis is with annual rainfall ($r^2=0.63$), followed by the AP:NAP ratio ($r^2=0.59$), longitude ($r^2=0.53$), July temperature ($r^2=0.42$), elevation, January temperature and summer rainfall ($r^2=0.3$).

The secondary trend in the data appears to be one of landscape openness (DCA axis 2). The correlation with forest cover ($r^2=0.47$) is followed by correlations with January temperature ($r^2=0.45$), July temperature ($r^2=0.38$), elevation ($r^2=0.32$), longitude ($r^2=0.26$), and summer rainfall ($r^2=0.25$). The third DCA axis (Figure 4.29) has weak negative correlations with the AP:NAP ratio ($r^2=0.28$) and annual rainfall ($r^2=0.12$). Interestingly, charcoal concentrations had little correlation with any of the measured variables, suggesting that fire occurrence may be largely independent of physical environmental factors.

These results indicate that the composition of pollen assemblages is strongly influenced by climatic factors, especially rainfall. This is hardly surprising in a semi-arid region, but it is perhaps surprising that this characteristic is so plainly revealed through pollen spectra. Responses to temperature generally follow the altitudinal trend and indicate that the forested sites have slightly warmer, drier summers than the treeless mountain grasslands, even though their annual rainfall is similar.

Of interest is the relationship between rainfall and arboreal pollen representation. In semi-arid regions such as the study area, this relationship suggests that basin morphometry, lake depth and water level variability exert a much greater influence on AP:NAP ratios than does forest cover. In fact, forest cover appears to have little relationship to AP:NAP ratios in this study.

An ecological dimension can be added to the DCA results by examining the taxa most responsible for the patterns observed. The relationships between DCA axes and pollen taxa are shown in Table 4.12. These taxa have the advantage of being relatively common types that can be expected in most samples from the study area.
Figure 4.28. DCA axes 1 and 2 biplot of sample scores (points), new TWINSPAN groups (symbols) and correlated environmental variables (vector lines). Samples are labelled by site and sample number (see Figures 4.3 and 4.24). Taxa correlations are shown at right, with TWINSPAN indicators in bold typeface. Axis units are standard deviations × 100.

Figure 4.29. DCA result, axes 2 and 3.
Table 4.12. Pollen taxa most strongly correlated with each of the DCA axes. Correlation coefficients ($r^2$) are given in parentheses.

<table>
<thead>
<tr>
<th>Axis</th>
<th>Positive Correlates</th>
<th>Negative Correlates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chenopodiaceae (0.95), Polygonum aviculare-t. (0.46), Lamiaceae (0.22)</td>
<td>Carpinus betulus (0.57), Fagus (0.29), Picea (0.28), Corylus (0.27)</td>
</tr>
<tr>
<td>2</td>
<td>Quercus (0.48), Ophioglossum (0.29), Hypericum-t. (0.28), Fraxinus (0.26)</td>
<td>Pinus (0.39), Apiaceae (0.35), Ranunculus (0.30), Rumex (0.20)</td>
</tr>
<tr>
<td>3</td>
<td>Trifolium repens-t. (0.32), Secale-t. (0.27), Oxyria-t. (0.26), Plantago major-t. (0.25)</td>
<td>Triticum-t. (0.42), Fagus (0.38), Caryophyllaceae (0.36), Ostrya-t. (0.31)</td>
</tr>
</tbody>
</table>

Consistent with the rainfall gradient identified in DCA axis 1, the taxa positively correlated with this axis are all xerophilous herbs, while negative correlates are moisture-loving trees (Table 4.12). The second axis, a gradient of forest cover, puts oaks and oak forest associates together against pines and herbs found mainly in treeless environments. The third axis is difficult to interpret, but may have something to do with local land use. Positive correlates are species often associated with heavy grazing and pasturage, while negative correlates are associated with grain agriculture (Triticum and Caryophyllaceae) and secondary woodland vegetation (Fagus and Carpinus orientalis).

Based on the strength of correlations with the first two DCA axes, it seems possible to reconstruct gradients of rainfall, temperature and forest cover from fossil data using these indicator taxa. These and TWINSPAN indicators provide the means to develop a detailed picture of past climate, vegetation and landscape openness from pollen data.

**Conclusion**

This analysis of modern pollen-vegetation relationships along an environmental gradient has shown that pollen assemblages in the study area change in accordance with broad-scale vegetation patterns. Chenopodiaceae pollen dominates in the semidesert-steppe lowlands. Pollen produced by deciduous trees (particularly Quercus) becomes important in the forest belt. And, above the tree line, Pinus and Poaceae pollen are dominant.

The relationship between vegetation and pollen is not straightforward, however. A most significant problem for interpretation is the dominance of grasses (Poaceae) in both wetland and terrestrial floras from many of the sites. Because wetland and terrestrial grasses cannot be distinguished by pollen morphology,
Poaceae pollen percentages cannot be interpreted in any meaningful way and constitute a major source of ‘noise’ in pollen data from this region. The problem could be overcome by sampling deep lakes without wetland vegetation, but this would restrict analysis to larger lake basins that are a poor source of information on local vegetation history. Neither can the Poaceae problem be resolved with reference to pollen assemblages from terrestrial soils and moss polsters; in this area these are fundamentally different to lake sediment spectra and have limited value as modern analogues.

Certain plants, because of their pollination strategy, their abundance in the vegetation and environmental factors that limit pollen production, are under-represented in pollen spectra from the study area. These include *Fraxinus*, *Corylus* and most trees that inhabit the lower tree line (*Prunus spinosa*, *Paliurus spina-christi*, *Spiraea hypericifolia*, *Carpinus orientalis*, etc.). Xerophyte scrub communities appear to be almost invisible palynologically and perhaps can be identified only by the abundance of associated taxa like *Plantago* and *Artemisia*. In addition, the pollen production of some species does not relate to their abundance in vegetation in a linear fashion. This is exemplified by *Quercus iberica* and *Carpinus orientalis*, the two dominant trees of the lower tree line (forest-steppe zone); both appear to have decreased pollen production at the lower limits of their distribution, perhaps as a physiological response to aridity.

Other pollen taxa are over-represented and these include *Pinus*, Chenopodiaceae, Plantaginaceae and Polygonaceae. All of these plants appear to have very high pollen production and dispersion. *Pinus* pollen is an indicator of treeless environments in the study area, as it is carried from lower altitudes by the wind. The same process introduces pollen of *Pterocarya*, *Buxus*, *Juglans*, *Castanea*, *Olea europaea* and others from distant sources. The presence of these pollen taxa does not necessarily indicate the presence of source plants in the surrounding vegetation.

An aim of this study was to determine whether forested and open vegetation types could be differentiated using pollen data, a question that has thus far proved difficult to answer in the mountainous Caucasus region (Kvavadze, 1993; Stuchlik and Kvavadze, 1995). The arboreal to non-arboreal pollen ratio, the traditional yardstick of landscape openness, has no relationship with forest cover in the sites and
samples studied here. In Southern Georgian lakes, the AP:NAP ratio is influenced much more by basin size, water depth and hence pollen source-area than it is by forest cover. AP:NAP ratios may therefore prove useful for reconstructing changing lake levels within particular sites.

Forest cover or landscape openness can be gauged indirectly by numerical analysis. Taxa such as Quercus, Ophioglossum, Hypericum-type and Fraxinus are characteristic of forested vegetation, whereas Pinus, Apiaceae, Ranunculus and Rumex distinguish treeless environments. Using these and other indicators, ordination scores may be calculated for new samples through weighted averaging to detect changes in forest cover from fossil pollen data. The same is true for rainfall, which is the dominant environmental gradient affecting pollen assemblages in the study area, as well as temperature and land-use, which are also identifiable palynologically. Despite pollen assemblages from this semi-arid region being subject to distortion by changing lake levels and highly localised differences in vegetation, broad-scale environmental gradients are detectable using numerical analyses that isolate a signal from background noise.

Some of the observations arising from this study may have applicability beyond the realm of Southern Georgia. For instance, the clear relationship between AP:NAP ratios and rainfall could help explain, in part, reduced AP levels during the last glacial maximum as lake levels receded in response to aridity. Likewise, the apparent reduction in some trees’ pollen production at the forest-steppe border suggests that different species respond to environmental gradients by varying pollen production, a factor that may be responsible for no-analogue pollen spectra in late glacial-aged lake deposits around the world.
CHAPTER FIVE
THE TBILISI AREA

Introduction

With a knowledge of the relationship between Southern Georgia’s present-day vegetation and the pollen produced by it, the following chapters move to the question of vegetation history and apply the knowledge gained in the previous chapter to the analysis of fossil pollen preserved in lake deposits. The results are grouped into three geographic areas: the Tbilisi area, the Tsalka Plateau, and the Black Sea coast. It is the first of these that is presented here.

Tbilisi is nowadays surrounded by cultural landscapes. Like most major cities in Western Asia, its vegetation has been strongly modified by past human activities. Yet the Georgian capital differs from many others in retaining considerable tracts of forest in its immediate surrounds. The city itself is located on the very border of forest and steppe, and thus its vegetation reflects not only human influences, but also climatic ones. Because variations in the position of the lower tree line can be traced using pollen analysis, the Tbilisi area provides an opportunity to examine these changes in the light of past climatic fluctuations and a long, well-documented, socio-economic history.

The lost forests of Tbilisi

It is widely believed that Tbilisi was surrounded almost entirely by forests up until the 19th century. Various botanists have concluded that these original forests were of beech (Sosnovskii, 1915) or oak (Ketskhoveli, 1959), although the available historical evidence for this is fragmentary and often ambiguous. When Tbilisi was founded as the Georgian capital, King Vakhtang Gorgasali was out hunting pheasants, which, being birds of the forest, seem to indicate that Tbilisi was a forest in the sixth century AD (Ketskhoveli, 1959; Sosnovskii, 1915). Curiously, though, the same king soon issued an edict for his subjects to quit the city and flee to the distant forests of Kakheti:
“He dispatched heralds so that they might abandon the
villages and cities which were not fortified and flee to
the people of the Caucasus and Kakheti, because
Kakheti was forested and was impenetrable by
enemies.” (Thomson, 1996, p. 219)

Had Tbilisi’s forests vanished in the few years since the city’s establishment?

Georgia’s 18\textsuperscript{th} century geographer, Prince Vakhushti Bagrationi, describes
places around the city good for hunting, taken by some to signify a forested landscape
(Sosnovskii, 1915). But Vakhushti never once mentions the word ‘forest’ in his
\textit{Description of Tbilisi} (Vakhushti Bagrationi, 1983). Instead, he notes that ‘from
Tbilisi to Mtskheta is waterless, yet fruitful,’ including the plain of Didi Dighomi:
‘dry, but grassy, and burgeoning with sheep and cattle in winter’. The hills above,
‘from the Vere River up to Tsqneti\textsuperscript{4} are all orchards’ (Vakhushti Bagrationi, 1983, p.
439).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Mtatsminda_Funicular.jpg}
\caption{Two photographs of the Mtatsminda (Holy Mountain) funicular railway. The left-hand photograph was taken in 1905, and the right-hand photograph in 2003 next to the Palaeobiology Institute. In a century forests have expanded to such an extent that the Church of St David so prominent in the older photograph is scarcely visible in the present-day. (Source: Gersamia, 1984, and author’s collection).}
\end{figure}

\textsuperscript{4} Less than 2.5 km NW of Tsavkisi Wetland.
Vakhusti’s contemporary, and botanist to Louis XIV, Joseph de Tournefort, visited Tbilisi in 1702 and described the surrounding mountains as being “quite bare” and a population that relied on dung fuel rather than wood for cooking (Tournefort, 1718, p. 230). Old photographs show that the hills were still “quite bare” during the early 20th century (Figure 5.1).

Because of these contradictions, the question of Tbilisi’s original vegetation seems impossible to answer on the basis of historical evidence. On botanical grounds, Ketskhoveli (1959) came to the following reconstruction:

‘Around Tbilisi, the plains and hills were once covered with beautiful forest. Here, many forest types were distributed: gallery forest of poplars and oak along the Kura floodplain; on the hills grew forests of Georgian Oak, with maples, ash, hornbeam, wild pears, wild apples and rowan trees. Forests of oak and elm grew on the plains; savanna on south-facing slopes. But where are these forests today? Only fragments can be found, high in the hills, where they escaped destruction.’ (Ketskhoveli, 1959, p. 344).

When this reconstruction is compared to the only pollen record from the Tbilisi area, Lake Lisi, there is little evidence for forests. The Lake Lisi record (Kvavadze, 1999b) is dominated by Pinus, Chenopodiaceae and Asteraceae, and suggests that steppe landscapes prevailed around the lake through much of the period represented by the 10-metre-long core. However, because this very detailed record has no independent radiocarbon chronology and appears to be affected by post-depositional pollen degradation (Dr Eliso Kvavadze, pers. comm.), it is difficult to interpret the results in any historical sense.

The significance of Tbilisi’s past vegetation extends well beyond questions of historical geography. The city’s location at the very border of forest and steppe means that aridity exerts a major influence on the vegetation; because of steep topography and sharp environmental gradients, the lower tree line here could be expected to respond with great sensitivity to climatic changes. The area is also known
for its high plant biodiversity, especially in phrygana and xerophyte scrub communities. Little is known about the history of these important semi-arid communities because they are so poorly expressed in pollen spectra (Bottema, 1974, see also Chapter Four).

The Tbilisi landscape is highly heterogenous. This is the product of the rugged terrain, steep environmental gradients, and, significantly, the varied impact of humans. Along with rainfall and temperature variations, disturbances such as fire, deforestation and grazing must have moulded the vegetation in the past. The relative contribution of each of these factors to the evolution of heterogenous vegetation is unknown. It is clear that these issues can only be resolved with reference to multiple sites in different plant communities.

Using palaeoecological data from four sites along the altitudinal transect presented in Chapter Four – two sites in the semidesert-steppe, one in xerophyte scrub and one in oak-hornbeam forest – this chapter seeks to answer the following questions:

What was the past character of Tbilisi’s vegetation?

How did it change through time?

Were these changes related to climatic or anthropogenic factors?

**Topography and climate**

The Tbilisi landscape is exceedingly varied, owing to its dissected topography and complex history of land-use. Tbilisi’s hilly surrounds are composed mostly of Upper Eocene and Miocene sedimentary rocks that have been heavily warped and folded to create a rugged topography of jagged peaks and steep ravines. As mentioned in Chapter Four, this landscape is punctuated by a number of small lake basins (Figure 5.2), formed through suffosion, landslips and preferential weathering (Dzhanelidze, 1980; Janelidze, 1948).

‘The climate of Tbilisi is excellent and invigorating… the summer is hot, but not unbearably so; winter is cold; and both spring and autumn are wonderful’ (Vakhushti in Maruashvili, 1956, p. 47).
Tbilisi’s climate varies considerably according to topography. Low-lying areas southeast of the city are very hot and dry in summer, with an average annual temperature range of 2-23 °C (winter-summer) and annual precipitation less than 500 mm. In contrast, the mountains around the city have a temperature range of 0 to 20 °C and rainfall up to 800 mm (Svanidze and Papinashvili, 1992). Two precipitation minima occur annually: during winter and late summer (Figure 5.3).

**Figure 5.2.** Map of the Tbilisi area showing the location of lakes, forests and land over 1000 metres in elevation (source: GUGK 1:200,000 topographic map series, 1984). Pollen diagrams are available for sites with underlined names.

**Figure 5.3.** The variety of Tbilisi climates (average monthly temperature and precipitation data compiled from Gulisashvili, 1964).
Vegetation

“The ‘Tbilisi landscape’ therefore, determined mainly by shrub, steppe and partly by mountain xerophile vegetation, has rather a dismal aspect.” (Sakhokia, 1961, p. 18)

Complex topography, microclimates and land-use patterns enable a great variety of vegetation types to coexist within a relatively small area. Far from being dismal, Tbilisi’s vegetation is extraordinarily species-rich, with some 1643 or so species – about 25% of the total number of plant species found in the Caucasian flora and 40% of all species represented in Georgia (Gagnidze, 2005; Sakhokia, 1961). A few species are local endemics, including Primula saguramica and Anthemis saguramica. Six major vegetation groups can be enumerated (Sakhokia, 1958):

Semidesert – Composed largely of Artemisia fragrans-Chenopodiaceae (Salsola, Suaeda, Petrosimonia spp.) associations. This community is found only in the driest areas of the city, often in association with salt lakes.

Steppe – Dominated by Bothriochloa ischaemum, Festuca valesiaca and other grasses, this community is widespread on the left bank of the Mtkvari (Kura) River and in some places where woodland or shrubland has been cleared.

Scrub – Composed of Juniperus, xerophile Pyrus species and deciduous maquis (forest species assuming shrubby form – Quercus iberica, Carpinus orientalis, C. betulus, Fraxinus excelsior etc.). This community is found on lower mountain slopes and in some cleared areas, especially near Mtskheta.

Forest – Most frequently an association of Quercus iberica and Carpinus orientalis, with a lesser role played by Fagus orientalis (on north slopes), Carpinus betulus and Pinus kochiana. Found on most of the mountains surrounding the city.

Shibliak – This is a shrubby community whose indicator species is the Christ Thorn (Paliurus spina-christi). It often takes the place of forest where clearing has taken place and under the continual influence of livestock grazing. It may be found in association with steppe vegetation or with species typical of the forest understorey (maquis). Other typical species include Spiraea hypericifolia, Lonicera iberica, Rhamnus pallasii, Carpinus orientalis, Crataegus, Cotoneaster and Rosa spp.
Phrygana – A community of widespread but fragmentary distribution, occurring chiefly amongst scrub and steppes. It is characterised by low, exceedingly prickly subshrubs (Astragalus, Astracantha and Acantholimon spp.) or perennials possessing pungently scented foliage (Thymus tiflisiensis, T. transcaucasicus, Teucrium polium etc.). They occur particularly in places where livestock grazing is so heavy that no other plants can establish there – even the grasses amongst individual phrygana plants are often chewed down to the soil.

Alongside these six groups are azonal plant communities found along rivercourses and in proximity to salt lakes (Ukleba, 1989), as well as other, more obviously anthropogenic vegetation types, such as walnut groves, orchards, vineyards, croplands and pine plantations.

The following sections describe pollen records from four sites that have yielded new data on the history of vegetation in the Tbilisi area.

The Sakhare and Kumisi records

Lakes Sakhare and Kumisi are salt lakes situated in the lowland semidesert-steppe zone. Their vegetation is detailed in Chapter Four, along with an analysis of their modern pollen spectra.

Sedimentology and dating

Dr Ian Thomas (University of Melbourne) collected cores from both lakes in May 2002. The Sakhare Lake core was 90 cm long, composed of sticky black muds with occasional inclusions of sand-sized particles and decayed organic matter (Table 5.1). These sediments are low in organic content, with loss on ignition values in the lower part of the core of around 10%, increasing slightly in the upper part (Figure 5.4). Magnetic susceptibility values fluctuate considerably, but again are generally higher in the upper part of the Sakhare core. The one radiocarbon date from 83-84 cm
depth yielded an age of 1450±80 $^{14}$C BP (OZG-614), which calibrates to calendar years between 425-693 AD (1525-1257 cal. yr BP).

Over the past 1500 years or so, sedimentation in this small lake basin has been very slow. The rate of sedimentation (approximately 0.6 mm per annum) and low organic content are attributable to small catchment size and the aridity of the climate. If hydrological conditions have changed substantially at Sakhare Lake in recent millennia, this is not clearly reflected in its sediments.

Table 5.1. Sediment description of the Sakhare Lake core.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Colour (Munsell)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-45</td>
<td>10YR2/1</td>
<td>Black clay/silt with some reed fragments and sand particles</td>
</tr>
<tr>
<td>45-70</td>
<td>10YR2/1</td>
<td>Black clay/silt with sand inclusions</td>
</tr>
<tr>
<td>70-80</td>
<td>10YR2/2</td>
<td>Dark grey clay/silt with abundant sand inclusions and mottling</td>
</tr>
<tr>
<td>80-90</td>
<td>10YR2/3</td>
<td>Compact, dark grey silt</td>
</tr>
</tbody>
</table>

Figure 5.4. The Sakhare Lake core: lithology, radiocarbon dating, bulk density, magnetic susceptibility, moisture and organic content determinations. Pollen zones at right.

Based on highest probability 2-sigma (95%) result; i.e. Method B of Stuiver and Reimer (1993). Please see Appendix D for further details on radiocarbon dates.
Table 5.2. Sediment description of the Lake Kumisi core.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Colour (Munsell)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-70</td>
<td>10YR3/3</td>
<td>Massive yellowish sulphide muds</td>
</tr>
<tr>
<td>70-115</td>
<td>10YR4/2</td>
<td>Strongly laminated silts with <em>Ruppia</em> and <em>Chara</em> macrofossils</td>
</tr>
<tr>
<td>115-180</td>
<td>10YR4/2</td>
<td>Laminated silts with <em>Ruppia</em> and some macroscopic charcoal</td>
</tr>
<tr>
<td>180-250</td>
<td>10YR2/2</td>
<td>Massive dark grey silt with <em>Chara</em>. (algal?) filaments and charcoal</td>
</tr>
</tbody>
</table>

Figure 5.5. The Lake Kumisi core: lithology, radiocarbon dating, bulk density, moisture and organic content determinations. Shaded areas indicate laminated sediments. Pollen zones at right.

The second core, from the centre of Lake Kumisi, is composed of unconsolidated sulphide muds in the upper part, and laminated silts in the lower part (Table 5.2). These laminations are usually 2-5 mm in thickness and are most apparent at 90-110 cm, 150-155 cm, and 168-177 cm depth. Macrafossil remains of *Chara* and *Ruppia* occur in some levels; carbonates are consistently present throughout the profile. Organic content ranges between 10 and 17%, the higher values occurring between 190-120 cm in the weakly laminated sediment unit (Figure 5.5). A radiocarbon date from bulk organics at 246 cm depth produced an age of 1150±40 14C BP (OZG-616), corresponding to calendar ages between 771 and 904 AD (1179-1046
cal. yr BP). This date is cautiously accepted, while acknowledging that uncertainty remains (cf. Figure 5.23).

Given the sedimentological changes in the Kumisi core, it is probably unreasonable to assume constant sedimentation. The increased abundance of redeposited pollen in the upper metre suggests that erosional inputs have increased in recent centuries. On average, the Kumisi sediments accumulated at a rate of 2.1 mm per annum, approximately 3.5 times faster than the Sakhare material. This is due to Lake Kumisi’s much larger, steeper catchment and the additional sediment inputs provided by the Nagubi Creek, the tributaries of which rise in the Teleti Range. Each tributary begins in a deeply incised ravine and joins with others to form the Nagubi on the flat, alluvial plain NW of Lake Kumisi. The name ‘Nagubi’, and that of its main tributary, the ‘Chanchrebi’, suggests that this alluvial plain was a reed swamp in the historical past (in Georgian, Nagubi means ‘former pond’ and Chanchrebi means ‘swampy.’) Thick Quaternary lacustrine and alluvial sediments underlie the whole Kumisi Basin and ought be the subject of more detailed study.

In the 250 cm profile studied here, the lowermost and uppermost sediments are most similar in sedimentological and textural characteristics. The sediment units between 70 and 180 cm have, in contrast, higher organic content, more plant macrofossils and obvious laminations. These laminations are made up of light-coloured carbonate layers deposited during summer and darker layers of organic detritus and inorganic material deposited in the cooler, wetter months (see Lemke and Sturm, 1997). Summer evaporation concentrates the dissolved carbonates, which in turn precipitate out of the water column and are incorporated into the sediment. This process is not occurring in Lake Kumisi today, but is observed in Lake Van in Eastern Anatolia (Lemke and Sturm, 1997). The formation of laminated sediments is usually associated with lakes that are relatively deep compared to their surface area and where bioturbation is negligible (Saarnisto, 1986). If these conditions were to be met in Lake Kumisi in the past, the lake level must have been considerably higher than it is now. This would suggest that the period of laminated sediment accumulation occurred under a climate of higher rainfall or reduced evaporation.
Pollen diagrams

The Lake Kumisi pollen diagram is presented in Figure 5.6. Prior to the artificial manipulation of the lake’s level two decades ago, Chenopodiaceae plants were common in the vegetation of the saline flats of the Kumisi Basin (Ketskhoveli, 1959). As well as being part of the broader semidesert flora, Chenopodiaceae can be regarded as part of the wetland vegetation. Chenopodiaceae pollen have been excluded from the dryland pollen sum for that reason. The diagram is subdivided into five pollen assemblage zones:

Zone K-1. Typical semidesert-steppe pollen taxa – Chenopodiaceae, Artemisia, Poaceae and Polygonum aviculare-type – dominate the first and every zone. Amongst arboreal pollen, Pinus, Quercus and Carpinus betulus are most abundant. Some shrub taxa typical of scrub vegetation, such as Acer, Juniperus, Rhamnus-type and Hippophaë, are relatively important during this zone, despite their poor pollen representation. Amongst wetland and aquatic plants, Ruppia pollen dominates and is accompanied by the brackish-water Potamogeton subgenus Coleogeton, as well as Typha, Cyperaceae and Phragmites-type. Charcoal proportions increase through this zone; declining towards the end.

Zone K-2. Arboreal taxa increase in the second zone, especially Carpinus betulus, Quercus and Alnus. The olive (Olea europaea), which was present in Zone K-1, vanishes in Zone K-2. Two other economic plants, Vitis and Morus, also decline somewhat. Amongst non-arboreal taxa, Chenopodiaceae and Polygonum aviculare-type percentages decline and fluctuate considerably throughout the zone. Most other herbaceous types remain more or less stable. Ruppia becomes dominant in the aquatic flora along with Botryococcus green algae. Charcoal concentrations are higher in this zone than any of the others and dung fungi (Sporormiella) are all but absent.
Figure 5.6 (above and previous page). The Lake Kumisi pollen diagram. Dryland pollen sum excludes Chenopodiaceae. See Appendix E for the complete pollen diagram.

Zone K-3. Arboreal pollen decline and herbaceous taxa expand. Foremost amongst the latter are semidesert taxa such as Chenopodiaceae, Polygonum aviculare-type, Lamiaceae and various Asteraceae. *Ruppia* dominates the aquatic component in
the lower part of this zone, replaced by *Potamogeton* subgenus *Coleogeton* in the upper part. Charcoal concentrations are relatively low.

Zone K-4. This fourth zone differs little from the preceding zone, except that Chenopodiaceae and *Polygonum aviculare*-type decline, whilst Poaceae and *Artemisia* expand. *Juniperus*, Ostrya-type and *Cannabis*-type also increase through this zone. *Potamogeton* subgenus *Coleogeton* replaces *Ruppia*, as in the previous zone.

Zone K-5. The final zone sees a further, slight decline in forest taxa (*Quercus, Carpinus betulus, Corylus, Ulmus*) and a modest expansion of *Juniperus, Rhamnus*-type, *Cotinus* and *Platanus*. At the same time, Chenopodiaceae and *Polygonum aviculare*-type increase, and *Ambrosia*, introduced in the 1930s from North America, appears for the first time. *Ruppia, Potamogeton* subgenus *Coleogeton* and *Botryococcus* all decline through this zone.

The pollen diagram from Sakhare Lake is shown in Figure 5.7. Unlike the well-preserved Kumisi material, pollen in the Sakhare Lake sediments were affected by oxidation. The diagram is split into two pollen assemblage zones:

Zone S-1. The dominant pollen types in this zone are Chenopodiaceae, *Artemisia*, Poaceae and *Polygonum*. These are set against a diverse backdrop of herbaceous pollen types. The role of arboreal pollen is minor, suggestive only of long-distance pollen transport. Mid-way through the zone, Chenopodiaceae and *Artemisia* percentages drop suddenly and Poaceae increase. This trend is reversed toward the end of the first zone, when charcoal concentrations also begin to rise.

Zone S-2. The transition to the second zone is accompanied by the brief appearance of *Potamogeton* and *Sparganium* pollen and a persistent increase in Cyperaceae. This suggests a freshening of the water in Sakhare Lake. At the same time, *Polygonum* declines and Chenopodiaceae increases. The changing abundances of major pollen taxa indicate a relationship between Chenopodiaceae and *Artemisia* on the one hand, and Poaceae, *Polygonum* and Cyperaceae on the other. Charcoal concentrations are higher through this second zone than the first.
Figure 5.7. The Sakhare Lake pollen diagram. Dryland pollen sum excludes Chenopodiaceae. See Appendix E for the complete diagram.
Numerical analyses

In the previous chapter, pollen data from a range of environments were analysed using detrended correspondence analysis (DCA). This analysis showed that rainfall, temperature and forest cover were the most important environmental gradients related to the composition of pollen spectra in Southern Georgia. Each of these gradients is associated with varying ratios of different pollen types, e.g. pollen spectra with high proportions of Chenopodiaceae compared to *Carpinus betulus* are almost certainly from the arid zone, just as a high ratio of *Quercus* to *Pinus* pollen is characteristic of forest landscapes. By applying the same ratios to fossil pollen data through weighted averaging, it is possible to reconstruct these environmental gradients in the past.

The results of this procedure applied to the Sakhare Lake record are shown in Figure 5.8. Environmental changes around this site have been relatively subdued through the course of the last 1500 years. The primary gradient, one of rainfall and partly temperature, shows that conditions were slightly moister or cooler 1500 years ago. Other phases with a climate similar to today’s occurred around 1000, 700 and 300-200 years ago. These periods were rhythmically interspersed with drier times, but these changes had a minor impact on the vegetation.

The second gradient is a measure of forest cover (and partly temperature). It shows that semidesert-steppe vegetation has existed in its present form around Sakhare Lake for at least 1500 years. The third gradient also demonstrates remarkable stability.

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6 Throughout, weighted averaging has been applied to dryland pollen percentages, rather than the adjusted percentages shown in the pollen diagrams (see Chapter Four).

7 Assuming uniform sedimentation rates.
The history of Lake Kumisi appears to have been more changeable (Figure 5.9). The primary rainfall gradient shows that the climate 1100 years ago was, in palynological terms, quite similar to today’s. At some time around 900 years ago, the climate suddenly became much wetter, reverting to a drier state about 700 years ago. It became wetter again 500-400 years ago and dried during the last few hundred years. This climatic model is substantiated by the sedimentology of the Lake Kumisi core –
the laminated sediments coincide perfectly with these periods of hypothesised wetter climate. In those times, Lake Kumisi must have been considerably larger and deeper than it is now as a result of increased stream and rainwater influx or reduced evaporation.

The second gradient shows that although arboreal pollen percentages fluctuate considerably in the Lake Kumisi pollen diagram, the extent of forest in the Lake’s catchment changed very little. The only possible forest expansion event occurs at the same time as the first wet phase, between 900 and 800 years ago, but was very short-lived and of low magnitude. Importantly, the lack of variation in the second gradient demonstrates that fluctuating arboreal pollen percentages during the earlier wet phase are merely the result of increased pollen source area as rainfall increased and the lake became larger (cf. surface samples K2 and K3 in Chapter Four). The second wet phase is accompanied not by arboreal pollen, but by *Artemisia* and *Ruppia*. Because *Artemisia* pollen percentages are positively correlated with atmospheric moisture (El-Moslimany, 1990) and *Ruppia* pollen is most abundant in shallow saline waters (Vance and Mathewes, 1994), this second phase is probably the result of decreased evaporation rather than increased rainfall.

If the third gradient can be interpreted in terms of land-use, it may be that during the wetter phases some farmers put aside the cattle prod and took up the plough.

*The Lake Jvari record*

Lake Jvari is situated at an altitude of 570 m in a steep-sided depression next to the 6\textsuperscript{th} century Jvari Monastery, one of Georgia’s oldest cruciform churches and perhaps the country’s most iconic building. The geology of this area is very diverse, consisting of marine sand, marl, conglomerate and tufa of Eocene, Oligocene and Miocene age. These sedimentary rocks have been tilted, faulted and eroded to form a WSW-ENE-trending valley occupied by Lake Jvari on one side of the Kura River and the deep ravine of Karsanis-Khevi on the other. Like most of the salt lakes around Tbilisi, Lake Jvari was probably formed through a combination of tectonic activity and the suffosion of underlying gypsum (Dzhanelidze, 1980). Upwellings on the lake surface suggest that the lake is largely fed by subterranean springs.
Lake Jvari is surrounded by a mixture of forest, shibliak scrub and open steppes (Figure 5.10). The dominant species in the forest are *Carpinus orientalis*, *C. betulus*, *Quercus iberica* and *Fraxinus excelsior*, with an understorey of *Helleborus caucasicus*, various grasses and *Echinops sphaerocephalus*. At the forest edges, species such as *Spiraea hypericifolia*, *Crataegus curvisepala*, *Cotoneaster integerrimus*, *Prunus spinosa*, *Lonicera iberica* and *Acer laetum* are more or less common.

*Paliurus spina-christi* dominates in areas of shibliak vegetation, along with *Rosa canina*, *Spiraea hypericifolia* and *Genista flagellaris*. The open, semidesert-steppe vegetation that grows on the lake terrace is dominated by grasses, with *Artemisia chamaemelifolia*, *Cirsium arvense*, *Eryngium campestre*, *Echium vulgare*, *Euphorbia squamosa* and many other species. The lake itself is so salty and alkaline that few vascular plants grow in or near the water. The exception is *Ruppia spiralis*, which grows in the water when the lake is full. Once the water evaporates, only halophilous algae remain.
The land around Lake Jvari is mostly used as rough pasture for cattle. Pine plantations are also common in the area, as are plantings of cedar and poplar. Hunters roam through the neighbouring forests, which, along with the lake and its sediments, are the property of the Patriarch of Georgia.

**Sedimentology**

The 2.5-metre-long Lake Jvari core was collected in September 2003 from the centre of the then dry lake. It consists of black, unconsolidated, sulphide muds in the upper 40 cm, changing to soft, homogenous, dark-grey marl in the lower part. The sediments are highly alkaline (pH >10) and carbonate rich. Sediment moisture and organic content exhibit considerable variation, but generally decline with increasing depth (Figure 5.11). The highest loss-on-ignition value (28%) occurs at the surface, and the lowest (9%) at 150 cm. Macrofossils, mostly *Chara* oogonia, *Ruppia* seeds and filaments, occur throughout the core.

![Figure 5.11. The Lake Jvari core: lithology, bulk density, moisture and organic content determinations. Biostratigraphic markers used for dating purposes are shown. Pollen zones at right.](image)

The extreme salinity and alkalinity of Lake Jvari is a function of its considerable age, its water source in alkaline springs, the lack of inflowing or outflowing streams, and intense evaporation during hot, dry summers.
No radiometric dates were obtained for the Lake Jvari core, but on the basis of pollen markers and correlation with other records (see below) it seems to span the last 2000-2500 years. If this is correct, sedimentation has occurred at an average of 1.0-1.3 mm per year. This rate falls somewhere between that of Lake Kumisi and Sakhare Lake, consistent with the lake’s catchment size, topography and climate.

Pollen diagram

Pollen preservation throughout the Jvari material is excellent, despite the alkalinity of the sediments. This is because the strongly reducing conditions protect pollen from oxidation. Good preservation also implies that this lake has not desiccated completely in recent centuries, even though the sediment surface may be exposed in dry years. The Jvari pollen diagram (Figure 5.12) is divided into three pollen assemblage zones:

Zone J-1. The lowermost zone is characterised by relatively high arboreal pollen proportions, particularly *Pinus, Juniperus* and *Carpinus betulus*. Amongst non-arboreal taxa, Poaceae dominates, followed by *Artemisia*, Chenopodiaceae and indicators of open pastures – *Galium*-type, *Plantago lanceolata, P. major*-type and *Trifolium repens*-type. An abundance of *Sporormiella* dung fungal spores confirm the existence of grazing, and the presence of *Paliurus* (*Rhamnus*-type) pollen indicates that shibliak vegetation was already present at that time. The landscape during this first zone was probably a mixture of forest, shibliak and open pastures, much as it is presently. *Ruppiap is the most important aquatic taxon, followed by Potamogeton subgenus Coleogeton, indicating that the lake water was brackish to saline.*
Figure 5.12 (above and previous page). The Lake Jvari pollen diagram. Percentages calculated conventionally. See Appendix E for the complete diagram.
Zone J-2. Arboreal pollen declines at the beginning of the second zone, compensated by a slight increase in steppic herbs, especially *Centaurea nigra*-type. Amongst economic plants, pollen of the walnut (*Juglans*) appears for the first time, and both wheat (*Triticum*-type) and grape (*Vitis*) pollen become more abundant. *Sporormiella* proportions reach very high levels: 8.5% of the total pollen sum. Following a charcoal peak mid-way through this zone, *Carpinus betulus*, *Quercus* and *Pinus* percentages increase, but non-arboreal pollen percentages do not change appreciably. Only *Marrubium* and *Polygonum aviculare*-type pollen appear to rise after this temporary increase in AP. Charcoal concentrations peak in the upper part of the zone and then decline steadily through the remainder of the record. In the lake itself, *Ruppia* and *Botryococcus* populations fluctuated considerably and were at times replaced by *Potamogeton* subgenus *Coleogeton*. Presumably this occurred during higher lake phases when the water was less saline.

Zone J-3. The uppermost zone comprises only two samples, distinguished from the previous zone by an increase in arboreal pollen proportions (especially *Juniperus* and *Pinus*) and a decline in *Artemisia* and Chenopodiaceae. The appearance of *Ambrosia*-type and *Zea mays* pollen in this zone place it within the 20th century. *Sporormiella* declines to its lowest levels in the entire Jvari record, suggesting that grazing intensity has decreased in the last 100 years. Charcoal concentrations follow the same trend.

**Numerical analysis**

The results of applying the weighted averaging technique to the Lake Jvari material are shown in Figure 5.13. The primary, climatic gradient follows the *Ruppia* pollen curve very closely, indicating that the changes in atmospheric moisture were reflected with exceptional clarity in both dryland and aquatic pollen spectra. *Ruppia* pollen was most abundant in relatively dry periods, when lake levels were consequently low. When the lake level was higher, *Potamogeton* species became more abundant and the accumulation of organic matter and arboreal pollen in the sediments increased.
The second gradient represents changes in forest cover. It shows that the extent of woodland has oscillated throughout the record, but that the changes were relatively minor. The DCA scores here do not indicate that forest cover was ever continuous, nor do they suggest that forest was ever completely absent. This accords with the persistence of *Paliurus* shibliak and steppic pasture indicators throughout the Lake Jvari pollen record. Comparison of the first two gradients permits the conclusion that forest area expanded when the climate was wetter, and retracted either as a result of fire or when the climate became drier. Grazing pressure also had a strong influence on the vegetation.

The third axis seems to indicate that grazing was more widely practiced during drier times, and cropping during wetter phases, but this relationship is far from clear or straightforward. It also seems that relaxation of grazing pressure aided the spread of (secondary) woodland in some instances.

Dating these changes relies on the appearance of *Juglans* and *Olea europaea* pollen at a depth of 200 cm. These pollen taxa appear consistently in pollen records from the study area from the Roman Period onwards (see Chapter Nine). The rainfall gradient shown in Figure 5.13 also correlates well with the same curves for the last
2000-2500 years from other sites (Tsavkisi, Imera and Aligol – this chapter and Chapter Six).

While some dating uncertainties remain, in broad terms both landscape and climate at Lake Jvari 2000 years ago were similar to today’s. Around 1500 years ago the climate became drier, and forest cover retracted somewhat as grazing pressure increased. Similarly dry spells recurred about 1000 years ago and 500 years ago, interrupted by periods with cooler or wetter conditions. In essence, though, the landscape changed remarkably little through the last 2500 years. The Lake Jvari pollen diagram, like those from Lake Kumisi and Sakhare Lake, is a good example of vegetation and land-use stability in the face of climatic variability.

The Tsavkisi Wetland record

Tsavkisi Wetland is a reed-dominated mire located in the hills six kilometres west of Tbilisi, mid-way between the villages of Tsqneti and Tsavkisi, at an elevation of 1110 metres. Within an anticlinal fold of Upper Eocene sedimentary units (tufogenetic sands, clays, marls and schists) in the eastern Trialeti Range, it occupies a triangular depression that was probably created by the faulting, metamorphosis and subsequent erosion of interbedded saline sedimentary strata (Dzhanelidze, 1980; Tsereteli, 1971). This tectonic genesis is reflected in the steepness of the basin sides, the wetland’s lateral constriction, and the straight, geologically-determined basin sides. The wetland surface covers an area of approximately 32 ha. A map of the geomorphology (Figure 5.14) highlights the complexity of the surrounding relief. Data on the site’s vegetation and modern pollen representation are given in Chapter Four.

Whilst the wetland has no visible inflow (it is at least partially spring-fed), there is a small outlet that flows westward into the Ukanakhevi (Back Creek). This outlet was inactive during all visits to the site and is probably intermittently active only after heavy rain.
Figure 5.14. Map of Tsavkisi Wetland, showing principal geomorphic features, vegetation units and coring location. Compiled from aerial photographs, topographic maps and ground surveys.

Figure 5.15. The Tsavkisi Wetland core: lithology, moisture content, loss-on-ignition and carbonate determinations. Presence of gastropod remains and pollen zones shown at right.
Sedimentology and dating

Dr Ian Thomas (University of Melbourne) and Dr Henrikh Avakov (Georgian Institute of Palaeobiology) collected the first core from Tsavkisi Wetland in May 2002. The core was one metre in length and was obtained with a Russian corer at a place between the southern shore and the centre of the wetland. At a metre’s depth, the corer repeatedly struck an obstruction, so further penetration was not possible. The wetland sediments were cored twice more: in September 2003 and July 2005. In 2003, Michael Fletcher and I cored to a depth of 7.8 m using a ‘sticky clay’ auger. The length of this core was limited by a lack of equipment rather than a lack of sediment below 7.8 metres. In 2005, the record was extended to a depth of 11.1 m. Hydrostatic pressure at this depth was too great to permit further boring with hand-operated equipment. Both of these cores were obtained from the centre of the wetland (see Figure 5.14).

The sediments of Tsavkisi Wetland are extremely varied, consisting predominantly of lake marl. They alternate between silty and more organic strata, and contain macrofossils including gastropod shells, molluscs, *Chara* oogonia, *Phragmites* fragments and *Potamogeton* seeds.

**Table 5.3.** Sediment description of the Tsavkisi Wetland cores.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Colour (Munsell)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>10YR4/3</td>
<td>Soft, brown detritus peat with gastropod remains</td>
</tr>
<tr>
<td>30-35</td>
<td>10YR2/1</td>
<td>Black, elastic peat layer containing abundant rootlets</td>
</tr>
<tr>
<td>35-50</td>
<td>10YR3/2</td>
<td>Dark-brown peaty sediment with gastropod remains</td>
</tr>
<tr>
<td>50-54</td>
<td>10YR2/1</td>
<td>Black peaty silt with abundant reed fragments</td>
</tr>
<tr>
<td>54-117</td>
<td>10YR3/2</td>
<td>Brown organic-rich marl with plant remains, charcoal and gastropods</td>
</tr>
<tr>
<td>117-142</td>
<td>10YR5/2</td>
<td>As above, only lighter in colour</td>
</tr>
<tr>
<td>142-159</td>
<td>10YR3/1</td>
<td>Crumbly, peaty marl with abundant gastropod and mollusc remains</td>
</tr>
<tr>
<td>159-170</td>
<td>10YR2/1</td>
<td>Black, elastic peat, well decomposed with some gastropod remains</td>
</tr>
<tr>
<td>170-185</td>
<td>10YR3/2</td>
<td>Brown marl sediments with laminations, charcoal bands and gastropods</td>
</tr>
<tr>
<td>185-188</td>
<td>10YR2/1</td>
<td>Distinct black band (charcoal?)</td>
</tr>
<tr>
<td>188-225</td>
<td>10YR3/2</td>
<td>Brown peat layer with abundant gastropod remains</td>
</tr>
<tr>
<td>225-295</td>
<td>10YR3/2</td>
<td>Brown lake marl</td>
</tr>
<tr>
<td>295-335</td>
<td>10YR3/2</td>
<td>Dark-brown, organic-rich marl</td>
</tr>
<tr>
<td>335-440</td>
<td>10YR2/1</td>
<td>Soft, dark-grey marl</td>
</tr>
<tr>
<td>440-445</td>
<td>10YR3/2</td>
<td>Brown marl sediments</td>
</tr>
<tr>
<td>445-505</td>
<td>10YR3/2</td>
<td>Crumbly, brown peaty sediment (with gastropod layer at 455 cm)</td>
</tr>
<tr>
<td>505-600</td>
<td>10YR4/4</td>
<td>Soft, yellow, organic-rich marl</td>
</tr>
<tr>
<td>600-625</td>
<td>10YR3/2</td>
<td>Dark-brown, peaty marl</td>
</tr>
<tr>
<td>625-665</td>
<td>10YR3/2</td>
<td>Brown marl sediments</td>
</tr>
<tr>
<td>665-915</td>
<td>10YR2/1</td>
<td>Soft, dark-grey marl with laminations</td>
</tr>
<tr>
<td>915-960</td>
<td>10YR3/2</td>
<td>Hard, crumbly, dark-brown marl</td>
</tr>
<tr>
<td>960-1045</td>
<td>10YR2/1</td>
<td>Very soft, dark-grey marl</td>
</tr>
<tr>
<td>1045-1080</td>
<td>10YR3/2</td>
<td>Compact, brown peaty sediment (gastropod layer at 1065 cm)</td>
</tr>
<tr>
<td>1080-1110</td>
<td>10YR2/1</td>
<td>Soft, dark-grey marl</td>
</tr>
</tbody>
</table>
The lowermost section of the core consists of massive, dark grey, silty sediment. Layers with a more peaty texture occur between 1080-1045 cm and 960-915 cm. Above 665 cm the sediments are altogether more organic, first dark brown, then yellow and unconsolidated. The sediment changes sharply to crumbly, dark brown silty peat above five metres, then changes again to dark grey silts that closely resemble those from the bottom of the core. Around three metres’ depth, the sediments yet again become peatier. Brown crumbly peat appears at 2.25 m and the upper part of the core is characterised by cappuccino-coloured silty gyttja with peat layers, abundant gastropods, charcoal bands and the macrofossil remains of wetland plants. A detailed description is given in Table 5.3.

Moisture content and loss on ignition curves are given in Figure 5.15. The sediments can be classed broadly into three phases based on organic content: silt-rich basal sediments (1110-640 cm), silts with a higher organic content (630-190 cm) and the peaty upper layers (185 cm to the surface). Every sample from this core contained carbonates. In the silty sediments, this was held in sedimentary carbonates; in the peat layers, it resided in gastropod remains.

The sedimentological changes in the Tsavkisi core can be interpreted with reference to analogous lakes in the study area. The dark-grey lake marl sediments resemble those from salt lakes such as Jvari, Sakhare and Shavi Lakes (Figure 5.2), which are situated at lower altitudes than Tsavkisi Wetland, experience a more arid climate, and have less vegetation cover. Tsavkisi Wetland’s dark-grey sediments were probably deposited in similar conditions, of greater aridity and intense summer evaporation. However, the laminations visible in parts of the Tsavkisi core are absent from these other lakes, suggesting that although the past climate was more arid, lake levels in Tsavkisi Wetland were still relatively high, with intense summer evaporation.

The organic layers in the Tsavkisi core were probably deposited when the water level was stable or aquatic vegetation was able to colonise the waters due to a dilution of dissolved salts. This could have occurred with increased precipitation, less droughty summers or reduced evaporation. Lakes with peat accumulation in the
present-day include those on the Tsalka Plateau (see Chapter Six), which experience high lake levels in summer when most aquatic plants are growing rapidly.

Because Tsavkisi Wetland has no inflowing streams and its small geologically-determined outflow is stable and has only recently been met by the sediment level, these observations can be used to provide a model of lake level change through the period represented by the core. I think it most likely that the changes observed in the Tsavkisi Wetland core were driven by variations in precipitation, evaporation and sedimentation. The influence of tectonic movements or anthropogenic impacts cannot be discounted, but it seems more parsimonious to regard the changes as reflective of Holocene climatic variability, given that the various sediments can be tied to modern analogues in other lakes that differ primarily in their altitudinal and hence climatic characteristics.

Before these data can be incorporated into a lake level curve for Tsavkisi Wetland, the dating of the sediments must be first considered. Radiocarbon dating of the Tsavkisi sediments has proved exceedingly problematic because of contamination by older carbonates and younger humic material. Old carbonates are brought into the basin from the erosion of the surrounding Eocene sedimentary rocks and also from alkaline aquifers that provide some of the wetland’s water. Three different methods were employed in the pre-treatment of the samples – acid-base-acid (ABA), pollen isolation and acid leaching. The discrepancies between the dates are shown in Figure 5.16 (see also Appendix D).

The two samples pre-treated by traditional ABA methods at the Australian Nuclear Science and Technology Organisation (ANSTO) gave the most convincing results, based on the appearance of dating markers (Juglans and Olea pollen) and biostratigraphic correlation with other records from the study area.
Figure 5.16. Problematic dates for Tsavkisi sediments: discrepancies between AMS radiocarbon dates pre-treated by different methods, presented in stratigraphic order.

Dating the isolated pollen fraction using the bleaching and oxidation method of Brown et al. (1989) produced radiocarbon ages that appear to be much too old. In some cases the pollen dates’ divergence from the ABA-derived chronology is 3000 years. Kilian et al. (2002) have studied this ageing phenomenon in detail using the varved sediments of Lake Gosciaz in Poland. They showed that pollen concentrates produced dates that were approximately 700 years too old when compared to the lake’s varve chronology. In contrast, macrofossils preserved in the same sediments were around 100 years too old. They suspect that the large surface-to-volume ratio and high porosity of pollen grains allows ‘dead’ carbon to adhere to pollen exines (Kilian et al., 2002).

Two additional dates, from Beta Analytic and the University of Waikato, are more difficult to dismiss. They are younger than either the ABA or pollen-fraction chronology. Both dates overlap temporally, and differ stratigraphically by 10 cm. These dates may be erroneously young due to contamination during coring (by use of an auger) or through infiltration by younger humic acids, which may have been incompletely removed by pre-treatment. While these possibilities could also apply to the ANSTO ABA dates, contamination during coring is less likely because the samples were taken from higher in the profile (hence less hydrostatic pressure). The ANSTO samples were also gravity separated before ABA pre-treatment, eliminating
contamination from humic material bound to mineral particles, a potential source of erroneous ages in clay- and silt-rich samples (Dr G. Jacobsen, ANSTO, pers. comm.).

I have adopted the ANSTO ABA chronology as the best representation of the sediments’ age based on three factors: the advantages of the pre-treatment method (complete removal of humic acids), vegetation changes of probable regional extent (a sharp rise in *Quercus* ~5000 years ago) and reference to sedimentation rates in comparable sites. Uncertainty remains, however, and is not likely to be resolved without age-determinations for various sediment components within each dated horizon.

Using the ANSTO ABA chronology, the Tsavkisi Wetland record encompasses the last 8000 years. Sedimentation rates between 8000 and 2000 years ago were, on average, 1.6 mm per annum. In the last 2000 years, the rate of sedimentation has slackened somewhat (0.8 mm per annum), possibly as the sediment level rose to meet the basin’s intermittent outlet and inhibited further infilling, or as local vegetation changes reduced sediment supply.

### Aquatic pollen

In addition to the sedimentological data already discussed, changes in lake levels can be studied with reference to the aquatic pollen types preserved in the various sedimentary layers (see Figure 5.18, in the following section).

The lowermost, silty sediments (1110-640 cm) contain large amounts of *Myriophyllum* pollen. Most other aquatic and wetland types are poorly represented during this stage, although *Typha* and Cyperaceae pollen occur consistently and there are a number of peaks in *Pediastrum* algae.

*Myriophyllum* pollen are difficult to interpret – milfoil may live in still water bodies for long periods of time without flowering, propagating entirely by vegetative means. Even where the plant is abundant, pollen percentages are often low (Huntley and Birks, 1983). Some species can be forced into flower by fluctuating water levels (Orchard, 1985). Wasylikowa (1967) interpreted high and rapidly varying concentrations of *Myriophyllum spicatum* macrofossils in mid Holocene sediments from Lake Zeribar, western Iran, as indicative of fluctuating water levels and a warm climate. After 6000 cal. yr BP, *Myriophyllum* in Lake Zeribar declined to be replaced
by *Ceratophyllum*, indicating a more stable water level (Wasylikowa, 1967; Wasylikowa, 2005).

This pattern is mirrored so precisely in the Tsavkisi sediments that it seems plausible its cause was the same: a climate with seasonal drought gave way to conditions of relative hydrological stability after 6000 cal. yr BP. Water fluctuations within this phase can be traced through *Potamogeton* pollen (indicative of a depth of standing water) and, on the other hand, *Spirogyra* (shallow warm water) and *Caltha* (boggy conditions) (Ketskhoveli, 1973; van Geel et al., 1981; van Geel and van der Hammen, 1978). So, although the water level may have been more stable between 5000 and 4000 cal. yr BP, it may have been lower than previously due to the rapid infilling of the water column by *Ceratophyllum* (Hejný, 1960; Wasylikowa, 1967).

After 4000 cal. yr BP, *Ceratophyllum* and most other aquatic species declined and the sediments became increasingly silty. The only pollen taxon to increase then was *Potamogeton* subgenus *Coleogeton*, which is able to tolerate brackish water (Tutin et al., 1980) and suggests that the lake water became more saline. Toward the end of this stage, *Potamogeton* (subgenus *Potamogeton*) began to rise, signalling the return of a substantial depth of fresh water. It then declined to the benefit of *Ceratophyllum* and *Caltha* as the lake paludified, beginning around 2000 cal. yr BP. Water levels remained low, but free of summer desiccation, during the phases of peat deposition. These are notable for the presence of abundant unripe *Sphagnum* spores (identified by J. van Leeuwen, Institute of Plant Sciences, Bern) and fungal remains indicative of shallow water (cf. van Geel et al., 1981; van Geel and van der Hammen, 1978). In recent centuries the wetland has changed from a sedge swamp to a *Typha-Phragmites* association.

A tentative lake level curve for Tsavkisi Wetland is given in Figure 5.17, taking into account sedimentological and palynological data.

**Figure 5.17.** A tentative lake level curve for Tsavkisi Wetland.
Tsavkisi Wetland

Trees and shrubs

Grasses and herbs

Pollen summary

Depth cm

T-10
T-9
T-8
T-7
T-6
T-5
T-4
T-3
T-2
T-1
Figure 5.18 (above and previous page). The Tsavkisi Wetland pollen diagram. Pollen percentages calculated from a conventional dryland pollen sum. See Appendix E for the complete diagram.
Pollen diagram

The sediments of Tsavkisi Wetland are exceedingly rich in pollen. In the 129 stratigraphic levels analysed, a total of 250 different types of pollen, fungi and other microscopic remains were identified. The pollen diagram (Figure 5.18) is divided into ten palynological assemblage zones based on statistical splitting (Birks and Gordon, 1985):

Zone T-1. The first zone has high proportions of herbaceous pollen (especially Chenopodiaceae, Artemisia and Poaceae). Many of these species are, additionally, indicators of open vegetation, e.g. Secale-type, Arctium-type, Centaurea nigra-type, Caryophyllaceae, Convovulus arvensis-type, Cuscuta-type, Gentianella campestris-type, Phyteuma-type, Helianthemum, Prunella-type and Plantago spp. The dominant arboreal pollen type is Quercus, followed by Carpinus betulus and Fagus. Poorly-represented pollen types (see Chapter Nine Maps) include Ephedra distachia-type, E. fragilis-type, Salix, Castanea, Pistacia, Tilia, Viscum, Juniperus and many Rosaceae. The mere presence of these pollen types suggests that their parent plants were quite prevalent in the surrounding vegetation. Charcoal particles are consistently represented through this zone, decreasing in abundance in the upper part. Of interest is the high proportion of Sporormiella dung fungal spores, indicative of grazing herbivores (van Geel and Aptroot, 2006). These decline in the upper part of the zone, when Poaceae and Triticum-type increase.

Zone T-2. The second zone is similar to the first, except that Poaceae declines and various pasture indicators increase (Potentilla-type, Filipendula, Polygonum aviculare-type and Plantago species). Sporormiella dung spores and charcoal particles also increase, as does Juniperus, suggesting more intensive pastoral activity compared to the first zone. Pollen of juniper’s parasite, Arceuthobium oxycedri, appears in this zone, confirming the local occurrence of Juniperus shrubs. As in the first zone, Myriophyllum dominates the aquatic pollen group.

Zone T-3. The transition to the third zone is accompanied by a rapid increase in arboreal pollen, especially Quercus, Carpinus betulus and Fraxinus. With the important exception of Thalictrum, a plant of forest edges, all herbs and grasses decline. Charcoal concentrations and dung fungal spores also diminish and the aquatic vegetation changes from Myriophyllum-dominated to Ceratophyllum-
dominated. This zone records the expansion of deciduous (oak-ash) woodland in the Tsavkisi area.

Zone T-4. At the beginning of the fourth zone, *Fraxinus, Quercus* and *Corylus* decline. They are replaced by herbs such as *Hornungia*-type, *Potentilla*-type, *Filipendula*, *Polygonum aviculare*-type, *Gentiana*, Apiaceae, Asteraceae and rosaceous shrubs. In the middle of this zone, *Juniperus* increases in tandem with *Plantago*, *Cirsium*, *Centaurea*, *Galium*-type, *Rumex*, *Urtica*, *Gentianella* and *Helianthemum*. These taxa indicate open vegetation, probably juniper scrub with dry meadow herbs. The climate must have been dry and droughty for juniper to become so important. Although fire-loving bracken, *Pteridium*, is well represented in this zone, charcoal concentrations are not significantly higher than in Zone T-3 and large charcoal particles (representing local fires) are rare. Brackens also spread under the influence of heavy grazing (Moore and Stevenson, 1982), a more plausible explanation for their representation throughout this zone, given that quantities of *Sporormiella* dung fungus reach up to 8% of the total pollen sum. *Sporormiella* values of 4% are considered a reliable indication of high livestock densities (Davis and Shafer, 2006); hence the Tsavkisi record indicates very high densities. Perhaps intense grazing pressure played a leading role in maintaining the openness of the vegetation.

Zone T-5. In the fifth zone, grass pollen (Poaceae) increases dramatically and arboreal pollen all but disappear. Amongst herbaceous pollen otherwise dominated by Poaceae, *Plantago*, *Potentilla* and *Filipendula*, some relatively rare pollen types appear – *Scorzonera*, *Echinops*, *Cuscuta*, *Melampyrum*, *Polygala*, *Sideritis* and *Verbena*. Many of these are characteristic phrygana species of the dry grasslands and pastures on the hills around Tbilisi (Ketskhoveli, 1959).

Zone T-6. *Plantago* species and *Sporormiella* decline in the sixth zone, at the same time as charcoal concentrations and arboreal pollen begin to increase. *Pinus* becomes important for the first time in the history of the site and the pollen of *Juglans* and *Olea europaea* appears for the first time.

Zone T-7. This zone includes the most remarkable change in the Tsavkisi pollen record. After the resurgence of arboreal pollen in the previous zone, here *Carpinus betulus* comes to dominate suddenly and absolutely, reaching up to 47% of
dryland pollen. Poorly-represented pollen of *Carpinus orientalis* (*Ostrya*-type) also peaks at this time, as dense forests overtook the Tsavkisi landscape.

Zone T-8. This zone witnesses the decline of the short-lived hornbeam forests. It occurs as charcoal concentrations become much higher. Monolete fern spores, of the Aspleniaceae and Polypodiaceae families, maintain values of between 8 and 16 percent throughout this zone, compared to values generally <1% in the remainder of the record. By and large, these represent ferns of the forest floor that proliferated after the withdrawal of *Carpinus* forests. Increasing percentages of *Pinus* and various herb pollen types indicate a return to a more open landscape in this zone.

Zone T-9. The vegetation became even more open and steppic in the ninth zone, as ferns and arboreal pollen decline, and Poaceae, Chenopodiaceae and *Plantago* increase. Charcoal particles indicate that fire retained an important impact on the vegetation. Cyperaceae briefly becomes the most important wetland taxon in this zone.

Zone T-10. The role of grasses diminishes in the final zone, countered by the re-emergence of arboreal types (*Pinus, Quercus, Fagus*) at the same time as *Vitis* pollen increases and *Picea* and *Cannabis* achieve their highest representation in the record. This event was coincident with very high charcoal concentrations and followed by a proliferation of Chenopodiaceae. The decreased importance of fire in the latter part of the zone is echoed in a Chenopodiaceae decline and increased arboreal pollen percentages. Importantly, dung fungi (*Sporormiella* and *Podospora*) and grazing indicator pollen (*Potentilla*-type, *Ranunculus acris*-type, *Plantago major*-type and Fabaceae) are much reduced through Zones 7-10, suggesting that grazing pressures were lighter through the last 2000 years than during prior millennia.

**Numerical analyses**

The great complexity of the Tsavkisi pollen diagram can be reduced to a few major trends with the aid of statistical methods. The results of weighted averaging based on modern pollen data are shown in Figure 5.19. The climatic gradient seems to indicate that precipitation fluctuated considerably from the beginning of the record, stabilising after 6000 years ago with higher rainfall. The climate became gradually drier between 4000 and 2000 years ago, but shifted back during the expansion of
Carpinus betulus around 1900 years ago. Conditions became again drier in more recent times. Correlations between this reconstructed trend and aquatic pollen (Table 5.4) show that Ceratophyllum, an aquatic plant requiring between 60 and 200 cm water depth (Korelyakova and Gorbik, 1989), is related to phases of wetter climate; while sedges, shallow water fungi and pollen degradation occurred when water levels were lower.

The gradient of forest cover exhibits a trend that is inversely related to the first gradient ($r^2 = 0.75$). Since forest cover is positively-correlated with winter temperature in the study area (see Chapter Four), this second gradient is also a proxy for temperature variations. Forest cover was most extensive between 5200 and 3800 cal. yr BP (oak-ash forest) and 1900 and 1600 cal. yr BP (hornbeam forest). It was more restricted during all other times.

The third gradient shows that land-use in the earliest part of the Tsavkisi record oscillated between livestock herding and grain agriculture as climatic conditions varied. A comparison of the Sporormiella (grazing indicator) and Triticum-type (agriculture indicator) curves strongly supports this assessment (Figure 5.20). After 6800 cal. yr BP, grazing appears to have occupied a primary place near Tsavkisi Wetland. This changed with the advance of forests 5200 to 3800 cal. yr BP,
but afterward grazing returned and became extremely important. Pastures went into
decline around 2000 cal. yr BP, followed by the expansion of hornbeam forest and the
establishment of walnut groves in the Tsavkisi area. Since that time, grazing has been
reintroduced, but at levels far less intense than in the past.

Table 5.4. Wetland pollen taxa and other microfossils most strongly correlated with each of the DCA
axes, and all pollen types correlated with charred particles (CPs) and loss on ignition (LOI). Correlation coefficients ($r^2$) are given in parentheses.

<table>
<thead>
<tr>
<th>Axis 1</th>
<th>+ Cyperaceae (0.37), degraded pollen (0.29), Mougeotia (0.19), Closterium (0.13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Dryland pollen concentration (0.16), Ceratophyllum (0.12)</td>
</tr>
<tr>
<td></td>
<td>+ Ceratophyllum (0.30)</td>
</tr>
<tr>
<td>Axis 2</td>
<td>- Degraded pollen (0.22), Closterium (0.10)</td>
</tr>
<tr>
<td></td>
<td>+ Sporormiella (0.38)</td>
</tr>
<tr>
<td>Axis 3</td>
<td>- Botryococcus (0.09)</td>
</tr>
<tr>
<td></td>
<td>+ Pinus (0.23), Alnus (0.19), Chenopodiaceae (0.11), Vitis (0.11)</td>
</tr>
<tr>
<td>CPs</td>
<td>- Filipendula (0.05), Fraxinus (0.05), Caryophyllaceae (0.04), Juniperus (0.04)</td>
</tr>
<tr>
<td>LOI</td>
<td>+ Unripe Sphagnum spores (0.31), Pinus (0.30), Charcoal concentrations (0.21)</td>
</tr>
<tr>
<td></td>
<td>- Polygonum aviculare (0.13), Galium (0.12), Filipendula (0.11), Sporormiella (0.09)</td>
</tr>
</tbody>
</table>

Figure 5.20. The Tsavkisi land-use gradient compared with palynological indicators of cultivation
top) and pasturage (bottom). Pollen zones T-3 and T-7 were forested stages with diminished local
agricultural or pastoral activity.

Vegetation history

While these trends are useful for interpreting changes in climate, forest cover
and human impact, they provide little data on how the composition of the vegetation
changed through time. To establish this, the pollen data were analysed using Two-
Way Indicator Species Analysis (TWINSPLAN), providing a statistical basis for
reconstructing past vegetation changes.
The relevant TWINSPLAN groups and their indicators appear in Table 5.5. The classification splits the Tsavkisi pollen record into two ‘stages’. The earlier stage encompasses the six millennia prior to the Classical Period. It occupies pollen zones T-1 to T-5 and is indicated by relatively high proportions of *Juniperus*. For this reason it is referred to as the ‘*Juniperus* stage’. The second stage commenced in the Classical Period and continues through to the present day. This period is referred to as the ‘*Pinus-Juglans* stage’. Each of the two stages is divided further into ‘phases’, discussed below.

<table>
<thead>
<tr>
<th>Stage/phase</th>
<th>Indicator species (and cut levels)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Juniperus</strong></td>
<td><em>Juniperus</em> (2%)</td>
</tr>
<tr>
<td>Phase 1</td>
<td><em>Artemisia</em> (10%)</td>
</tr>
<tr>
<td>Phase 2</td>
<td><em>Plantago coronopus</em>-type (presence)</td>
</tr>
<tr>
<td><strong>Pinus-Juglans</strong></td>
<td><em>Pinus</em> (5%), <em>Juglans</em> (presence), <em>Ostrya</em>-type (presence), <em>Cannabis</em>-type (presence)</td>
</tr>
<tr>
<td>Phase 3</td>
<td><em>Polygonum aviculare</em>-type (presence), <em>Cirsium</em>-type (presence)</td>
</tr>
<tr>
<td>Phase 4</td>
<td><em>Carpinus betulus</em> (5%), <em>Fraxinus</em> (presence), <em>Zelkova</em>-type (presence)</td>
</tr>
</tbody>
</table>

The *Juniperus* stage (8000-2000 cal. yr BP) – Juniper is a shrub or tree characteristic of Caucasian scrub and savanna vegetation. It was more clearly much more prevalent in the Tsavkisi area prior to the Classical Period than it is at present. It must have been quite abundant locally, as the pollen of its associated parasite, *Arceuthobium oxycedri* attests. Junipers are extremely sensitive to fire (Grove and Rackham, 2001), a characteristic exploited by graziers in the Alps today to prevent junipers invading mountain pastures. Although the charcoal record from Tsavkisi demonstrates that fires did occur through the *Juniperus* stage, their frequency and intensity appear to have been low compared to the subsequent *Pinus-Juglans* stage. Grazing seems to have been the dominant land-use during the *Juniperus* stage, as indicated by high proportions of *Sporormiella* dung fungal spores throughout. The *Juniperus* stage can be divided into two major phases:

Phase 1 (pollen zones T-1 to T-3): This phase lasted from 8000 until about 3800 cal. yr BP. It is characterised by high proportions of *Artemisia* pollen and is associated with *Quercus* and Rosaceae. These species are found together in both xerophile woodland and scrub communities in this part of Georgia (Ketskhoveli, 1959). Taking into consideration the forest cover gradient discussed in the previous section, it appears that the vegetation during pollen zone T-1 was open scrub, gradually becoming more wooded through zone T-2 and forming a forest during T-3.
Phase 2 (pollen zones T-4 and T-5): The indicator species for Phase 2 is *Plantago coronopus*-type. This pollen type includes several *Plantago* species that grow primarily in grasslands and pastures. Associates of *Plantago* during this phase include *Juniperus, Agrimonon eupatoria, Helianthemum, Aster, Campanula, Liliaceae, Scleranths, Geranium* and *Ranunculus acris*-type. *Plantago* and these associated species occur in phrygana communities around Tbilisi (Ketskhoveli, 1959). This suggests that grazing pressure during pollen zones T-4 and T-5 was sufficiently intense to mould vegetation composition. Increased proportions of *Juniperus, Acer* and *Carpinus betulus* during pollen zone T-4 indicate that the vegetation changed from scrub with phrygana elements to a landscape that was much more open and steppic in zone T-5.

The *Pinus-Juglans* stage (2000 cal. yr BP to the present) – This stage, beginning some time in the Classical Period, has *Pinus, Juglans, Ostrya*-type and *Cannabis*-type as its indicator species. Pines are usually found on poor, rocky soils where more competitive deciduous trees will not grow, but also compete with these trees in less marginal habitats by promoting fire through flammable leaf litter and resinous bark (Grove and Rackham, 2001; Rackham, 1990). The correlations in Table 5.4 demonstrate that *Pinus* and fire are interrelated. Both *Ostrya*-type and *Cannabis*-type represent plants that favour various kinds of disturbance.

The appearance of *Juglans* pollen, alongside *Olea europaea*, strongly suggests that these economically-important plants were introduced to the Tbilisi area by Greek or Roman colonists. While *Juglans* is cultivated near the Tsavkisi Wetland today, the climate in the hills above Tbilisi is too cold for olives, which are not cultivated in Georgia at present. The 18th century Georgian geographer, Vakhushht Bagrationi, describes places on the lower Khrami River which, ‘more than other places, produce pomegranates, figs, olives and other fruits’ because, ‘in winter it is warm and very hot in summer’ (Vakhushht Bagrationi, 1983, p. 428). The low, but consistent percentages of *Olea* pollen in both the Tsavkisi and Kumisi records demonstrate that olives were grown in the lowlands of Eastern Georgia from the Hellenistic Period until relatively recent times.

Phase 3 (pollen zones T-6, T-8, T-9 and T-10): This phase appears several times through the *Pinus-Juglans* stage, namely during much of pollen zone T-6, the upper part of T-8, all of T-9 and sporadically through T-10. Its indicators are
Polygonum aviculare-type and Cirsium-type. These types represent various species that colonise open, often disturbed ground. Other taxa associated with phase 3 include Plantago, Potentilla, Cuscuta, Sanguisorba minor and Gentianella campestris-type, all of which are found in meadows and steppes.

Phase 4 (pollen zones T-6, T-7, T-8 and T-10): The final phase in Tsavkisi’s vegetation development occurs momentarily during pollen zone T-6, through the whole of T-7 and the earlier part of T-8, and finally at various times during T-10. The uppermost sample from the record, representing the present-day vegetation, falls into this phase. Within the context of the Pinus-Juglans stage, indicators of the last phase are Carpinus betulus, Fraxinus and Zelkova-type, all representing deciduous forest trees. This phase occurred at times of greater forest cover, interspersed with the more open and steppic vegetation of Phase 3. This analysis indicates that the vegetation is more forested now than it was 100 years ago, a fact confirmed by early postcards of Tbilisi and aerial photographs taken in the mid 20th century (Figure 5.21).

Based on these results, the following stages of vegetation development, climate and land-use are proposed for the Tsavkisi area (Table 5.6). The conclusion to be drawn from this vegetation history is that the landscape near Tsavkisi Wetland was, for much of the last 8000 years, much less forested than it is today.

Table 5.6. Stages of vegetation development, climate and land-use at Tsavkisi Wetland.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Time (BP)</th>
<th>Reconstructed vegetation</th>
<th>Moisture</th>
<th>Temp.</th>
<th>Land-use</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td>8000-6800</td>
<td>Open rosaceous scrub</td>
<td>Moderate</td>
<td>Cool</td>
<td>Cereals/grazing</td>
</tr>
<tr>
<td>T-2</td>
<td>6800-5100</td>
<td>Shibliak vegetation</td>
<td>Moderate</td>
<td>Warm</td>
<td>Grazing</td>
</tr>
<tr>
<td>T-3</td>
<td>5100-3800</td>
<td>Oak-ash woodland</td>
<td>Wet</td>
<td>Very warm</td>
<td>? Forestry</td>
</tr>
<tr>
<td>T-4</td>
<td>3800-2800</td>
<td>Juniper scrub and phrygana</td>
<td>Moderate</td>
<td>Warm</td>
<td>Heavy grazing</td>
</tr>
<tr>
<td>T-5</td>
<td>2800-2000</td>
<td>Steppe-phrygana</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Heavy grazing</td>
</tr>
<tr>
<td>T-6</td>
<td>2000-1900</td>
<td>Steppic fallow land</td>
<td>Moderate</td>
<td>Cold</td>
<td>? Grazing</td>
</tr>
<tr>
<td>T-7</td>
<td>1900-1600</td>
<td>Hornbeam secondary forest</td>
<td>Very wet</td>
<td>Very warm</td>
<td>? Forestry</td>
</tr>
<tr>
<td>T-8</td>
<td>1600-1000</td>
<td>Ferny meadow (deforested)</td>
<td>Dry</td>
<td>Cool</td>
<td>Orchards</td>
</tr>
<tr>
<td>T-9</td>
<td>1000-600</td>
<td>Steppe</td>
<td>Very dry</td>
<td>Moderate</td>
<td>Grazing</td>
</tr>
<tr>
<td>T-10</td>
<td>600-today</td>
<td>Forest-steppe</td>
<td>Dry</td>
<td>Cool</td>
<td>Forestry/grazing</td>
</tr>
</tbody>
</table>

Climatic characteristics (moisture and temperature) for each zone are relative averages. Timeline based on linear interpolation.
Discussion

Finding Tbilisi’s lost forests

The vegetation history of Tbilisi and its surrounds has attracted the attention of a number of botanists and other workers over the years. The general opinion is that the vegetation of Tbilisi was thickly forested until quite recently, having been destroyed by human activity in recent centuries (Badenkov et al., 1990; Ketskhoveli, 1959; Sakhokia, 1961; Sosnovskii, 1915; Tumajanov, 1971). This is a view that now seems difficult to reconcile with the long histories of steppe and xerophyte communities yielded by the pollen records, but it is nonetheless a view long held and widely accepted.

An alternative analysis of Tbilisi’s vegetation history is presented by the palaeobotanist Avakov (1982). He notes that, in the panoramic drawings made by the French botanist Joseph Tournefort during his visit to Tbilisi in 1702, the hills around Tbilisi appear quite deforested. Likewise, the 1673 engraving by Jean Chardin, although depicting lush avenues of trees and gardens in the city, illustrates the surrounding hills apparently devoid of forest (Figure 5.22).
Any trees around the city were, according to Avakov (1982), probably burnt for charcoal production, and the open areas thus created could then be used economically for grazing, gardens and agriculture. The same author has even observed areas near the city where thick-trunked forest trees (Fagus orientalis) have invaded former agricultural terraces, indicating that a relaxation of human impact has resulted in reafforestation in some places. The pollen records strongly support Avakov’s alternative view.

Forests are, of course, represented in the Tsavkisi pollen record, but their appearance is of far shorter duration than that of xerophyte communities. And any notion that the lost forests were of primaeval character can be dispensed with completely. Forests throughout the Tsavkisi pollen record were as much the product of deliberate human intervention as any other plant community represented. Unfortunately the record does not extend back sufficiently far to see whether primaeval forests existed at any stage during the earliest Holocene, but given the
aridity of the climate at that time (Lemke and Sturm, 1997) and the long history of human habitation in Eastern Georgia (Kiguradze, 1986), it would be surprising if dense, tall-timbered forest was widespread about Tbilisi prior to the Neolithic, except in the most sheltered of situations.

This raises the question of the relative importance of climatic and anthropogenic factors in determining the course of Tbilisi’s vegetation through the Holocene.

**Climatic changes and human impacts**

The climatic trends distilled from the pollen data in this chapter demonstrate that forest cover expanded during phases of warmer and/or wetter climate. Perhaps the best evidence for Holocene climatic change in the Caucasus region is the oxygen isotope record from Lake Van, in eastern Anatolia (Lemke and Sturm, 1997). This record has the advantage of coming from a very large lake (thus reflecting changes on a regional scale), and being independent of its pollen-based vegetation history (Wick et al., 2003) (which is subject to many influences other than climate). Van shows that the climate became gradually warmer and wetter through the course of the early Holocene, peaking in relatively moist and warm conditions between 6000 and 4000 years ago. Then the climate became briefly drier and somewhat cooler, and this cooler climate appears to have lasted until about 2000 years ago. After that time the climate seems to have been quite variable, but not substantially different to what we experience today.

The oxygen isotope curve from Lake Van sits alongside the climatic and forest cover trends from Sakhare, Kumisi, Jvari and Tsavkisi in Figure 5.23. The correspondence between the early part of the record from Tsavkisi and the Van isotopic curve is extraordinarily good. Clearly forest cover in the Tbilisi area at this time was responding very faithfully to variations in temperature and precipitation, perhaps caused by changes to the Atlantic and Mediterranean weather systems during the mid Holocene (Wick et al., 2003). These climatic shifts are also reflected in the changing textural characteristics of the Tsavkisi sediments.
Figure 5.23. Environmental trends from the Tbilisi area compared to a regional climatic trend. Comparison of the Lake Van isotopic records (bold curves at centre) with the results of weighted averaging applied to pollen records from the Tbilisi area (shown at the same scale). INSET: An attempt to match the Kumisi and Jvari records to the Tsavkisi record using environmental trends. The result could suggest that the $^{14}$C date for the Kumisi record is 1000 years too young, while the adopted Jvari chronology is 500 years too old. It may also indicate that Tsavkisi pollen zone T-8 was of shorter duration than the linear age-depth model suggests, which would be more in harmony with the ephemeral plant community represented in T-8.

The close relationship between the Van and Tsavkisi records breaks down during the *Carpinus* expansion at Tsavkisi during the Classical Period. The Tsavkisi climatic record would seem to suggest a dramatic increase in temperature and rainfall at this time. The rainfall trend may be evident also in the Jvari and Kumisi records if their respective chronologies are ignored (Figure 5.23 inset). What changed in the Tbilisi environment two thousand years ago to cause its climatic signal to deviate so considerably from the regional one?

Several possibilities could be entertained. One is that Tbilisi’s climatic characteristics are inherently different to Lake Van’s and hence their history cannot be expected to accord in all aspects. A second possibility is that the isotopic record is less sensitive to certain types of climate change than pollen. A third possibility is that
human impacts on the vegetation have mimicked the influence of climate, quite independently of regional climatic changes.

The Tbilisi and Lake Van areas differ in their climatic characteristics, but also have a number of similarities. Tbilisi is situated at an altitude of 490 m, compared to Lake Van’s 1650 m. Orography is important in the distribution of rainfall, which in both areas varies from less than 500 to over 800 mm per annum (Schweizer, 1975; Svanidze and Papinashvili, 1992). Both experience a period of moisture deficit in summer. This is more pronounced at Van, whereas Tbilisi also has dry winters brought on by persistent anticyclonic activity in lowland Eastern Caucasus (Svanidze and Papinashvili, 1992). Maritime influence on both areas is minor because the mountain ranges of Western Georgia and Northern Anatolia intercept rainfall originating over the Black Sea.

If, however, maritime influence was greater in the past, this might be expected to manifest in Tbilisi to a greater extent. Atlantic low-pressure cells track across the Black Sea from the Mediterranean, bringing heavy rain to the Colchis lowland during winter (Lydolph, 1977). An intensified westerly influence, or a weakened high-pressure cell over Central Asia, could allow moisture-laden, relatively warm air-masses to enter Eastern Georgia during winter, reducing the continentality of the climate.

Two aspects of the Tsavkisi pollen record may support this theory: the appearance of *Olea europaea* pollen and the sharp rise of *Carpinus betulus* in the Roman Period. It seems that *Olea* was grown in the lowlands near Tbilisi in the past when winters were less severe (see Appendix A). An “explosive expansion” (Godwin, 1975, p. 266) of *Carpinus betulus* in some parts of Europe during the Roman Period has been ascribed to the same diminished continentality that allowed grapes to be grown widely in England (Huntley, 1988; Huntley and Birks, 1983). A problem with this theory is that it is not recorded universally in palaeoenvironmental records (e.g. Davis et al., 2003). Nor can it account for the extraordinary rate at which the open landscapes of Tsavkisi were converted from open pastures to dense forest during the Roman Period.

The second hypothesis – that the isotopic record is insensitive to climatic changes that pollen data may record – can be dismissed by comparing the Lake Van isotopic and pollen records (Lemke and Sturm, 1997; Wick et al., 2003). It is true that
isotopic and pollen data record certain climatic events differently (Siegenthaler and Eicher, 1986), but the Lake Van pollen record exhibits remarkable stability throughout the Roman Period, with no evidence for a the forest expansion so apparent at Tsavkisi.

The answer may instead lie in the human history of the area. From the abundance of Sporormiella dung fungal spores in the Tsavkisi sediments, we know that livestock grazing was a very significant, and perhaps dominant, activity in the surrounding land. Its impact on the vegetation was to suppress the growth of forest and to allow scrub, shibliak and phrygana communities to gain the upper hand. This relationship between grazing and vegetation persisted until it was broken down in the Roman Period. After the massive expansion of hornbeam forests during that period, fire thenceforth played a defining role in the ecology of forest and steppe communities.

On the Mediterranean island of Crete, a recent increase in pine in the vegetation has been attributed to a change from a grazing-dominated landscape to a fire-dominated one (Rackham, 1990). If one compares the charcoal (fire indicator) and Sporormiella (grazing indicator) curves from Tsavkisi, they suggest that this same process occurred in the mountains around Tbilisi in Classical times. The economy of the Tbilisi area changed considerably as Western cultural influences were first felt. Land-use of the hills around the city changed from pastures to orchards.

Forest composition changed as well. The importance of Quercus, Juniperus and Fraxinus declined, and forests of Carpinus betulus and C. orientalis expanded suddenly and rapidly. The causes for this event in Europe have been debated for many years (Godwin, 1975; Huntley, 1988; Huntley and Birks, 1983). Around Tbilisi, milder winters certainly could have aided hornbeam’s spread. But to disqualify human intervention would be to ignore the appearance of olive and walnut pollen, the decline of livestock grazing and the increasingly intensive fire regime that led up to the rapid spread of these pure Carpinus forests.
The extraordinary rate at which these trees enveloped the landscape seems difficult to explain in terms of ecological succession. Instead, it seems more probable that hornbeam were already present in the vegetation prior to their expansion. Today, stunted copses of hornbeam grow in many areas that are heavily grazed by livestock (Figure 5.24). These ‘cow coppices’ are so bitten-down that they seldom develop into mature trees. Their pollen production must also be severely restricted. Once livestock are removed, cow coppices of hornbeam grow rapidly, overtopping all other shrubs, herbs and grasses, and turning into forest within a few years. I have little doubt that this process occurred on a large scale at Tsavkisi during the Roman Period. Just why it occurred is a matter for speculation, but as Lang (1966) puts it:

“Once Roman hegemony was established, however, the Iberians rapidly adapted themselves to Roman ways, which had far-reaching effects on Georgia’s social and economic life. The building of roads gave the country access to markets in Asia Minor and other parts of the Roman Empire” (Lang, 1966, p. 86).
The Romans were doubtlessly beguiled by Strabo’s descriptions of the country’s almost incredible bounty. Here, the fruits “spring up for them without sowing and ploughing”, grains “when sown only once produce two crops or even three”, and the vines “yield so much that the people leave a large part of the fruit on the branches” (Strabo, 1928, XI.4.3). Once Georgia was swept forcibly into the Roman Empire’s sphere of trade, it seems that some villagers established orchards and vineyards in suitable places with alacrity, and introduced new plants like the olive and walnut. Grazing was forced into areas not so valued: the lowland steppes and highland grasslands, as well as continuing in places unsuited to horticulture (e.g. Lake Jvari.)

Presumably the utilization of forests changed as well. *Carpinus* wood burns hot and is particularly prized for the manufacture of charcoal (Huntley and Birks, 1983). Removing livestock from the vegetation could allow coppicing practices to be introduced. Coppices can provide substantial quantities of small-diameter wood for charcoal making on a very short rotation (Rackham, 1988; Rackham, 2001). Fire became part of the maintenance and management of these woodlands once grazing livestock were no longer present to control the vegetation. Most of the woodlands around Tbilisi show clear signs of having been coppiced in the recent past.

What the Tsavkisi pollen record suggests is that humans have played a pre-eminent part in shaping Holocene vegetation composition on a local scale. Climate has had more bearing on the density of cover, a relationship that was accentuated by land-use changes during the Roman Period. Tbilisi’s vegetation exists in a state of fragile equilibrium between land-use, forest-cover and climate. In the vicinity of Tsavkisi Wetland, oak forests spread widely only during the early-middle Bronze Age, while since the Roman Period various forms of secondary forest, forest-steppe and steppe prevailed. Vegetation types such as shibliak and phrygana existed since the early Holocene under the influence of grazing, while steppe and secondary forest are moulded to a greater degree by fire (Figure 5.25). At many times during the past 8000 years the vegetation was much more open than at present, a fact that may help account for the area’s high botanical diversity.
Figure 5.25. A schematic model for plant community succession in the Tbilisi area under different and increasing human impacts. The ability of this process to operate in reverse (i.e. reafforestation) is determined largely by topography, since rugged terrain provides ample refuge for forest trees, whilst plains and plateaux, once deforested, are unlikely to recover quickly.

Concluding remarks

In this chapter, I have presented a pollen-based reconstruction of vegetation changes in the Tbilisi area over the past 8000 years. In specific terms, the development of the vegetation in the hills can be traced from scrub and shibliak in the Neolithic and Chalcolithic Periods (8000-5000 years ago), oak-ash woodland in the Bronze Age (5000-3500 cal. yr BP), through to more steppic phrygana communities in the Iron Age (ca 3000 cal. yr BP), to dense secondary forests and cultural vegetation in the Roman Period and finally to a stage where forests were destroyed by fire, recovered and destroyed again, resulting in the present-day landscape of forest and steppe. At a lower altitude (Lake Jvari), the xerophytic vegetation since the Roman Period has been a model of stability. And, under changing climates, the vegetation of the lowland steppes has remained open and grassy through the past millennium.

Significantly, analysis of microscopic charcoal and dung fungal spores has shown that land-use patterns at one site (Tsavkisi) changed dramatically as the Iberian Kingdom was subsumed by the Roman Empire. Up until the Roman invasion, livestock grazing was of great importance in the hills above Tbilisi, leading to the preservation of open vegetation from the earliest times. Grazing maintained xerophytic scrub, shibliak and phrygana communities and prevented the encroachment of forest. But, around 2000 years ago, intensive grazing appears to have declined in favour of orchards, vineyards, gardens and forests. This means that the economy of the hills around the city changed dramatically as cultural and
economic influences arrived from the West, influences that included the cultivation of the olive and walnut.

Climate has always played a role in determining the past character of Tbilisi’s surrounding vegetation, as shown by the expansion of woodland during a warmer, wetter phase 6000-4000 years ago. Rainfall variations have allowed xerophytes to expand in drier phases and grasses under wetter conditions. However, human activity has also been a dominant force on the vegetation around Tbilisi. If fire and grazing are removed, forest rapidly expands from its refuges in the gorges and gullies to cover areas formerly occupied by steppe, scrub and agricultural land (Avakov, 1982).

Since the most ancient of times, farmers and graziers have wittingly curtailed the expansion of forests onto agricultural and pastoral lands, and in doing so have created a varied cultural landscape with its own unique flora. Such a heterogenous landscape has existed near Tbilisi for at least 8000 years, and it could be argued that the entire course of Holocene vegetation development has been shaped by human hands.
CHAPTER SIX
THE TSALKA PLATEAU

Introduction

Let us now turn our attention westward and upward, to the mountain pastures of Southern Georgia and the question of their vegetation history. The Tsalka Plateau is the northernmost part of the South Georgian Uplands, a vast expanse of volcanic terrain that stretches southward from the Trialeti Range to the Georgian border, where it intergrades with the even more extensive highland plateaux of Armenia and northeastern Anatolia. The Tsalka Plateau is hemmed in to the west by the Samsari Range, rising to 3300 m; and to the east by the steep, forested slopes of the Algeti Valley. Its landscape is a striking combination of flat, grassy plains punctuated by the abrupt peaks of volcanic cones and craters (Figure 6.1).

Figure 6.1. Photograph of the Tsalka Plateau at sunset. Near Lake Bareti (August 2003).

All this land is devoid of forest. It is not true to say, however, that the landscape is devoid of trees. The stunted beech trees on Mt Tavkvetili, the pine
savannas of remote parts of Javakheti, the occasional birch above Nariani Vale, the fragments of mountain oak woodland near Tsalka, wild pears on the Ortashua Plateau: these and other examples have suggested to botanists for many years that this landscape was not always without forest (Grossgeim, 1948; Gulisashvili, 1964; Ketskhoveli, 1959; Nakhutsrishvili, 1999; Sosnovskii, 1933).

Historical evidence suggests that at least part of these highlands was forested even as recently as the 16th century. The *Register of the Gurjistan Vilayet*, in which the Ottomans recorded all the towns within their territory, speaks of the “forested Javakheti region in Khertvisi Liva”\(^8\) (Jikia, 1941, p. 191). Vakhushti Bagrationi, the 18th century geographer, mentions pines and spruces growing near Lake Tabisquri, west of the Tsalka Plateau, where no such trees exist today (Vakhushti Bagrationi, 1983).

Archaeological evidence may also point to a forested landscape: Bronze Age grave goods depicting deer-hunting scenes in forests, the extensive use of timber in Bronze Age burial chambers and other constructions, and the presence of forest fauna in archaeological vertebrate assemblages (Bendukidze, 1979; Burney and Lang, 1971; Howell-Meurs, 2001; Kufitin, 1941; Kushnareva, 1997). These disparate lines of evidence point to the intriguing possibility that past landscapes were radically different to those we see today.

But evidence that these highland plateaux were never forested is equally abundant. It includes the palynological investigations of Margalitadze (Margalitadze, 1977; Margalitadze, 1995; Margalitadze and Ramishvili, 1972a), who argued on the basis of four pollen diagrams that grassy vegetation had dominated the Javakheti and Tsalka Plateaux throughout the Holocene. Faunal assemblages from archaeological sites, although containing some forest species, also include fauna more commonly associated with open landscapes (Bendukidze, 1979). The geographical reports of Vakhushti Bagrationi and Joseph Tournefort suggest that the southern highlands of the Caucasus were mostly treeless by the early 18th century (Tournefort, 1718; Vakhushti Bagrationi, 1983). And a few botanists have suggested that the mountain

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\(^8\) Khertvisi is an impressive mediaeval fortress at the confluence of the Kura and Paravani Rivers.
xerophilous plants observed in these highlands indicate that steppic vegetation is the original cover (e.g. Kuznetsov, 1909).

The question of the Tsalka Plateau’s past vegetation is important for understanding the present-day vegetation of the region and for contextualising a very rich archaeological record. It is also of value in estimating how long present-day pastoral activities in the region, such as transhumant grazing, have been practised. The flat, homogenous landscapes of the Tsalka Plateau provide an ideal counterpoint to the extreme variety of the Tbilisi area. While topography and aspect surely have a strong bearing on the direction of vegetation changes around Tbilisi, these factors cannot be considered important on the Tsalka Plateau. This important difference enables the vegetation histories of the two areas to be compared to identify changes driven by regional climate change versus more localised events.

**Topography, climate and vegetation**

The Tsalka Plateau has a muted relief ranging from 1500-1700m elevation and relatively few surface streams. The geology of the Plateau is entirely Plio-Pleistocene basalts, dolerites and andesite-basalts (Gudzhavidze, 2003). Its geomorphology is somewhat more complex, owing to tectonic movements beneath the basalt mantle. Maruashvili (1971) has distinguished seven geomorphological zones (Figure 6.2).

![Geomorphological scheme for the Tsalka Plateau (Maruashvili, 1971). Study sites are numbered thus: 1. Lake Aligol; 2. Lake Bareti; 3. Lake Imera.](image)
The climate is cold and continental. In Tsalka township the average annual temperature is 5.8 °C. The summers are mild, with an average August temperature of 15.8 °C and an absolute maximum of 30 °C (Figure 6.3). The winters are harsh: their average January temperature is −5.3 °C, and the absolute minimum is −32 °C (Kordzakhia, 1961, in Margalitadze, 1977). Rainfall in Tsalka averages 638 mm per annum, most of which falls in May-June (Figure 6.3). The winters are quite dry, but patchy snow cover lasts between 75-100 days per year, arriving at the end of November and remaining until the end of March (AN GSSR, 1964).

The vegetation of the individual study sites is described in Chapter Four. The mountain steppic grasslands of the Tsalka Plateau are very rich in species. The dominant species in every location are grasses: *Agrostis planifolia*, *Festuca valesiaca*, *F. ovina*, *Phleum phleoides*, *P. pratense*, *Dactylis glomerata*, *Deschampsia parviflora*, *Poa pratensis*, *Alopecurus aequalis*, *Agropyron repens*, *Koeleria cristata*, *Melica taurica*, *Nardus stricta* and several others. Tall herbaceous vegetation elements grow amongst grassy meadows in moister places, and include giants such as *Heracleum sosnowskii*, *Cephalaria gigantea* and *Grossheimia macrocephala* (Figure 6.4). Drier places, such as the rocky slope beside Lake Aligol, have a sparser cover of xeric herbs, such as *Hypericum perforatum*, *Thymus rariflorus*, *Allium albidum*, *Sedum oppositifolium*, and rosaceous shrubs. The diversity of *Centaurea*, *Cirsium* and other Asteraceae in these highlands is quite extraordinary.

Apart from the occasional *Salix caprea*, *Quercus macranthera*, *Betula litvinowii* or *Pinus kochiana* tree, the Tsalka Plateau is treeless. According to Ketskhoveli (1959), only 2% of the Tsalka region can be classified as forest, and most of this grows in the ravines bordering the Plateau itself. Pine plantations were
established on the Tsalka Plateau during the Soviet period and now constitute the dominant tree cover in many places.

Figure 6.4. Two Caucasian endemic tall herbs, *Grossheimia macrocephala* (left) and *Heracleum sosnowskii* (right), growing near the Nariani Wetlands of the Tsalka Plateau (August 2003).

The Lake Imera record

Lake Imera is a small, shallow wetland located about two kilometres ENE of Imera village, just north of the Manglisi-Tsalka Road. Its vegetation has been described in detail in Chapter Four and consists of a diverse wetland flora surrounded by steppic grasslands. Although the lake is shallow and a floating sedge mat is gradually covering its surface, it is still visited by fishers, both human and avian. The surrounding meadows are mostly used for haymaking, and their stubble is burnt in autumn. The lake water is quite clean and very low in mineral cations compared to other similar lakes in the region (Table 6.1). Lake Imera has little minerogenic input as a consequence of its small catchment size and gently sloping relief.
Table 6.1. Analysis of lake waters from sites in the Southern Georgian Volcanic Uplands.

<table>
<thead>
<tr>
<th></th>
<th>Imera</th>
<th>Bareti</th>
<th>Aligol</th>
<th>Cherepanov</th>
<th>Gomnis</th>
<th>Tabisquri</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride (mg.l(^{-1}))</td>
<td>&lt;0.5</td>
<td>0.7</td>
<td>3.4</td>
<td>0.6</td>
<td>1.1</td>
<td>4.9</td>
</tr>
<tr>
<td>Nitrate (mg N.l(^{-1}))</td>
<td>&lt;0.25</td>
<td>&lt;0.25</td>
<td>&lt;0.25</td>
<td>&lt;0.25</td>
<td>&lt;0.25</td>
<td>-</td>
</tr>
<tr>
<td>Sulphate (mg.l(^{-1}))</td>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td>&lt;5.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Sodium (mg.l(^{-1}))</td>
<td>&lt;2.5</td>
<td>3.2</td>
<td>&lt;2.5</td>
<td>&lt;2.5</td>
<td>3.2</td>
<td>9.3</td>
</tr>
<tr>
<td>Potassium (mg.l(^{-1}))</td>
<td>&lt;1.0</td>
<td>&lt;1.0</td>
<td>19.4</td>
<td>&lt;1.0</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Magnesium (mg.l(^{-1}))</td>
<td>&lt;2.5</td>
<td>4.4</td>
<td>8.1</td>
<td>&lt;2.5</td>
<td>3.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Calcium (mg.l(^{-1}))</td>
<td>7.1</td>
<td>14.8</td>
<td>30.7</td>
<td>5.6</td>
<td>11.9</td>
<td>8.6</td>
</tr>
<tr>
<td>pH</td>
<td>6.18</td>
<td>6.65</td>
<td>7.37</td>
<td>6.01</td>
<td>6.63</td>
<td>7.40</td>
</tr>
<tr>
<td>Alkalinity (mmol.l(^{-1}))</td>
<td>0.49</td>
<td>1.26</td>
<td>2.83</td>
<td>0.45</td>
<td>1.04</td>
<td>-</td>
</tr>
<tr>
<td>Hardness (mmol.l(^{-1}))</td>
<td>0.29</td>
<td>0.61</td>
<td>1.18</td>
<td>0.22</td>
<td>0.50</td>
<td>-</td>
</tr>
</tbody>
</table>


**Sedimentology and dating**

The Lake Imera cores were collected from the floating sedge mat, as close to the centre of the lake as possible. The first core was collected in May 2002 by Dr Ian Thomas (University of Melbourne). This core was 198 cm long. Michael Fletcher and I made a second expedition to Lake Imera in September 2003 and, with the aid of a ‘sticky clay’ auger, reached weathered bedrock at 393 cm from the same coring location (Figure 4.19).

The sediments of the Imera cores consist of alternating peat and silt layers in the upper part, and compact grey silt in the lower section. The major changes in sedimentology are shown in Figure 6.5. Detailed information on the Imera sediments is provided in Tables 6.2 and 6.3.

![Figure 6.5. Simplified graphic comparison of Lake Imera sediment cores from 2002 and 2003.](image-url)
Table 6.2. Sediment description of the 2002 Lake Imera core.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Colour (Munsell)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-47</td>
<td>10YR2/1</td>
<td>Sedge peat with increasing decomposition and silt content with depth</td>
</tr>
<tr>
<td>47-61</td>
<td>10YR2/1</td>
<td>Black silt with organic inclusions</td>
</tr>
<tr>
<td>61-92</td>
<td>10YR1.7/1</td>
<td>Peat with silt in upper and lower sections</td>
</tr>
<tr>
<td>92-108</td>
<td>10YR3/1</td>
<td>Black silt with organic inclusions</td>
</tr>
<tr>
<td>108-146</td>
<td>10YR2/1</td>
<td>Peat with variable silt content, <em>Potamogeton</em> and <em>Ceratophyllum</em> macrofossils</td>
</tr>
<tr>
<td>146-152</td>
<td>10YR1.7/1</td>
<td>Sharp transition (146 cm) to black silt with organic inclusions and charcoal</td>
</tr>
<tr>
<td>152-198</td>
<td>10YR4/1</td>
<td>Compact grey silts</td>
</tr>
</tbody>
</table>

Table 6.3. Sediment description of the 2003 Imera core. There are some differences in colour between the 2002 and 2003 cores because the 2002 core was described in the laboratory after sampling, while the 2003 core was described in the field during sampling.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Colour (Munsell)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>10YR2/2</td>
<td>Dark brown detritus peat</td>
</tr>
<tr>
<td>10-13</td>
<td>10YR3/1</td>
<td>Grey clay-silt band</td>
</tr>
<tr>
<td>13-30</td>
<td>10YR2/2</td>
<td>Silty peat</td>
</tr>
<tr>
<td>30-60</td>
<td>10YR2/2</td>
<td>Dark brown crumbly peat</td>
</tr>
<tr>
<td>60-63</td>
<td>10YR3/1</td>
<td>Dark grey silt band</td>
</tr>
<tr>
<td>63-105</td>
<td>10YR2/1</td>
<td>Decomposed sedge peat, with many black bands (charcoal particles)</td>
</tr>
<tr>
<td>105-115</td>
<td>10YR1.7/1</td>
<td>Black humic silty peat</td>
</tr>
<tr>
<td>115-190</td>
<td>10YR4/1</td>
<td>Compact grey silts</td>
</tr>
<tr>
<td>190-206</td>
<td>10YR1.7/1</td>
<td>Blackened silts. Abundant macroscopic charcoal particles</td>
</tr>
<tr>
<td>206-240</td>
<td>10YR4/1</td>
<td>Compact grey silt with small white mineral concretions at 215cm-depth</td>
</tr>
<tr>
<td>240-276</td>
<td>10YR4/1</td>
<td>Compact grey silt with many small, angular pebbles and sand</td>
</tr>
<tr>
<td>276-370</td>
<td>10YR4/1</td>
<td>Compact grey sandy silt with no pebbles</td>
</tr>
<tr>
<td>370-393</td>
<td>10YR4/1</td>
<td>Compact grey sandy silt with many small pebbles. Weathered bedrock at 393cm-depth.</td>
</tr>
</tbody>
</table>

The two cores correlate well stratigraphically, and for this reason, when constructing a continuous record, depths for the 2003 core were corrected with reference to lithological changes in the 2002 core; specifically the 41 cm difference between the upper boundary of black silty sediments at 146 cm in the 2002 core and 105 cm in the 2003 core.

Apart from depth, the major difference between the two cores is the depth of the uppermost peat layer. The reason the 2003 core is truncated is that this core was taken through the sedge mat floating on the lake, whereas the 2002 core was taken 2 metres to the west, from the edge of the mat in open water. A period of sediment deposition is therefore missing from the top of the 2003 core. It also must be noted that the greenish sandy sediments between 276 and 393 cm in the 2003 core (equivalent to 317-434 cm, 2002 core) contained negligible amounts of pollen, and
probably correspond to a terrestrial palaeosol or weathered basalt rather than wetland or lake sediment.

Magnetic susceptibility and loss-on-ignition measures are negatively-correlated throughout the Lake Imera core (Figure 6.6). This indicates that magnetic minerals are held in the inorganic fraction, which is probably enriched with basaltic titanomagnetite particles (Thompson et al., 1975). There is no evidence in the charcoal record (see below) for catchment fires causing magnetic susceptibility variations (sensu Gedye et al., 2000; Rummery, 1983).

![Figure 6.6.](image)

**Figure 6.6.** The Lake Imera core: lithology, core overlap, radiocarbon dating, magnetic susceptibility, loss-on-ignition and arboreal pollen ratios. Pollen zones shown at right.

Perhaps the most striking relationship in the Imera record is between organic content and arboreal pollen percentages (Figure 6.6). The peaty sediments contain high proportions of arboreal pollen, whereas non-arboreal pollen dominates in the hard, silty sediments. As noted in Chapter Four, AP:NAP ratios in the study area reveal much more about the sedimentary environment than they do about forest cover. This is because small, shallow lake basins tend to desiccate under the semi-arid climate. In the Tsalka region, lake levels are usually lowest in spring, when most trees are releasing pollen. On this basis, it is suggested that the reductions in the
AP:NAP ratio represent low lake levels (at least seasonally) and reduced pollen source area, rather than having any ecological significance. Lake Imera is particularly sensitive to changes in precipitation and evaporation as it is a closed lake that relies completely on rainfall and groundwater to sustain its water level.

The six radiocarbon dates from the Imera material fit a consistent chronological series (Figure 6.6, Appendix D). Sedimentation rates have varied quite considerably through the last 10,000 years. The highest sedimentation rates are recorded between 1530-930 cal. yr BP (1 mm per annum), followed by the period of 4850-4470 cal. yr BP (0.8 mm p.a.). The slowest rates were in the early part of the record (7471-4850 cal. yr BP: 0.02 mm p.a.). In general, peat layers accumulated at least twice as quickly as the silty sediments.

![Figure 6.7. A tentative lake level curve for Lake Imera, based on sedimentological data. Age model based on linear interpolation of radiocarbon dates (Figure 6.17).](image)

The sedimentological data can be brought together with the radiocarbon chronology to provide a sequence of lake level fluctuations over the past 10,000 years (Figure 6.7). This curve is limited by the accuracy of the radiocarbon determinations as well as the sensitivity of the measured sedimentological variables to lake level change. The lowermost levels, of probable late Pleistocene age, accumulated when the lake was dry. Low lake levels continued through the early Holocene, but gave way to slightly moister conditions about 8000 years ago. The lake began to dry again beginning 5000 years ago and low lake levels continued until about 2300 cal. yr BP. After this the lake filled completely and peat began to form. Peat formation progressed until interrupted by two drying phases: a short spell of perhaps a century’s duration around 1500 years ago, followed by a longer droughty period lasting from
about 800 to 1200 AD. Lake levels reacted to increased evaporation, reduced rainfall or changes in seasonality during all low phases.
Figure 6.8 (above and previous page). The Lake Imera pollen diagram. Percentages calculated from separate arboreal and non-arboreal pollen sums. See Appendix E for the complete diagram.
Pollen diagram

Lake Imera’s pollen diagram (Figure 6.8) has been constructed using percentages calculated from separate arboreal and non-arboreal pollen sums. This is to account for the changes in source area that occurred during low lake levels. The silt-rich sediments contain abundant pollen of local types from the Poaceae, Asteraceae, Lamiaceae, Brassicaceae and Polygonaceae families. Under the pollen source-area model proposed by Jacobson and Bradshaw (Jacobson and Bradshaw, 1981), Lake Imera’s pollen spectra will be dominated by ‘regional’ pollen when the lake is full. Any reduction in water level, and hence site diameter, will result in ‘extra-local’ and ‘local’ pollen flooding the lake’s pollen spectra (Figure 6.9).

![Figure 6.9](image)

Figure 6.9. Relationship between lake levels and pollen source-area at Lake Imera. A. Schematic cross-section of Lake Imera, with water depth and basin diameter measurements based on field observation. B. Pollen source-area versus basin size (after Jacobson and Bradshaw, 1981); dashed lines indicate the relative contribution of regional, extra-local and local pollen at varying lake levels. Depths as measured at the coring site.

Pollen preservation in the peat sediments was very good. The same could not be said of the silty strata, in which a small proportion of pollen grains were corroded. Pollen degradation occurred when the lake dried and its sediment surface was exposed to oxidation. Preservation was not so bad, however, as to prevent confident pollen identification. The pollen diagram is divided into five stratigraphic zones:

Zone I-1. The first zone, spanning the period from approximately 10,000 to 5000 cal. yr BP, has high proportions of Carpinus betulus, Fagus, Zelkova-type and Corylus amongst the arboreal pollen, and non-arboreal pollen dominated by Poaceae, Cichorium-type, Ranunculus-type, Apiaceae and Polygonum aviculare-type. A striking feature of this zone is the large amount of Dipsacus-type, Campanula, Thalictrum, Filipendula and pollen of other subalpine herbs. Some of these insect-pollinated plants are very much under-represented palynologically, such that their
abundance in pollen zone I-1 suggests that subalpine herbaceous plants were widespread, if not dominant, in the early-mid Holocene vegetation around Lake Imera. The wetland vegetation of that time consisted mostly of grasses and sedges, consistent with low lake levels. Charcoal concentrations are high through the middle and upper parts of the zone.

Zone I-2. The second zone begins with a substantial peak in charcoal concentrations, which suggest that fires were commonplace on the Tsalka Plateau between 6000 and 5000 years ago. As the fires became increasingly intense, fire-adapted taxa such as Pinus and Alnus increased in importance, while Carpinus betulus and Zelkova-type declined. The cessation of fires after 5000 cal. yr BP led to the expansion of Quercus (probably Q. macranthera). The ground flora changed at the same time. Most of the subalpine herbs so prevalent in the first zone yield to Lamiaceae, Fabaceae, Caryophyllaceae, Polygonaceae, Papaver and Hypericum-type. These are types more characteristic of dry grasslands than of herbfields. However, since Chenopodiaceae and Artemisia percentages are reduced through this zone, there is no evidence for the expansion of true steppe vegetation.

Zone I-3. Towards the end of the second zone and beginning of the third, Quercus begins to decline. Between 3500 and 2500 cal. yr BP, a cooling climate led to the contraction of oaks and their replacement by pine (Pinus kochiana) and fir (Abies nordmanniana). Triticum- and Secale-type pollen suggest that grain was being cultivated in close proximity to Lake Imera at this time. Like the previous zone, charcoal concentrations are low and the wetland vegetation was composed of grasses and sedges.

Zone I-4. Beginning some time around 2400 cal. yr BP, this zone sees the complete transformation of the vegetation. The most significant aspect of this zone is the extraordinary abundance of charcoal in the sediments. Numerous charcoal peaks suggest that fires ravaged the Tsalka Plateau frequently between 2400 and 1700 cal. yr BP. Their impact on the vegetation was profound. Abies, a tree easily killed by fire (Tinner et al., 2000), ceased to exist in the vicinity of Lake Imera. Even pine was reduced through successive fires. Grassland herbs such as Chenopodiaceae, Artemisia, Galium, Liliaceae, Urtica, Rumex and Plantago species increased dramatically, signalling the arrival of more open vegetation. This zone also sees the arrival of Juglans and Olea europaea. After deforestation, Lake Imera began to fill
with water, which was readily colonised by *Potamogeton*. Sedges and grasses were pushed to the lake fringes by elevated water levels.

Zone I-5. The final zone is characterised by relative vegetation stability. The destructive fires of zone I-4 gave way to a cycle of low-intensity burning in zone I-5, which may have helped to maintain the grassland vegetation in a state of ‘plagioclimax’. Grazing appears to have been an important land-use during the past 2000 years, indicated by rising percentages of *Plantago major*-type, *P. lanceolata*-type, *Rumex* and *Pteridium*. Two lake regressions, at 1500 and 1000 cal. yr BP respectively, allowed the plants represented by *Polygonum aviculare*-type, Brassicaceae and *Cichorium*-type pollen to colonise the drying lake bed, just as they had done through much of the early and mid Holocene.

**Numerical analyses**

As in previous chapters, the approach to analysing these data with multivariate methods relates back to the environmental gradients produced in Chapter Four. The result of applying weighted averaging to the Lake Imera pollen data is given in Figure 6.10. It shows that the first trend, one of rainfall, confirms the lake level reconstruction in Figure 6.7. Effective moisture was moderate during the early and middle part of the Imera record, with a distinct ‘dry spell’ during the oak expansion of 5000-3000 cal. yr BP. Then, it seems, rainfall increased and peaked around 2000 years ago. Two dry spells occurred in the late Holocene: one at 1500 cal. yr BP, and a later, longer one centred on the Mediaeval Period.

It is difficult to determine whether this trend is indeed a measure of actual precipitation, or reflects changes in local vegetation due to lake level fluctuations or soil moisture availability. Evidence for a dry spell at Lake Imera between 5000-3000 cal. yr BP conflicts with evidence from Lake Van that this period was one of high lake levels and an ‘optimum’ in temperature and precipitation (Wick et al., 2003). However, the hydrology of Lake Imera is very different to Van, driven by direct precipitation, groundwater fluctuations and evaporation. High rainfall in early summer now sustains Lake Imera through the hottest and driest months of late summer. Low lake levels could be expected if this rainfall arrived earlier or was distributed more evenly through the year. An hypothesised mid-Holocene increase in
winter rainfall relative to summer rainfall (Wick et al., 2003) seems to fit with this explanation. Hotter summers could cause Lake Imera’s level to drop independently of any change in precipitation. And because groundwater levels in a plateau landscape can be strongly influenced by the presence or absence of trees, which act as groundwater ‘pumps’ (Moore, 1986; Moore and Evans, 1991), any tree cover in the past could have drawn down Lake Imera considerably.

Figure 6.10. Environmental changes at Lake Imera: rainfall, forest cover and land-use gradients produced by weighted averaging. Chronology based on linear interpolation of calibrated $^{14}$C ages.

When the gradient of forest cover is applied to the Imera material, three phases of afforestation are apparent. The first occurred during the expansion of Carpinus betulus and Zelkova-type around 7500 years ago; the second during the oak expansion of 5000-3000 cal. yr BP; and the third in recent decades. With DCA axis 2 values below 80, none of these afforestation events is substantial enough to suggest that trees more than partially covered the landscape. Not surprisingly, the phase with the least forest cover is associated with the large fires beginning 2400 years ago.

The third trend may pertain to land-use. If so, it indicates that grazing intensified during the Mediaeval Period. Secondary forest succession was greatest following the cessation of fires 5000 years ago and after the demise of oak woods 3500-3000 years ago.
Table 6.4. Stages in vegetation development, climate and land-use at Lake Imera.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Time (BP)</th>
<th>Reconstructed vegetation</th>
<th>Moisture</th>
<th>Temp.</th>
<th>Land-use</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-1</td>
<td>10000-5000</td>
<td>Meadows and mixed woods</td>
<td>Moderate</td>
<td>Warm</td>
<td>Grazing?</td>
</tr>
<tr>
<td>I-2</td>
<td>5000-3200</td>
<td>Oak-dominated savanna</td>
<td>Dry</td>
<td>Very warm</td>
<td>Various</td>
</tr>
<tr>
<td>I-3</td>
<td>3200-2400</td>
<td>Open coniferous woodland</td>
<td>Moderate</td>
<td>Cold</td>
<td>Cereals?</td>
</tr>
<tr>
<td>I-4</td>
<td>2400-1600</td>
<td>Treeless grasslands</td>
<td>Wet</td>
<td>Cool</td>
<td>Grazing</td>
</tr>
<tr>
<td>I-5</td>
<td>1600-0</td>
<td>Grassland with few trees</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Grazing</td>
</tr>
</tbody>
</table>

Climatic characteristics (moisture and temperature) for each zone are relative averages.

In terms of vegetation development, these data are synthesised in Table 6.4. The vegetation surrounding Lake Imera went from moist subalpine meadows with a scattering of trees, through a stage in which oak was the dominant tree and the ground flora was dry grassland; oaks were replaced by conifers as the climate cooled, and these in turn gave way to treeless grasslands after a series of destructive fires. The continued impact of grazing, burning and small-scale cropping has maintained this essentially deforested landscape through until the present-day.

The Lake Bareti record

Lake Bareti is situated only 3 km WNW of Lake Imera, separated from it by a low hill called Mt Bareti (1670 m). Lake Bareti is much larger than Lake Imera, but is still quite a shallow lake. It lacks the distinct terraces seen at Lake Imera because it has a small, intermittent outflow to the west. Like Imera, however, the lake’s water balance is determined by direct precipitation, runoff, groundwater and evaporation, as it has no permanent inflow. The lake basin is home to a pine plantation and some abandoned fishing huts. Today, the surrounding land is used mainly for grazing and haymaking.

Sedimentology and dating

Prof. Brigitta Ammann, Willi Tanner (Institute of Plant Sciences, Bern University) and I collected the Lake Bareti core from a boat in August 2003. We used a Perspex piston corer with a barrel 130 cm long and obtained a core of that length from the centre of the lake where the water was 155 cm deep. The material was dark brown, homogenous gyttja with an increasing proportion of silt in the lower 30 cm.
As the core contained no visible stratigraphic changes, no sediment description is given here.

Loss-on-ignition and moisture content provide more insightful information on the sedimentology of the Lake Bareti core (Figure 6.11). Organic content peaks at around 50% in the middle part of the core. The upper 30 cm, and particularly the lower 30 cm, have a higher proportion of inorganic material – as much as 75% at a depth of 100 cm. At various points in the lake’s history, either inorganic input increased through catchment erosion, or lake productivity declined.

One radiocarbon date was obtained on bulk carbon at 122-124 cm depth. This yielded an age of $900\pm40 \, ^{14}\text{C} \text{yr BP}$ (OZH-070), corresponding to calendar years between 1032-1217 AD. Since that time the Lake Bareti sediments have been accumulating at an average rate of 1.3 to 1.7 mm per annum.

![Figure 6.11](image)

**Figure 6.11.** The Lake Bareti core: lithology, radiocarbon dating, moisture and organic content determinations, and pollen summary. Pollen zones at right.
Figure 6.12 (above and previous page). The Lake Bareti pollen diagram. Percentages calculated from separate arboreal and non-arboreal pollen sums. See Appendix E for the complete diagram.

Pollen diagram

The Bareti material contained abundant, well-preserved pollen from a great diversity of plants. The pollen diagram (Figure 6.12) is divided into two pollen assemblage zones:

Zone B-1. Non-arboreal pollen dominates the first zone. Amongst these, Poaceae, Chenopodiaceae and Artemisia are the most prevalent. Arboreal pollen occupies a subordinate position, comprising less than 35% of the dryland pollen sum. Pinus is dominant, followed by Quercus, Fagus, Carpinus betulus and Ostrya-type.
Amongst aquatic pollen, Cyperaceae, *Myriophyllum* and *Equisetum* are well represented, as are *Pediastrum*, *Botryococcus*, *Spirogyra* and other fungal remains. Charcoal concentrations are low throughout the early part of the Bareti record.

**Zone B-2.** The second zone differs very little in pollen composition to the first. The major difference lies in the abundance of arboreal pollen, which in this zone averages 55%. Increasing proportions of *Plantago lanceolata*, *P. major* and *Urtica* in the upper 30 cm suggest some localised disturbance in the catchment in the last century. The age of this disturbance is confirmed by the appearance of *Ambrosia*-type pollen in the upper part of the record. Disturbance had a considerable impact on the wetland vegetation, as Cyperaceae, *Myriophyllum*, *Alisma* and some algal species increase quite dramatically in the upper part of the record. This may relate to recent eutrophication due to construction works and the establishment of pine plantations during the Soviet Era or from the earlier peopling of the Tsalka Plateau by Pontic Greeks displaced from Turkey in the late 19th and early 20th centuries.

**Numerical analysis**

Overwhelmingly, the Lake Bareti record demonstrates stability in highland vegetation over the past 800-900 years. Weighted averaging produced three trends (Figure 6.13). The first of these closely resembles the ratio of arboreal pollen to non-arboreal pollen and relates to moisture. As the nearby Lake Imera record has shown, this trend may relate simply to lake regression, which, by reducing pollen source area, increases the relative abundance of herbaceous pollen. At Lake Bareti this is reinforced by the loss-on-ignition, Cyperaceae and *Myriophyllum* curves, which indicate a reduced lake level in the lower and upper parts of the record. Between 900 and 700 years ago, Lake Bareti existed as a shallow wetland. It is tempting to associate this regression with the climatic anomaly often called the ‘Mediaeval Warm Period’ (Bradley et al., 2003) since there is no pollen evidence for afforestation at this time.

The second trend, of forest cover and temperature, seems to suggest that some afforestation has occurred in recent decades. *Quercus* pollen has become more abundant in the Bareti sediments recently, whereas *Pinus* has declined somewhat. This is surprising given that pines have presumably increased in the lake catchment
after being planted there following World War II. The same recent increase in reconstructed forest cover is seen in the Imera material and may reflect a broad-scale pattern. It must be kept in mind that this ‘forest cover’ gradient also responds to changes in temperature.

![Figure 6.13. Environmental changes at Lake Bareti: rainfall, forest cover and land-use gradients produced by weighted averaging.](image)

The third trend appears to indicate that grazing was of increased importance during the late Mediaeval Period and the 20\textsuperscript{th} century compared to other times. The paucity of dung fungi in the Bareti material unfortunately prevent any independent analysis of this trend, although pollen types associated with grazing do appear in greater abundance during the upper and lower parts of the record. These anthropogenic indicators are associated with lower charcoal concentrations, suggesting that land-use patterns did indeed shift.

While these trends are suggestive of changes, they were changes of a very low magnitude. For at least the last 900 years, mountain grasslands like the present ones have existed in the landscape around Lake Bareti.
The Lake Aligol record

Twelve kilometres west of Lake Bareti lies Lake Aligol. This small wetland is situated mid-way between the town of Santa and the Tsalka Reservoir (Figure 6.2). The site is now bypassed by the British Petroleum Baku-Tbilisi-Ceyhan oil pipeline. The site’s elevation is 1534 m above sea level. Its catchment has muted relief and is composed of Upper Pliocene to Quaternary lava flows (dolerite and andesite-basalt), and the lake itself is approximately 200 by 300 m in diameter. Although the site has a potential catchment area of 1 km$^2$, overland flow is negligible due to the porosity of the surrounding volcanic plains. Santa Township relies on springs for their water supply, suggesting a significant groundwater increment in this terrain.

The water of the lake is generally harder and higher in cations than other volcanic lakes of the region (Table 6.1). This is probably due to the lake being much reduced in volume, thereby concentrating chemical solutes within the remaining water body. The weathered boulders at the southern end of the lake suggest a basin of considerable age, such that dissolved salts may have been accumulating in the basin.
water for a significant length of time. The size of the catchment, its erosion history and groundwater may also influence the water chemistry.

Lake Aligol occupies a closed basin dammed by a basaltic outcrop (Figures 6.14 and 6.15). The water depth in the centre of the lake was 64 cm in early September 2003, and it is reported as having been dry during ornithological surveys carried out in March and April 2000 (Anon., 2002). A distinct lake terrace on the eastern side of the basin and black organic soil along the excavated pipeline route, however, provide evidence that the lake level has been significantly higher in the past (Figure 6.15). The current area occupied by wetland vegetation and standing water covers six hectares.

![Figure 6.15. Map of the morphometry of Lake Aligol, including sampling locations and cross-sectional profiles of the lake terrace (source: ground survey, 2003). Shrubs at foot of basalt outcrop: P: Populus nigra; S: Salix caprea; M: Malus orientalis.](image)

Land use around Lake Aligol presently consists of rangeland grazing and haymaking. There are several recent pine plantations on the hills behind the village of Santa (Figure 6.14), and terraced fields and gardens within the village. The presence of several Bronze Age ‘kurgans’ (burial mounds) in the area between the lake and the Tsalka Reservoir speaks of quite different land uses in the past.
Table 6.5. Comparison of plant community composition and pollen spectra at Lake Aligol (‘pollen 1’ = lake centre sample; ‘pollen 3’ = near shore sample). See Table 4.2 for explanation and legend.

<table>
<thead>
<tr>
<th>Trees and shrubs:</th>
<th>% cover</th>
<th>% pollen 1</th>
<th>% pollen 2</th>
<th>% pollen 3</th>
<th>Pollen type represented</th>
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<tbody>
<tr>
<td>Salix caprea</td>
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<td>Populus nigra</td>
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<td>Populus</td>
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<td>Rosa spinosissima</td>
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<td>Pulsatilla violacea</td>
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<td>Agropyron repens</td>
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<td>Festuca valesiaca</td>
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<td>Sagittaria sagittifolia</td>
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<td>Juncus effusus</td>
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<td>Juncus articulatus</td>
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<td>Scolochloa festuca</td>
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<td>Scirpus lacustris</td>
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<td>Myriophyllum spicatum</td>
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<td>Lemma-type</td>
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<tr>
<td>Lemma trisulca</td>
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</tbody>
</table>
Vegetation

The vegetation surrounding Lake Aligol is very similar to that of much of the Tsalka Plateau, i.e. mountain steppic grassland (Festucetea valesiaca). There are a number of cultivated trees in Santa village, mostly poplars, willows and fruit trees, and pine plantations nearby. A few dwarf shrubs are scattered along the southern shore of the lake, i.e. *Malus orientalis, Salix caprea, Populus nigra* and *Rosa spinosissima*. The dominant species in the grasslands are *Festuca valesiaca* (60-70%), *Bromopsis variegata, Agrostis planifolia* (55-65%) and *Phleum phleoides* (40-45%). A number of other grasses and herbaceous plants were found in our survey and are presented in Table 6.5.

The wetland vegetation is dominated by *Scirpus lacustris* (60%) and *Typha latifolia* (20%). Besides these, the wetland plant association includes the sub-aquatic plants listed in Table 6.5. Because the lake is uniformly shallow, there is no obvious zonation of wetland vegetation in relation to water depth. Aquatic species in the lake include *Polygonum amphibium, Sparganium neglectum, Myriophyllum spicatum* and *Lemna trisulca*.

The pollen spectra of surface sediments (Table 6.5) shows that Poaceae are dominant both in the vegetation and palynologically. This relationship is complicated, however, by the presence of Poaceae in the wetland flora. The same complication arises with Mentha-type pollen, produced both by plants in the wetland (*Mentha arvensis*) and those growing on the dry, rocky slope south of the lake (*Thymus rariflorus*). The shrubs that grow at the foot of this slope are very poorly represented in pollen spectra; arboreal pollen is dominated instead by long-distance transported *Pinus, Quercus, Fagus* and *Carpinus*.

Sedimentology and dating

The Aligol core was collected on 10th September 2003 using a Russian corer and ‘sticky clay’ auger. The sediments were mostly compact silts, but somewhat organic in the upper metre. The auger penetrated to a depth of 310 cm in extremely hard, green-grey, clay sediments.
Table 6.6. Sediment description of the Aligol core.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Colour (Munsell)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>10YR2/1</td>
<td>Organic detritus</td>
</tr>
<tr>
<td>5-21</td>
<td>10YR3/2</td>
<td>Crumbly, tessellated silty peat with iron stains</td>
</tr>
<tr>
<td>21-36</td>
<td>10YR3/1</td>
<td>Black silt with brown bands and organic material</td>
</tr>
<tr>
<td>36-43</td>
<td>10YR3/2</td>
<td>Compact brown peat</td>
</tr>
<tr>
<td>43-48</td>
<td>10YR3/1</td>
<td>Crumbly, tessellated silty peat</td>
</tr>
<tr>
<td>48-56</td>
<td>10YR2/1</td>
<td>Dark brown peat</td>
</tr>
<tr>
<td>56-61</td>
<td>10YR1.7/1</td>
<td>Black silts with crumbly texture</td>
</tr>
<tr>
<td>61-84</td>
<td>10YR3/1</td>
<td>Compact brown peat with sand particles (iron stains 67 - 71 cm)</td>
</tr>
<tr>
<td>84-90</td>
<td>10YR2/1</td>
<td>Crumbly, tessellated silty peat</td>
</tr>
<tr>
<td>90-165</td>
<td>10YR2/2</td>
<td>Dark brown, compact silt</td>
</tr>
<tr>
<td>165-214</td>
<td>10YR4/1</td>
<td>Compact grey silt</td>
</tr>
<tr>
<td>214-236</td>
<td>10YR1.7/1</td>
<td>Black silt with abundant charred particles</td>
</tr>
<tr>
<td>236-252</td>
<td>10YR4/1</td>
<td>Compact grey silt</td>
</tr>
<tr>
<td>252-267</td>
<td>10YR6/1</td>
<td>Light grey silt (microscopy revealed abundant graminoid phytoliths)</td>
</tr>
<tr>
<td>267-310</td>
<td>10GY3/1</td>
<td>Extremely compact, grey-green silt</td>
</tr>
</tbody>
</table>

Figure 6.16. The Lake Aligol core: lithology, radiocarbon dating, magnetic susceptibility, moisture and organic content, and pollen summary diagram. Pollen zones at right.

The complex sedimentology of the Lake Aligol deposits is described in Table 6.6. The upper metre of the core is characterised by dark brown sediments varying in organic and silt content. Several of the organic strata have iron stains, suggestive of redox reactions, and a crumbly, tessellated structure, typical of a dried lakebed. The composition of these sediments was difficult to determine visually – due to lake regressions, it is possible that the peat layers have taken on a more silty texture.
through exposure to the atmosphere and subsequent oxidation. The loss-on-ignition
data therefore provide a better guide to sediment composition (Figure 6.16).

Loss-on-ignition values are highest between 36 and 72 cm depth (Figure 6.16),
corresponding to phases of peat deposition in the Aligol basin. The upper metre of
the core has higher organic content than the deeper sediments, which are mainly
compact silts. Sediments with the lowest organic content were the light-grey silts
between 252-267 cm. These data suggest that Lake Aligol did not exist as a
permanent water body during the earlier part of the sediment record.

Magnetic susceptibility measurements (Figure 6.16) show slightly elevated
values between 310 and 200 cm, lower susceptibility from 200 to 30 cm, and a phase
of high susceptibility in the upper 30 cm. In comparison with the loss-on-ignition
curve, the magnetic susceptibility curve is negatively-correlated. Interestingly, the
magnetic curve indicates enrichment of the sediments in the upper 30 cm,
corresponding to a low organic phase. This suggests that catchment erosion, thought
to be the source of magnetic particles in this basin, increased in more recent times.
Other possible erosion events occurred at 220-200 cm (mid Holocene) and in the
lower part of the record (Pleistocene-Holocene transition).

Ten samples were dated radiometrically. Pre-treatment of these involved
removing the inorganic component by gravity separation (as for pollen), although no
attempt was made to remove organic detritus or chitin. The results are shown in
Figure 6.16 and indicate that the Aligol record begins some 14,500 years ago, making
this the longest highland pollen record from the Caucasus. Two dates are reversed –
219 and 203 cm. It is difficult to reject either of these dates. The older one, 4660±50
\(^{14}\)C yr BP, is perhaps less likely to have been contaminated by younger carbon
through the use of the ‘sticky clay’ auger, but dead carbon introduced to the sediment
by an erosion event (see above) may have increased its radiocarbon age. The younger
date was obtained from the charcoal layer in the Aligol core, and its age agrees much
better with the corresponding charcoal layer and changes in sedimentation in the
Imera core (Zones I-1 to I-2). Rapid fluctuations and possible hiatuses in sediment
accumulation at Aligol mean a degree of uncertainty in deriving an age model. These
uncertainties, where possible, are taken into account below.
Figure 6.17. Age-depth profiles for records from Lake Imera (solid line) and Lake Aligol (dotted line). The graph shows a period of rapid sediment accumulation at both sites between 4000-4500 $^{14}$C yr BP (4400-5100 cal. yr BP), and a similar event associated with the beginning of the Holocene at 10,000 $^{14}$C yr BP (11,500 cal. yr BP).

Sediment accumulation rates in Lake Aligol have been extraordinarily slow. The late Pleistocene material accumulated at around 0.1 mm per annum, rising to three times that amount through the earliest few centuries of the Holocene. Rates then slackened (0.06 to 0.09 mm p.a.), and these lasted until the mid Holocene. Rates increased between 5500-4500 cal. yr BP (0.4 - 1.0 mm p.a.), before decreasing once again to 0.1 mm p.a. The late Holocene has seen a steady increase in accumulation rates, especially in the last 200 years, in which sediment has accumulated at 1.7 mm per annum. Hence Lake Aligol’s history of sedimentation is very similar to that of Lake Imera, with slow early-mid Holocene rates, rapidly increasing with peat formation in the last 2000 years (Figure 6.17).

This shared history is reflected in the lake level curve for Lake Aligol (Figure 6.18). The lake was seasonally dry from the late glacial to the mid-late Holocene, with the most severe desiccation associated with the Younger Dryas. Two thousand years ago, the lake’s water balance changed and lake levels stabilised. After a regression during the Mediaeval Period, the lake became a permanent water body and in that state it remained until very recently.
Figure 6.18. A tentative lake level curve for Lake Aligol. Age model based on linear interpolation, with 4660±50 14C yr BP date excluded.

Pollen diagram

Pollen preservation in the Lake Aligol core was generally very good, with the exception of the late glacial and earliest Holocene (pre-11 kya) sediments. Pollen percentages are calculated from separate arboreal and non-arboreal sums to account for the retraction in pollen source area during each lake regressive phase. The pollen diagram (Figure 6.19) is divided into six pollen assemblage zones:

Zone A-1. In the parlance of Northern European glacial stratigraphy, the Lake Aligol record begins in the Bølling-Allerød interstadial. Pollen spectra from this period are characterised by very high proportions of Chenopodiaceae, *Artemisia* and *Anthemis*-type pollen. In the arboreal group, *Juniperus* and *Ephedra* are dominant. Considered as a whole, these pollen spectra indicate conditions of extreme aridity and the existence of semidesert vegetation with scattered juniper and ephedra shrubs. Sedges grew in the wetland vegetation, along with *Butomus*, and *Pediastrum* bloomed in the water itself. Carbonised particles are constantly represented. Toward the end of this first zone, *Juniperus* and Chenopodiaceae decline, while *Artemisia*, other Asteraceae and *Ephedra* all rise to a conspicuous peak around 12,000 cal. yr BP.

Zone A-2. The second zone represents the first millennium of the Holocene. A succession of arboreal taxa is seen – beginning with *Betula*, followed by *Corylus*, then *Quercus* and a suite of more mesophilic taxa (*Abies, Fagus, Carpinus betulus*, etc.). Poaceae rises in abundance through the zone, along with *Polygonum aviculare*. It is difficult to interpret these because of the possibility that they grew on the dried lake bed. They could represent the expansion of grassy steppe communities in the Aligol area. The persistence of *Artemisia* and *Ephedra* indicates that conditions remained quite cool and arid. An interesting aspect of this zone is its abundance of
Triticum-type pollen. Rather than representing the inception of agriculture, wheat pollen here was probably produced by wild species growing amongst the wetland flora. This is an argument previously invoked by Bottema (1995) to explain high Cerealia-type proportions at Söğütlü, near Lake Van, in an area also known for wild cereals.

Zone A-3. The third zone witnesses the decline of Artemisia, Chenopodiaceae, Ephedra and Juniperus, the four taxa that epitomize late glacial pollen spectra from Aligol. They are replaced by a more mesic assemblage, in which Abies, Fagus, Carpinus betulus, Ostrya-type, Ulmus, Zelkova-type and Tilia are well represented amongst arboreal taxa, and Poaceae, Aster-type, Thalictrum, Apiaceae, Campanula, Dipsacus, Filipendula and Fabaceae become important herbaceous pollen types. This pollen assemblage is very similar to Lake Imera’s assemblage from the same period (Zone I-1). The similarity extends to the fire record: as at Imera, charcoal concentrations peak between 7000 and 5000 years ago (based on the date from the charcoal layer).

Zone A-4. This zone matches Zone I-2 from Lake Imera, in which oak pollen achieves its highest representation among arboreal taxa. At Aligol, the oak maximum is accompanied by elevated proportions of Juniperus, Poaceae, Hypericum perforatum-type, Polygonum aviculare-type and Brassicaceae. These taxa suggest a steppic vegetation type with oaks and junipers. Increases in Typha and Potamogeton-type indicate that water levels in the lake had begun to increase, at least seasonally. In the upper part of this zone Quercus gradually declines as Pinus and Abies move in from higher altitudes.

Zone A-5. The fifth zone sees Pinus rise to prominence amongst arboreal taxa, initially accompanied by Abies, which quickly vanished because of fires in the first millennium BC. Juglans pollen appears around the same time. Non-arboreal taxa indicate a return to less steppic conditions, with subalpine meadow taxa such as Dipsacus and Campanula returning. Brassicaceae (Sinapis-type) percentages are very high throughout this zone. It has been suggested that these may reflect plants (e.g. Cardamine or Rorippa spp.) growing in the wetland vegetation (J. van Leeuwen, Inst. Plant Sci., Bern University, pers. comm.). This hypothesis is supported by the
concomitant increase in *Oxyria*-type,\(^9\) which represents various *Rumex* species that grow, *inter alia*, in wet or seasonally inundated places (*R. crispus, R. maritimus, R. pulcher* and *R. conglomeratus*) (Ketskhoveli, 1975). Toward the end of Zone A-5, the habitat for these weedy species diminished, as higher *Potamogeton* and *Myriophyllum* proportions indicate increasing water levels.

Zone A-6. The final zone in the Aligol diagram is defined by increasing arboreal pollen values overall, related to the deepening of the lake. In compositional terms, however, there is little change from Zone A-5 to A-6. *Ostrya*-type and *Picea* are the only two taxa to show a substantial increase. Amongst herbs and grasses, Poaceae declines somewhat and open ground taxa such as Chenopodiaceae, *Artemisia*, Apiaceae, *Rumex, Plantago major*-type and Fabaceae increase. Spores of the dung fungus, *Sporormiella*, become quite abundant, especially in the upper 30 cm. This final phase appears to bear the distinct marks of heavy grazing, even down to the depletion of sedges (Cyperaceae) in the vegetation. Charred particles are exceedingly abundant through the lower part of the zone.

Figure 6.19 (previous pages). The Lake Aligol pollen diagram. Percentages calculated from separate arboreal and non-arboreal pollen sums. See Appendix E for the complete diagram.
Numerical analysis

A number of problems that relate to dating and sedimentation rates affect the Aligol record. Both Aligol and Imera are shallow lake basins and their sedimentary history is complex, as reflected in pollen influx rates from these sites (Figure 6.20). Periods of increased pollen accumulation coincide, paradoxically, with declining arboreal pollen ratios. It may be that the prominent peaks in pollen accumulation at both sites between 5500-4500 and 1500-1000 cal. yr BP are the product of differential pollen deposition brought about by changing lake levels or alterations to the density of wetland vegetation, but this remains very much an open question.

Slow sedimentation during the early Holocene means that the period from 11,000 to 5000 years ago is represented by as few as five pollen samples, approximately one per thousand years. The same applies to the period 4500 to 3000 years ago, represented by only two samples. Obviously it is difficult to extract meaningful environmental trends over such long time spans with so few samples. Hence the trends extracted by weighted averaging must be viewed with a considerable degree of caution. No doubt future research on lake sediments from Southern Georgia will help refine the coarse picture drawn here.

Figure 6.20 (opposite). A comparison of pollen influx (shaded) and pollen percentages (open curves) from Lakes Imera and Aligol, plotted on a calendar timescale. Arboreal to non-arboreal pollen (AP:NAP) ratios are shown at left and concentrations and influx of charred particles at right.
Figure 6.21. Environmental changes at Lake Aligol: rainfall, forest cover and land-use gradients produced by weighted averaging.

The first trend (Figure 6.21) represents moisture variations. It clearly shows the dry conditions of the late glacial gradually subsiding during the early Holocene. Slightly drier conditions returned, as at Lake Imera, during the oak maximum and later, during the Mediaeval Period.

The second trend differs quite sharply from the first. It has moderate values during the Bølling-Allerød interstadial. With the onset of the Younger Dryas, values plummet dramatically. If this trend is interpreted as representing forest cover, it indicates that the landscape was rendered treeless by events 12,000 years ago. If it represents temperature, it shows that winters became rapidly and considerably colder. The early Holocene birch-hazel advance led to a short-lived afforestation of the highlands at the end of this cold stage. The advance of typical woodland species (*Quercus, Fagus, Carpinus*), however, seems to have been delayed by the aridity of the early Holocene climate, and, around 5000 years ago, by a number of fires. It was not until 4500 years ago that forest cover (in the form of scattered oaks) increased. Subsequent increases can be seen during the late Holocene – around 3000 years ago and 1000 years ago, respectively. None of these, however, are sufficient to suggest that an unbroken forest canopy blanketed the Tsalka landscape. At best, forests were confined to places with suitable drainage and soil moisture, while scattered trees may
have occurred more widely. A series of fires after the Mediaeval Period led to the
demise of whatever trees remained near Lake Aligol in historic times.

The final trend has been interpreted elsewhere as indicating changes in land-
use. A sharp decline during the Younger Dryas may reflect the presence of wild
cereals in the wetland vegetation, as discussed above. If the remainder of the record is
representative of grazing intensity, then it appears that grazing increased in the Aligol
area 4500 years ago and continued through until approximately 2500 years ago. It
resumed in the Mediaeval Period, perhaps as the climate became more amenable to
pastoral activity, and has since remained an important economic practice on the
Tsalka Plateau.

Table 6.7. Stages in vegetation development, climate and land-use at Lake Aligol.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Time (BP)</th>
<th>Reconstructed vegetation</th>
<th>Moisture</th>
<th>Temp.</th>
<th>Land-use</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>14.5k-12k</td>
<td>Glacial semidesert-savanna</td>
<td>Very dry</td>
<td>Warm</td>
<td>?</td>
</tr>
<tr>
<td>A-2</td>
<td>12k-11k</td>
<td><em>Artemisia</em> steppe with birch &amp; hazel</td>
<td>Dry</td>
<td>Very cold</td>
<td>?</td>
</tr>
<tr>
<td>A-3</td>
<td>11000-5000</td>
<td>Meadows and mixed woods</td>
<td>Moist</td>
<td>Warm</td>
<td>?</td>
</tr>
<tr>
<td>A-4</td>
<td>5000-4000</td>
<td>Oak-juniper savanna</td>
<td>Moderate</td>
<td>Warm</td>
<td>Grazing*</td>
</tr>
<tr>
<td>A-5</td>
<td>4000-900</td>
<td>Open coniferous woodland</td>
<td>Moderate</td>
<td>Warmer</td>
<td>Grazing/crops</td>
</tr>
<tr>
<td>A-6</td>
<td>900-0</td>
<td>Treeless grasslands</td>
<td>Moderate</td>
<td>Warm</td>
<td>Heavy grazing</td>
</tr>
</tbody>
</table>

Climatic characteristics (moisture and temperature) for each zone are relative averages.

These trends are summarised in terms of vegetation development in Table 6.7.
During the late glacial, semidesert vegetation with scattered juniper and ephedra
shrubs prevailed near Lake Aligol. The climate at that time was hyper-arid, but seems
not to have been particularly cold; in fact, summers may have been warmer than at
present. The next stage was one of *Artemisia* steppe, with *Ephedra* shrubs and
advancing birch and hazel trees. This peculiar assemblage, which has no modern
analogue, may best be explained by conditions of extreme cold. In the early to mid
Holocene, subalpine meadows prevailed in the Tsalka highlands, interspersed with
mixed mesophytic trees and patches of beech woodland. More steppic conditions
came after 5000 years ago, when oaks, junipers and grassland taxa spread to form a
kind of savanna. This was succeeded by open coniferous woodlands and grassy
subalpine meadows, until the final demise of woodland species in the last millennium
and the instigation of heavy grazing and burning.
Discussion

The data presented in this chapter record a remarkably dynamic set of Holocene vegetation changes in the highlands of southern Georgia. The Tsalka Plateau has hot, droughty summers and very cold, snowy winters. These climatic factors alone were sufficient to explain many of the observed variations, especially during the late Pleistocene and early-mid Holocene. Human influences are also apparent from as early as the Chalcolithic Period (5000 cal. yr BP).

As previously noted, botanical researchers have long argued over whether the presently treeless highlands of Southern Caucasus were forested in the past. Small copses of trees in sheltered locations convinced many botanists that, “during the Holocene, when the climatic conditions were similar to those of nowadays, the entire territory of Georgia was occupied by forests” (Nakhutsrishvili, 1999, sect. 6).

Far fewer have been proponents of the idea that forests were never extensive in this part of the Caucasus. Margalitadze, on the basis of several pollen diagrams from the Javakheti and Tsalka Plateaux, concluded that “grassy phytocoenoses were predominant in the South Georgian Highlands during the Holocene” (Margalitadze, 1977, p. 144). Like the pollen diagrams presented in this chapter, Margalitadze’s diagrams were produced from the sediments of small lakes wetlands that appear to have experienced seasonally low water levels through the early and mid Holocene. This constraint made interpretation of the results particularly difficult (N. Margalitadze, Tbilisi Botanical Institute, pers. comm.), since there was no way of accounting for changes in pollen source area at that time.

The modern pollen data set presented in Chapter Four identified climatic and forest-cover trends in the present-day pollen spectra of the study area thought to be independent of pollen source-area variations. The application of the taxa weights generated by that analysis allowed the past forest cover of the Tsalka Plateau to be estimated. The results confirm that grassy communities prevailed throughout the Holocene, but they also demonstrate that open woodlands did, at various times, expand into the highlands as climatic conditions became more favourable. Forests, *senso stricto*, may have grown in protected situations and on better-drained slopes, but on the open plains near Lakes Imera and Aligol, the trees that advanced during the
mid Holocene formed a scattered cover. The term ‘savanna’, in its broadest sense, is perhaps the best structural analogue for this vegetation.

Temperate savannas often occur on flat terrain where the soils are deeply cracking clays (Archibold, 1995). The soils developed from igneous bedrock on the Tsalka Plateau are clay-rich; they are boggy and poorly drained in winter, desiccating and cracking in summer. Cracking soils tend to damage tree roots and favour plants with fine, fibrous root systems, especially grasses. On edaphic grounds it is therefore not surprising that grassy vegetation has dominated the Tsalka Plateau throughout the Holocene. Yet trees can and do establish on the Plateau, so soil was not the only factor limiting forest cover.

Climate changes and human impacts

In attempting to disentangle the influences of climate and humans on past vegetation dynamics, it is useful to compare climatic trends drawn from the pollen data to the regional signal of Lake Van. The Van record is based on two proxies: oxygen isotopes, which in the highly evaporated waters of Lake Van primarily reflect changes in regional water balance and atmospheric circulation (Prof. Neil Roberts, University of Plymouth, pers. comm.), and the Mg:Ca ratio, which is an indicator of lake salinity in the Van basin and hence of past lake levels and effective precipitation (Lemke and Sturm, 1997). Because Lake Van is situated in the same altitudinal zone as lakes Aligol, Imera and Bareti, the magnitude and direction of regional-scale climatic events could be assumed to be the same at all four sites.

Lake Van’s isotopic record is compared to environmental trends from the Tsalka Plateau in Figure 6.22. The most notable feature of the Van curves is the substantial peak in both lake salinity and $\delta^{18}O$ enrichment between 11,000 and 10,000 cal. yr BP. But as Roberts (2002) has rightly pointed-out, the Lake Van varve chronology places the beginning of the Holocene at 10,500 cal. yr BP rather than 11,500 cal. yr BP. It is more parsimonious to associate the peaks in Mg:Ca and $\delta^{18}O$ with the Younger Dryas stadial, which saw temperatures drop sharply across Europe at this time. At the Pleistocene-Holocene transition, lake levels at Van were drawn down by an estimated 260 m, an event attributed to increased aridity (Wick et al., 2003).
When a similar pattern is sought in the Lake Aligol environmental trends, the outcome is striking. The Younger Dryas is clearly portrayed at 11,500 cal. yr BP, but not, as might be expected, in the curve representing precipitation. The Aligol material suggests a dramatic decline in the trend representing forest cover and winter temperature. In contrast, the precipitation trend indicates that rainfall gradually increased through the terminal Pleistocene to peak 6000-7000 years ago. There is no evidence for an episode of increased aridity during the Younger Dryas from Lake Aligol, even though the climate then was more arid than it is presently.

A number of hypotheses could explain this apparent contradiction. It may be that the Aligol trends, because they were derived from modern analogues, are insensitive to no-analogue pollen spectra. That is, the high proportions of *Artemisia* and *Ephedra* pollen associated with the Younger Dryas event at Aligol are unreplicated in any modern plant community in the study area; their pollen types may even represent plants no longer extant. Hence the apparent trend towards colder winters and very open landscapes could be an artefact of the method. This hypothesis could have merit, but for the extraordinarily good agreement between the Aligol and Van curves. It seems very likely, accounting for probable dating discrepancies, that both curves record the same event.

Perhaps Aligol’s Younger Dryas signal is merely one of forest cover and does not reflect changing winter temperatures. Indeed, Aligol and Imera’s WA axis 2 curves from the mid to late Holocene have little in common. The Imera curve follows the Van oxygen isotope record closely, whereas Lake Aligol deviates from it considerably. Dating error cannot explain this divergence, as the precipitation trends from Aligol and Imera are quite similar. It could be argued that the Imera record is therefore sensitive to regional climatic changes, while Aligol is subject to highly localised changes in vegetation. Still, this hypothesis does not explain why the Younger Dryas is so plainly registered at Aligol.
Figure 6.22. Environmental trends from the Tsalka Plateau compared to a regional climatic trend. Comparison of the Lake Van isotopic records (bold curves at centre) with the results of weighted averaging applied to pollen records from the Tsalka Plateau (all shown at the same scale). The Younger Dryas stadial is indicated by grey shading, adjusted to account for the underestimated age of the Lake Van material.

If one accepts the Aligol trend as a true reflection of temperature, then it is possible that colder winters, not aridity, were the defining feature of the Younger Dryas in the study area. Hence continentality, rather than aridity per se, peaked some 12,000 years ago. How, then, can the low lake levels and enrichment of $\delta^{18}$O at Lake Van be explained? Lemke and Sturm (1997), in deriving a model for oxygen isotopes for Lake Van, assumed an overall temperature reduction of 5 °C during the Younger Dryas. This decline was insufficient to fully explain $\delta^{18}$O values from that period, so they factored a 20% reduction in humidity into the model, which accounted for the observed values and also agreed with carbonate geochemistry (Mg:Ca) results.
indicating lowered lake levels (Lemke and Sturm, 1997). From this the authors concluded that the climate around Lake Van during the Younger Dryas was cold and very dry.

Most of the Van region’s rainfall arrives during the cooler months, carried by westerlies from the Mediterranean and originating over the Atlantic. During the Younger Dryas, the influence of the Atlantic thermohaline circulation temporarily weakened, decreasing temperatures throughout Europe (Roberts, 1998). If, as the Aligol record suggests, winters in the region were much colder and more continental than now, winter precipitation would have been much reduced. The dry air of the continental winters could desiccate any snow falling through the winter months, denying Lake Van its source of melt-water and mimicking a reduction in humidity. Moreover, the switching-off of moisture-laden westerlies could increase evaporation during cold, dry winters and shift the rainfall pattern to warmer months. Atmospheric moisture and cloud cover generated by thermal convection currents, for instance, are more likely to have increased during spring and summer, sustaining semidesert-steppe plant life but still exposing Lake Van to intense evaporation. The Younger Dryas was most certainly arid, but perhaps not more than during the previous millennium. Roberts and Wright (1993) suggested that the late Pleistocene climate of Western Asia may have been cloudier or had greater effective moisture due to reductions in temperature and warm season evaporation.

Further support for this hypothesis may be found in the ecology of *Artemisia* and *Ephedra*, two taxa distinctly associated with the Younger Dryas at lakes Van, Aligol and others in the region (see van Zeist and Bottema, 1991). Both of these xerophytes demand some moisture through the growing season (Chikov, 1983; El-Moslimany, 1990). If the Younger Dryas were indeed the period of greatest aridity in the last 14,000 years, it would be unlikely to favour these taxa over Chenopodiaceae. *Ephedra* and *Artemisia* retained an important place in the early Holocene vegetation around Lake Van long after lake levels had risen, while Chenopodiaceae died away as the Pleistocene came to a close.

The early Holocene brought increased humidity to Southern Georgia. The Aligol and Imera records indicate that the climate became gradually wetter, peaking at the same time as water levels rose to their highest stand in Lake Van (Wick et al., 2003). Lakes Aligol and Imera, however, remained low or seasonally dry throughout
this period of increased precipitation and sedimentation rates were exceedingly slow (or later desiccation destroyed evidence of previous high lake levels). Pollen data from these sites suggests a very slow expansion of mixed deciduous communities at lower altitudes and the presence of subalpine herbaceous plants locally, indicating a climate with relatively cool, humid summers. Evidence for cool conditions can also be found in the Tsavkisi pollen record from near Tbilisi (previous chapter). This alone, however, does not explain the slow pace of afforestation. Wright et al. (2003) have invoked early Holocene aridity to explain delayed woodland expansion across the region, but climatic seasonality, human impact and migrational lags may also be considered important factors (Roberts, 2002).

Forest cover trends from lakes Aligol and Imera during the Holocene have little in common. The Imera trend follows the Van temperature variations closely (Figure 6.22). This might be expected because Lake Imera is twice the size of Lake Aligol and its pollen record consequently has a larger, more regional source-area. Interpreted in these terms, local and regional events can be differentiated. While woodlands expanded regionally between 9000 and 7000 cal. yr BP, around Lake Aligol forest cover remained very restricted. Between 7000 and 5000 cal. yr BP, woodland began to expand in the Aligol area, accompanied by ever increasing charcoal concentrations. The Lake Imera charcoal record is similar, and both suggest an increasing occurrence of fire in the vegetation. These fires were not regional but local events, clearly demonstrated by a high proportion of large charcoal particles (see Figures 6.8 and 6.19).

These fires are the first indelible mark of human impact on the vegetation history of the Caucasus region. Natural ignition can be disqualified for several reasons: Firstly, the apparent trend toward lower rainfall between 6000 and 5000 cal. yr BP at Aligol and Imera (Figure 6.22) is not seen in the Lake Van or Tsavkisi Wetland records, suggesting that the apparent drying of the Tsalka Plateau climate at this time is a function not of precipitation, but of heightened summer temperatures. Secondly, if hotter summers led to more frequent fires, there is no reason why these fires should have ceased abruptly 5000 years ago, while summer temperatures continued increasing. Thirdly, the Lake Van charcoal record shows no evidence of any change through this critical period, so it seems improbable that burning related to regional climatic change. Finally, archaeological evidence demonstrates that the Tsalka Plateau was already home to Chalcolithic pastoralists for whom grazing was
an economic mainstay (Kiguradze and Sagona, 2003). Roberts (2002) has hypothesised that human activity and aridity acted together to delay postglacial woodland expansion in Western Asia; this hypothesis is examined further in Chapter Nine.

Five thousand years ago fires ceased abruptly and a scattering of oaks populated the grasslands. Whether oak trees drew down water levels in Tsalka Plateau lakes or the hot, dry summers increased evaporation, low lake levels are characteristic of this phase. Both Van and Imera indicate that temperatures began to decline after 3500 cal. yr BP, allowing conifers to replace the more thermophilous oaks on the Tsalka Plateau. In the absence of fire, conifer woods became relatively dense, but this changed with the reinstatement of a fire regime around 2500-2300 years ago. Fire banished fir trees from the Tsalka Plateau and the vegetation became as open as it is now. High lake levels followed, implying a significant reduction in seasonal drought and continentality. And since deforestation can elevate groundwater in flat terrain, lake levels may have been influenced directly by human impact.

A firm correspondence between the Lake Van and Tsalka Plateau records through the last two thousand years is difficult to detect. The Tsalka Plateau pollen and lake level data indicate a substantial change in precipitation around one thousand years ago, coincident with the so-called Mediaeval Warm Period. Lake levels at Aligol, Imera and Bareti were much reduced through the Mediaeval and it seems that the climate briefly reverted to its mid Holocene state. Yet the Mediaeval here differs from previous climatic events in that it is registered only by the trend of precipitation and summer temperature (Figure 6.22). The Mediaeval Warm Period in Europe is thought to be the result of increased anticyclonic circulation in summer and a strong westerly influence through winter (Bradley et al., 2003). Persistent westerlies would be expected to bring moist, relatively mild winters to the Tsalka Plateau. Low lake levels are thus best explained by intense summer evaporation, but this question may be better addressed using palaeohydrological methods.

**Concluding remarks**

The Tsalka Plateau has yielded a record of changing vegetation, lake levels, climate and human impact spanning the past 14,000 years. The extraordinary
dynamism of its vegetation history is perhaps unexpected in such an unvaried landscape, but it must be remembered that the flat terrain, harsh winters and seasonal aridity that are characteristic features of the Tsalka Plateau today are the very features that make its vegetation so sensitive to climatic changes and human impacts.

Specifically, the Tsalka Plateau’s vegetation history passes from dry semideserts in the late Pleistocene, through the cold *Artemisia* steppes of the Younger Dryas, into a stage of subalpine meadows and advancing woodland that lasted until oak trees became established in open savanna vegetation 5000 years ago. As summers cooled in the late Holocene, oaks were gradually replaced by conifers; these, in turn, gave way to open grasslands in the last 2500 years.

Humans played a critical role in the development of the vegetation, manipulating its density and composition with fire. Six thousand years ago or even earlier, people were using fire to forestall the advance of woodland on subalpine pastures. More recently, between 2500 and 2000 years ago, fire was used to clear the vegetation and since then frequent, low intensity fires and incessant grazing have preserved the Tsalka Plateau’s rich mountain grasslands in a treeless state. The utility of small lakes is plainly revealed through their ability to trace changes of a local character that are obscure in pollen diagrams from large lakes.

In terms of past climate, the Tsalka Plateau records complement the regional climatic signal deduced from Lake Van, Eastern Anatolia. The Tsalka Plateau environmental trends indicate a hyper-arid climate 14,000 years ago led on to the dry, extremely cold winters of the Younger Dryas. The slow advance of woodland in the early Holocene is difficult to explain in climatic terms alone, but conditions were perhaps seasonally drier, cooler and cloudier than at present. By the mid Holocene, summer temperatures had increased, a trend that was reversed 3500-2500 years ago as climates cooled. A period of intensified evaporation followed 1000 years ago, before climates similar to the present established. This interpretation differs in some respects to the arguments of Wick *et al.* (2003) and Wright *et al.* (2003), particularly in relation to the Younger Dryas.

I now return to the original question posed at the beginning of this chapter: Was the Tsalka Plateau ever covered in forest during the Holocene? The evidence suggests that it was not. However, this is not to say that it was never wooded. At
certain, brief moments, scattered trees expanded into the mountain grasslands when climatic conditions and human activities allowed them to do so. On slopes and in gullies, pockets of forest probably existed in the past just as they do now. But the Tsalka Plateau is primarily a pastoral landscape and gives no indication of having been anything else for the last 11,000 years.
CHAPTER SEVEN
THE BLACK SEA COAST

Introduction

The foregoing chapters have dealt with the vegetation history of the semi-arid parts of Southern Georgia. Vegetation changes there can mainly be explained by variations in precipitation, temperature, and to a considerable degree, the impact of humans. The plain similarities between climatic records from Southern Georgia and Eastern Anatolia point to a common climatic history in the continental interiors of Western Asia. Undoubtedly aridity and continentality have had a strong bearing on the direction of past environmental change.

In areas where the climate is moist and maritime-influenced, aridity and continentality are not limiting factors for vegetation development. Even within the same geographic region, therefore, the vegetation histories of the coast and inland may diverge considerably. Comparing the impact of past events across a climatic gradient allows hypotheses about the nature of these events to be tested. Common aspects of history can be assumed to have large geographic extent, while differences point to more localised changes that may arise as a consequence of bioclimatic patterns. This chapter presents a pollen record from the humid Black Sea coast of Georgia as a climatic ‘control’ to the records thus far presented.

The Colchis Lowland

It could be argued that this part of the Black Sea coast lies in Southern Georgia, but it is outside the bounds of the study area as defined in Chapter Four and so it is appropriate to provide a general introduction to Western Georgia’s environment and history.

The Colchis lowland of Western Georgia is perhaps the most important refugium of Tertiary relict plants in Eurasia (Berg, 1950; Denk et al., 2001; Kikividze and Ohsawa, 2001). Colchis, known as Kolkheti in Georgian and Kolkhida in Russian, is a part of the Caucasian refugium, which also includes the southern coasts
of the Black and Caspian Seas. It is one of three major locations in Western Asia where thermophilous plants survived the cold and aridity of glacial periods (Röhrig, 1991). During the last glacial maximum, while most of Eurasia was covered by steppe and tundra vegetation, mixed deciduous and coniferous forests survived in Western Georgia (Tarasov et al., 2000). As a result, species-rich Colchic forests combine elements of Mediterranean, Euro-Siberian, Euxinian, Hyrcanian and East Asian floras (Nakhutsrishvili, 1999).

Colchis is perhaps best known as the legendary destination of Jason and the Argonauts. But far from being a mythical land, abundant archaeological evidence shows that this coastal plain was very densely populated during the 1st millennium BC and earlier, with highly-developed metallurgy from the mid-2nd millennium BC and Greek colonies from the 6th century BC (Lordkipanidze, 1994b; Tsetskhladze and Treister, 1995). Prehistoric settlements of the Black Sea coast of Colchis were of an unusual sort, inasmuch as they were situated on artificial mounds reclaimed from the wetlands and connected by canals.

A major force of environmental change in the Black Sea region is the Sea itself. It existed as a huge lake, isolated from the Mediterranean, during much of the Pleistocene and early Holocene (Fedorov, 1988). The proposition of a great early-Holocene deluge in 7550 cal. yr BP has initiated scholarly debate of biblical proportions (Aksu et al., 1999; Atanassova, 2005; Ballard et al., 2000; Görür et al., 2001; Mudie et al., 2002; Ryan et al., 1997; Uchupi and Ross, 2000). Even in the time period encompassed by this chapter, the Colchis coastline has experienced a number of marine transgressions and regressions. Most significant were the New-Black-Sea transgression (6500-4500 cal. yr BP), the Phanagorian regression (4500-2000 cal. yr BP) and the Nymphaean transgression of 2000-1000 cal. yr BP (Chepalyga, 1984; Tvalchrelidze et al., 2004). These Black Sea level changes were caused by tectonic subsidence, dune building, coastal sedimentation, climate change and eustatic sea level variations, and have left their imprint on the landscapes and settlement patterns of the Black Sea coast. In Colchis, the Nymphaean transgression paludified low-lying ground, drowned a number of settlements and formed extensive alder swamps and peat bogs (Dzhanelidze, 1980).

The peat deposits and history of Tertiary-relict plants in the Colchis lowland have attracted the attention of palynologists for 75 years. Much work has focussed on
the pre-Holocene sediments of Western Georgia, providing evidence for the existence of *Tsuga, Sequoia, Cryptomeria, Carya, Taxodium, Aesculus* and other taxa prior to their extinction during Pleistocene glacial periods (Shatilova, 1984; Shatilova and Mchedlishvili, 1980; Shatilova et al., 2003; Shatilova et al., 2002; Shatilova and Stuchlik, 1996; Tumajanov, 1971). Investigation of Holocene sediments in Colchis began in the early 1930s (Dokturovskii, 1931; Dokturovskii, 1936), and since then Neishtadt (1957), Neishtadt *et al.* (1965), Sluka (1973), Kvavadze (1982), Serebryannyi *et al.* (1984), Kvavadze and Dzheiranashvili (1987) and Kaffke *et al.* (2002) have provided data on the vegetation history of the Colchis coastal plain. Neishtadt (1957) condensed this history into three phases of forest development: a *Castanea* phase, a transitional phase, and a *Fagus-Carpinus* phase. The weight of scholarly opinion holds that this three-phase vegetation development was predominantly the product of Holocene climatic changes (Dzhanelidze, 1980; Kvavadze, 1982; Neishtadt, 1957; Sluka, 1973).

### Geography and climate

Colchis is a vast alluvial lowland, broadly triangular in shape (Figure 7.1). It is bordered to the north by the Caucasus Mountains (Kodori, Egrisi and Racha Ranges). To the east it narrows toward the Likhi Range, the watershed between the Black and Caspian Sea basins. The southern border of Colchis is formed by the Anticaucasus Mountains (Meskheti and Shavsheti Ranges).

The Colchis lowland is traversed by large rivers draining the southern slopes of the glaciated Caucasus Mountains (e.g. Rioni, Qvirila, Tskhenis-Tsqali and Enguri Rivers) and smaller rivers flowing from the Meskheti Range (e.g. Supsa, Acharis-Tsqali and Natanebi Rivers). The topography is muted and much of the plain is less than a hundred metres above sea level. Geologically, most of the plain is made of Quaternary alluvial and fluvioglacial sediments, derived from massifs of Eocene volcanics in the Anticaucasus and the complex folds of the Main Caucasus Range. Soils on the foothills are relatively fertile krasnozems and leached podzols, while the soils of the plains are alluvial and often waterlogged (AN GSSR, 1964).
A coastal strip with extensive peat-bog development runs for about 100 km from Kobuleti in the south to Ochamchire in the north. Many of these wetlands have been drained in the past 80 years for conversion to agricultural land (Badenkov et al., 1990; Ketskhoveli, 1959).

The climate of Colchis is ‘oceanic’ (Rübel, 1914) and heavily influenced by moist westerlies originating over the Black Sea. It is characterized by high rainfall and humidity year-round, and experiences fewer frosts than the more continental parts of Georgia (Walter, 1974). Most of the Colchis lowland receives more than 1500 mm precipitation per annum. The seaside town of Kobuleti in southern Colchis receives 2365 mm. Winter temperatures are mild (January average is 5 ºC, absolute minimum –4 ºC) and summers are warm (July average is 23 ºC, abs. max. 35 ºC) (AN GSSR, 1964).

Vegetation

Colchic vegetation is characterised by great diversity, with over 50 arboreal species and 800 herbaceous species (Kolakovskii, 1961). The moist temperate climate of Colchis has ensured the survival of a number of Tertiary-relict plants,
studied in some detail by Denk et al. (2001). They include *Alnus barbata*, *Carpinus betulus* (syn. *C. caucasica*), *Castanea sativa*, *Diospyros lotus*, *Fagus orientalis*, *Pterocarya fraxinifolia*, *Quercus hartwissiana*, *Q. iberica*, *Zelkova carpinifolia* and several others.

Lianas are very common, especially *Hedera colchica*, *H. helix*, *Dioscorea caucasica*, *Tanus communis*, *Periploca graeca*, *Smilax excelsa*, *Clematis vitalba* and *Vitis vinifera* subsp. *sylvestris* (Nakhutsrishvili, 1999). Another characteristic of Colchic forests is their evergreen understorey, with *Buxus colchica*, *Laurocerasus officinalis*, *Ruscus aculeatus*, *R. hypophyllum*, *Ilex colchica* etc. (Denk et al., 2001; Nakhutsrishvili, 1999).

The wetland flora of South Colchis is interesting in that it contains a number of Boreal taxa – *Menyanthes trifoliata*, *Drosera rotundifolia*, *Rynchospora alba*, *Carex lasiocarpa* and *Osmunda regalis* (Ketskhoveli, 1959). Peat bogs are dominated by *Sphagnum imbricatum*, *S. papillosum*, *S. palustre*, *S. rubellum* and moor-grass, *Molinia litoralis*, *Rhododendron ponticum* and *R. luteum* grow on the bog surface, and *Frangula alnus*, *Vaccinium arctostaphylos*, *Alnus barbata*, *Pteridium tauricum* and *Rubus* spp. occur at the bog margins (Akhalkatsi et al., 2004; Joosten et al., 2003).

Due to rapid development of the Colchis coastal lowlands for so-called ‘subtropical’ horticulture in the middle 20th century, however, very little of the original vegetation cover survives today (Figure 7.2) (Badenkov et al., 1990; Gvilava, 1996; Walter, 1974).

The *Ispani-II* record

The study site, *Ispani-II* (Figure 7.2), is located at the northern end of Kobuleti Township in southern Colchis. It is part of the South Colchis wetland system which includes the neighbouring *Ispani-I* wetland, now drained. The peat surface of the *Ispani-II* coring site is approximately two metres above sea level and 1.5 km from the sea shore (41° 51’ 47” N; 41° 48’ 4” E). It is covered with a *Sphagnum* carpet, composed mostly of *S. papillosum* with a small proportion of *S. rubellum* and *S. imbricatum*. *Molinia litoralis* grows amongst the *Sphagnum* mosses, giving the mire a grassy appearance (Figure 7.3), and a few *Rhododendron* shrubs are scattered across the mire.
Figure 7.2. Land-use patterns around the Ispani bogs in the Kobuleti area (compiled from Gvilava (1996), and 1:100000 GUGK topographic map series (1975)). The Ispani-II coring site is marked with an ‘x’.  

Figure 7.3. Photograph of the Ispani-II mire coring site in September 2003. Dr Izolda Machutadze (Batumi Botanical Garden) and Mr Matthias Krebs (Greifswald University) stand in the foreground, and the buildings of Kobuleti are visible in the background.
The same peat-bog was previously investigated in the 1930s (Dokturovskii, 1936), but since no radiocarbon dates are available for that pollen record, it was necessary to obtain new data at a higher taxonomic and sampling resolution.

**Sedimentology and dating**

Mr Matthias Krebs (Greifswald University) and I collected the Ispani-II core in September 2003 using a D-section corer, 5 cm in diameter and 50 cm in length. Sediments were cored to a depth of 950 cm below the living *Sphagnum* and subsampled in the field. The presence of *Alnus* and Poaceae macrofossils in the sediment core (Table 7.1) suggested that they were locally occurring at the time of pollen deposition, so I have excluded these taxa from the dryland pollen sum. However, because *Alnus* occurs in mixed Colchic forests as well as in marshes and Poaceae also includes many terrestrial types, I try to account for this in the discussion below.

**Table 7.1.** Sedimentology of the Ispani-II core. Units correspond to pollen zones in Figure 7.5.

<table>
<thead>
<tr>
<th>Unit(s)</th>
<th>Depth</th>
<th>Sediment</th>
<th>Colour</th>
<th>Macrofossils observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is-3, Is-4</td>
<td>0-510 cm</td>
<td><em>Sphagnum</em> peat</td>
<td>Brown to yellow</td>
<td><em>Sphagnum, Rhododendron, Molinia</em></td>
</tr>
<tr>
<td>Is-2</td>
<td>510-690 cm</td>
<td>Detritus gyttja</td>
<td>Black to brown</td>
<td><em>Alnus, graminoids, remains, charcoal</em></td>
</tr>
<tr>
<td>Is-1</td>
<td>690-950 cm</td>
<td>Peaty clay</td>
<td>Brown to grey</td>
<td><em>Phragmites, Alnus, Castanea, Trapa</em></td>
</tr>
</tbody>
</table>

Three lithological units can be identified in the Ispani-II sediments (Table 7.1). The lowermost unit (Is-1: 950-690 cm) consists of clay-rich sediments, containing both sandy and organic layers, charcoal and macrofossils (Table 7.1). Its organic content varies between 9% and 23% (Figure 7.5). The second unit (Is-2: 690-510 cm) is higher in organic content (32-51%) with a greater concentration of *Alnus* macrofossils. It is darker in colour and composed of decayed sedge, grass and wood. Above these gyttja layers, the sediment changes to *Sphagnum* peat (Is-3, Is-4: 510-0 cm). The most striking characteristic of the peat comprising this unit is that unhumified *Sphagnum* remains dominate the entire five-metre profile. The organic content of this unit varies between 90 and 98% (Figure 7.5).

The three AMS radiocarbon ages (Table 7.2, Figure 7.4) show that the clayey sediments of unit Is-1 accumulated between 5600 and 4500 cal. yr BP at a rate of about 0.25 cm.yr \(^{-1}\). The gyttja layers (Is-2) followed and accumulated slowly (≈0.06
cm.yr\(^{-1}\)) until approximately 1900 cal. yr BP, when *Sphagnum* peat (Is-3, Is-4) began to form. An additional radiocarbon age from Ispani-II material provided by Joosten *et al.* (2003) shows that *Sphagnum* peat accumulated slowly from 1900 to 1000 cal. yr BP (0.13 cm.yr\(^{-1}\)), but rapidly thereafter (0.43 cm.yr\(^{-1}\)).

**Table 7.2.** Radiocarbon determinations; calibrated ages from Method B of Stuiver & Reimer (1993).

<table>
<thead>
<tr>
<th>Sample depth (cm)</th>
<th>Lab. number</th>
<th>Material dated</th>
<th>Uncalibrated age (yr BP)</th>
<th>Calibrated age (cal. yr BP)</th>
<th>Calendar years</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>Joosten <em>et al.</em>, 2003</td>
<td><em>Sphagnum</em> remains</td>
<td>1021±33</td>
<td>988-908</td>
<td>962-1042 AD</td>
</tr>
<tr>
<td>520-525</td>
<td>Beta-209353</td>
<td>Woody fragments</td>
<td>1940±40</td>
<td>1953-1816</td>
<td>4 BC-134 AD</td>
</tr>
<tr>
<td>695-700</td>
<td>Beta-209354</td>
<td>Woody fragments</td>
<td>4060±40</td>
<td>4646-4420</td>
<td>2697-2471 BC</td>
</tr>
<tr>
<td>945-950</td>
<td>OZH-068</td>
<td>Bulk carbon</td>
<td>4900±50</td>
<td>5738-5583</td>
<td>3789-3634 BC</td>
</tr>
</tbody>
</table>

**Figure 7.4.** Age-depth graph for the Ispani-II core.

**Pollen diagram**

The Ispani-II pollen diagram is subdivided into four pollen assemblage zones (Figure 7.5), which correspond to the lithological units discussed above.

In the first zone (Is-1), spanning the period from 5600 to 4500 cal. yr BP, *Castanea* pollen dominates and, toward the end of the zone, peaks at 85% of dryland pollen. This occurs against a background of arboreal pollen in which *Pinus*, *Quercus*, *Fagus*, *Carpinus betulus*-type and *Corylus* are more or less equally abundant. Percentages of *Salix*, *Cannabis*-type and *Rhododendron* pollen and fern spores are greater in this zone than in the remainder of the record. *Alnus* proportions oscillate between 20% and 70% of total pollen. Wetland and aquatic pollen types include
Lythrum salicaria-type, Cyperaceae, Sparganium erectum-type and Trapa. Non-pollen palynomorphs of Spirogyra, Tetraploa, Pediasstrum and Ceratophyllum (see van Geel, 1978) are found solely in the middle of this zone. Charcoal is well represented (0.05-0.41 cm².cm⁻³).

The second pollen zone (Is-2) encompasses the period from 4500 to 1900 cal. yr BP. Castanea percentages decline dramatically at the commencement of the zone, and continue to decline throughout. Although this is matched to some extent by modest increases in Fagus, Carpinus betulus and especially Quercus, the most important increase is in the pollen of shrubs: Frangula alnus and Rhamnus-type (up to 19%), Viburnum (4%), Sorbus-type (1.5%) and Juniperus (1%). Pollen of the lianas, Hedera helix (up to 3%) and Vitis vinifera (up to 1%), is also best represented in this zone. Alnus pollen peaks at the beginning of the zone, but rapidly declines from 87% to 27% of total pollen as non-arboreal pollen percentages rise to 20% and charred particles reach very high concentrations (3.1 cm².cm⁻³). Aquatic pollen of Callitriche and Potamogeton appears during the first half of zone Is-2, to be replaced by Sphagnum spores, Poaceae, Cyperaceae and Osmunda regalis pollen in the upper half.

At the beginning of the third zone (Is-3), dated to 1900 cal. yr BP, Quercus declines somewhat as Fagus and Carpinus betulus-type increase. This zone sees the first occurrences of Juglans, Olea europaea, Morus, Buxus, Platanus and Pterocarya pollen. The latter rises to a considerable peak (18%) in the lower part of the zone, at the same time as Castanea pollen all but disappears. Although non-arboreal pollen percentages are reduced relative to zone Is-2, types such as Rumex, Plantago lanceolata, P. major-type, Filipendula, Urtica and Pteridium all increase in zone Is-3. Sphagnum spores, associated with fungal spores of Tilletia sphagni, are well represented throughout the third zone and Lycopodiella inundatum spores also appear in abundance (up to 19%) between 500-425 cm.

The final zone (Is-4), like the second, sees an overall decline in arboreal pollen. Fagus, Carpinus betulus, Quercus, Ulmus, Fraxinus, Zelkova and Pterocarya pollen percentages diminish, while Pinus and Castanea increase slightly and Corylus remains unchanged. The transition from zone Is-3 to Is-4 is accompanied by a considerable charcoal peak (0.7 cm².cm⁻³), declining Alnus percentages and increased inorganic sediment inputs. Pollen of introduced plants dominates this zone – Cryptomeria pollen reaches 48% and Ambrosia 15%. Zea mays appears also.
**Figure 7.5 (previous pages).** The Ispani-II pollen diagram, showing AMS dating locations and lithology, percentages of major tree, shrub, liana and non-arboreal pollen types, charcoal concentrations and detrended correspondence analysis (DCA) results. Additional $^{14}$C date (4 m-depth) from Joosten *et al.* (2003).

**Numerical analysis**

In previous chapters, temporal environmental trends have been reconstructed using weighted averaging scores based on the calibration data set in Chapter Four. However, since the bioclimatic characteristics of the Colchis lowland are so different to the Tsalka Plateau and Tbilisi area, it would be inappropriate to apply the same technique here. Detrended Correspondence Analysis (Hill and Gauch, 1980) was used instead.

DCA (Figure 7.5) identified two prevailing trends in the dryland pollen data. The first trend is positively-correlated with *Castanea*, Filicales, *Salix*, *Cannabis*-type and *Sinapis*-type (Brassicaceae); while negatively-correlated with *Fagus*, *Carpinus betulus*-type, *Corylus*, *Plantago lanceolata*-type, *Juglans* and several other arboreal taxa. It represents a change from *Castanea*-dominated woods in the mid Holocene to mixed forests in the late Holocene.

The second DCA axis is positively-correlated with *Cryptomeria*, *Ambrosia*-type, Filicales, *Castanea* and a number of herbaceous taxa; and negatively-correlated with *Fagus*, *Carpinus betulus*, *Ulmus*, *Fraxinus* and most arboreal taxa. This, then, probably represents the degree of forest cover or landscape openness. Zones Is-1 and Is-2 apparently had relatively open vegetation, with maximum afforestation occurring later, in Is-3. Forest cover then declined rapidly in the most recent zone.

**Discussion**

The three Holocene stages of Colchic vegetation development proposed by Neishtadt (1957) are clearly reflected in Zones Is-1, Is-2 and Is-3 of the new Ispani-II pollen diagram. The first zone represents the ‘*Castanea* phase’, the second zone the ‘transitional phase’, and the third the ‘*Fagus*-Carpinus phase’. The fourth pollen zone (Is-4) is a new phase – one characterised by declining forest cover and the prevalence of taxa introduced to Colchis during the Soviet period – termed the ‘Modern Invasive Phase’ (Connor *et al.*, in press).
The Castanea phase (pollen zone Is-1)

Chestnut (*Castanea sativa*) has survived repeated glacial periods in southern Europe, Colchis, Lenkoran and Eastern Georgia (Dolukhanov, 1966; Huntley and Birks, 1983; Zohary and Hopf, 1993). It typically has low pollen production and so proportions greater than 5% generally signify its local presence (Huntley and Birks, 1983). *Castanea* pollen percentages show considerable spatial heterogeneity and attain 32-59% of dryland pollen in the Ispani diagrams prepared by Dokturovskii (1936). In the new Ispani-II diagram presented in this paper, *Castanea* percentages reach 85% (or 70% with *Alnus* in the pollen sum), representing chestnut-dominated vegetation.

Today chestnut forests have a very restricted distribution in Georgia (Figure 7.1), having been adversely affected by timber felling and fungal diseases since ancient times (Dolukhanov, 1966). Their current distribution is confined to the sides of steep valleys in the foothills ringing the lowlands. *Castanea sativa* grows alongside other deciduous trees, especially in mixed forests dominated by *Fagus orientalis* and *Carpinus betulus* (Nakhutsrishvili, 1999). But it appears that the mid-Holocene forests at Ispani-II were dominated by chestnut alone, perhaps with an understorey of *Rhododendron ponticum*, *Ilex colchica*, *Sambucus nigra*, *Viburnum opulus* and ferns including *Polypodium*, *Pteridium* and *Anogramma*. Lianas such as *Hedera helix*, *H. colchica*, *Humulus lupulus* and *Vitis vinifera* also appear to have been present. Most of these taxa are insect-pollinated and therefore under-represented palynologically. The presence of *Cannabis*-type, Asteraceae-Cichorioideae, *Lamiaceae* and a few *Cerealia*-type pollen grains through the *Castanea* phase suggests that while chestnut trees dominated the landscape, it was not entirely covered by forest – in fact, trees other than chestnut appear to have been few.

Comparing the Ispani-II pollen record with others from Colchis, it is clear that the *Castanea* phase is inconsistently represented, both in age and magnitude (Figure 7.6). Maximum chestnut percentages occur in sediments dated prior to 6200 cal. BP in the Imnati record (Neishtadt et al., 1965), declining at least 2000 years earlier than at Ispani-II. Instead, *Quercus*, *Carpinus* and *Ulmus* are important between 6200 and 2100 cal. BP. At Supsa, *Pterocarya* dominates pollen spectra of the period encompassed by the *Castanea* phase at Ispani-II (Kvavadze, 1982). The Anaklia record (Serebryannyi et al., 1984) does show an increase in *Castanea* between 5300
and 3000 cal. BP, but its magnitude is insignificant compared to that of coniferous tree species: *Pinus, Picea* and *Abies*.

**Figure 7.6.** Comparison of Holocene chestnut (*Castanea*) pollen records from Colchis, arranged in south-north order (see Figure 7.1 for locations). Chronology based on linear interpolation of $^{14}$C dates (data from this chapter; Kvavadze, 1982; Kvavadze and Dzheiranashvili, 1987; Kvavadze and Dzheiranashvili, 1989; Neishtadt et al., 1965; Serebryannyi et al., 1984; Yazvenko, 1994).

*Castanea* dominates the Kobuleti-39 record (Kvavadze and Dzheiranashvili, 1987), from the Choloki estuary near the Ispani bogs, until the expansion of *Pterocarya* in about 1000 cal. yr BP (based on the Ispani-II chronology). A diagram from near Sukhumi (Kvavadze and Dzheiranashvili, 1989) demonstrates that *Castanea* replaced *Fagus* and *Abies* some 8000-9000 years ago and remained dominant for the remainder of the Holocene. Significantly, at the mountain site of Chamlukh (1650 m elevation), *Castanea* peaks after 3700 cal. yr BP (Yazvenko, 1994). Lowland diagrams by Sluka (Sluka, 1973) show that the *Castanea* phase lasted until 4800-4400 cal. yr BP near the seaside Nabada and Churia bogs. In the new Ispani-II diagram, the *Castanea* phase ended abruptly around 4500 cal. yr BP.

The close of the *Castanea* phase has been traditionally aligned with the end of the Atlantic ‘climatic optimum’ (Dzhanelidze, 1980; Kvavadze, 1982; Neishtadt, 1957; Sluka, 1973), but radiocarbon dating indicates that the phase was not regionally-synchronous (Figure 7.6). Either the dates are wrong, or the mid-Holocene abundance of *Castanea* in Colchis was not solely determined by climate.
The transitional phase (pollen zone Is-2)

The transitional phase is also variable in its timing and magnitude. Even in the original Ispani-I diagram prepared by Dokturovskii (Dokturovskii, 1936), Castanea percentages are much more consistent than in the new Ispani-II diagram. In the latter, chestnut declines rapidly and continues to diminish, whereas in Ispani-I, chestnut remains important throughout the transitional phase.

The new diagram presented here shows that the vegetation around the Ispani-II bogs during the transitional phase probably had fewer trees and a greater shrub cover than the Castanea phase. From 4500 to about 3000 cal. yr BP, the Ispani-II landscape was dominated by Alnus barbata, growing in swamp forests around extensive marshlands. There was also a significant shrubby component in the understorey, including Frangula alnus, Viburnum opulus and other shrubs that are found in coppiced Alnus back-swamp forests in Colchis today (Denk et al., 2001). The surrounding forests were a typically Colchic mix of Quercus hartwissiana, Fraxinus excelsior, Fagus orientalis, Castanea sativa, Carpinus betulus, Zelkova carpinifolia, Corylus avellana and other species. Some of these species could have grown in elevated parts of the Alnus back-swamp forests also.

At some time around 3000 cal. yr BP, the landscape around Ispani-II changed. The extent of Alnus barbata diminished, leaving open areas to be colonized by Frangula alnus and other shrubs. Herbs of open ground also increased – Poaceae, Asteraceae, Apiaceae and a suite of non-arboreal pollen are much better represented during the second half of the transitional phase. More than any previous period, this phase was marked by the increasing role of anthropogenic indicators (sensu Behre, 1986): Triticum-type, Secale-type, Rumex, Plantago lanceolata-type, P. major-type and Polygonum aviculare-type. The decline of Alnus and concomitant peak in grass pollen is accompanied by an enormous increase in charcoal concentrations, almost certainly indicating the extensive and repeated occurrence of fire.

The Fagus-Carpinus phase (pollen zone Is-3)

The Fagus-Carpinus phase begins at much the same time at Ispani-II bog as it does at Innati, Nabada and Churia, around 2000 cal. yr BP. It is absent from Anaklia
and Supsa, and appears somewhat later in the Kobuleti-39 diagram (Kvavadze, 1982; Kvavadze and Dzheiranashvili, 1987; Serebryannyi et al., 1984). At Ispani-II, it is characterised by the rapid expansion of *Carpinus betulus* and *Fagus orientalis*, and the appearance of *Olea europaea, Juglans* and *Pterocarya*. Many of the anthropogenic indicators (e.g. *Plantago lanceolata*-type, *P. major*-type, *Rumex*) that appeared during the transitional phase continue through the *Fagus-Carpinus* phase.

*Fagus orientalis* occurs in Colchis only in better-drained places, being unable to tolerate the boggy soils of *Alnus*-dominated swamps (Denk et al., 2001). Beech forests are nowadays the most widely-distributed forest type in Colchis, from sea-level up to about 2300 m. *Carpinus betulus* is the most common subdominant in Caucasian beech forests (Nakhutsrishvili, 1999). According to Denk et al. (2001), *Carpinus* is able to tolerate swampy soils in Colchis, but is always subordinate to *Alnus* and *Pterocarya* in such situations. The Ispani-II pollen record indicates that *Fagus-Carpinus* forests replaced *Castanea sativa* and mixed oak forests as well as areas of open land. *Pterocarya fraxinifolia* first appears in the record about 2000 cal. yr BP, but expands considerably in the Ispani area around 1000 cal. yr BP, invading areas of *Alnus* swamp forest. After the *Pterocarya* invasion, water tables may have lowered slightly, allowing the re-establishment of *Fraxinus* and *Quercus* in suitable habitats. The *Fagus-Carpinus* phase was a time of relative vegetation stability. According to the DCA results, it was also the phase with the greatest forest cover.

**The modern invasive phase (pollen zone Is-4)**

History records that much of the Colchis lowland was drained, deforested and turned over to plantations as a result of forced agricultural collectivisation beginning in the 1930s (Badenkov et al., 1990; Gulisashvili, 1964; Ketskhoveli, 1957). Under the Soviet Union’s increasingly insular economic structure, frost-free areas such as the Black Sea coast suddenly became valuable for their unique ability to satisfy demand for ‘subtropical’ crops such as tea and citrus from within. Broad-scale landscape modification is clearly represented in pollen evidence from this phase. Both *Cryptomeria japonica* and *Ambrosia*, plants introduced to Colchis at some time during the 1930s (Sharadze, 1987) (Dr Zurab Manvelidze, Batumi Botanical Garden, pers. comm.), dominate pollen spectra from the modern invasive phase.
The destruction of lowland forests is likewise recorded (Figure 7.5) as a decline in forest pollen taxa – *Fagus, Carpinus, Quercus, Ulmus* and *Fraxinus* – and also diminishing proportions of swamp taxa such as *Alnus* and *Pterocarya* as wetlands were drained and turned over to mechanised agriculture. Based on the appearance of marker taxa such as *Ambrosia* and historical records of early-mid 20th century deforestation in lowland Colchis, I believe that the modern invasive phase began in the 1930s, rather than in the post-Soviet period (i.e. after 1991) as suggested by Kaffke et al. (2002). It remains to be seen whether this new phase can be identified palynologically at other sites along the Black Sea coast of Georgia.

**Human impact**

It is difficult to ignore humans in any history of Colchis. The region was well known to Ancient Greeks through the legendary voyage of Jason and the Argonauts to capture the Golden Fleece from King Aeëtes, as well as the story of Prometheus, whom Zeus had chained to the Caucasus for giving fire to humankind. Colchis is associated with the names Strabo, Hippocrates, Herodotus, Xenophon and Pompey – soldiers, philosophers and adventurers for whom the land held a great fascination. By the 6th century BC, Ionian Greeks had established colonies right along the Black Sea coast (Braund, 1994; Tsetskhladze and Treister, 1995). These settlements consisted of clusters of log houses sited atop artificial mounds within the wetlands: “People spend their whole lives in the swamps and their wooden or reed houses are built on the water” (Pseudo-Hippocrates, Airs, Waters, Places, quoted in Tsetskhladze, 1997, p. 122). Such unusual settlements may have had a very peculiar impact on the vegetation.

The geographer Strabo (64 BC – 25 AD) describes Colchis as “well wooded with all kinds of timber” (Strabo, 1928, 11.2.15). Wood was the natural construction material for the lowland Colchians, who extensively used *Quercus, Castanea, Buxus, Fagus, Alnus* and *Fraxinus* for housing, tools and utensils from the Bronze Age (3rd-2nd millennium BC) onwards (Apakidze, 1991; Tsetskhladze, 1997). One might ask whether the economy of ancient Colchis exerted a selective influence over forest composition. For instance, chestnut trees may have been, at times, carefully conserved for their fruits (e.g. during the Bronze Age), while, at other times, felled for...
their timber, depending on people’s changing needs, technology and cultural affinities.

Despite extensive archaeological investigations of coastal settlements, a clear picture of their agricultural economy is yet to emerge. Historical sources are hardly more helpful. Pseudo-Hippocrates tells us that the Colchians’ crops were meagre on account of the perpetual rain, “distinguished by their flabbiness…and do not ripen properly” (quoted in Tsetskhladze, 1997, p. 122). Strabo, in contrast, informs us that, “the country is excellent both in respect to its produce… and in respect to everything that pertains to ship building; for it not only produces quantities of timber but also brings it down on rivers. And the people make linen in quantities, and hemp, wax, and pitch” (Strabo, 1928, 11.2.17). From archaeology we know that wheat, although found in many Colchian sites (Lordkipanidze, 1994b), could barely withstand the damp coastal climate and was often imported from neighbouring lands (Braund, 1994; Tsetskhladze, 1997). Millet was perhaps the only grain grown in the boggy parts of Colchis in antiquity (Braund, 1994), and laborious drainage works were necessary to increase the ground available for crop cultivation (Tsetskhladze, 1997). Despite this, agriculture held an important economic and symbolic place in the Colchian kingdom (Lordkipanidze, 1994b). Some have argued that Colchian lowland agriculture followed a ‘slash and burn’ or swidden model (Kushnareva, 1997), such is the rapidity of afforestation (cf. Berg, 1950, p. 195).

One could associate some form of slash-and-burn agriculture with the prominent charcoal peaks in the transitional phase of the Ispani-II pollen diagram. In an area with 2.5 metres of annual rainfall, it seems improbable that such fires occurred spontaneously. The composition of the vegetation obviously changed remarkably with the occurrence of frequent and widespread burning – alder swamp forest disappeared, light-demanding understorey plants proliferated and the cultivation of various agricultural plants increased. Considering the archaeological data, the swidden model here must encompass permanent settlements around which forests and open agricultural land were managed with the aid of fire. Archaeologists have noted the apparent decline of metallurgical production of axes and other implements coincident with Greek colonisation (Tsetskhladze and Treister, 1995). Indeed, this may have been a response to changing agro-forestry practices.
There is another possibility: that the charcoal record pertains to the wetland vegetation itself, and that the reeds and sedges themselves were burnt. This hypothesis has some merit when we remember that the settlements of the time were situated on mounds within the marshes, and that the people “seldom go on foot in the polis and emporium, but canoe up and down in dug-outs, for there are many canals” (Pseudo-Hippocrates, quoted in Braund, 1994, p. 49). Dense wetland vegetation could cause significant inconvenience to navigation, and setting it alight may have been the most effective means of its removal. Repeated fires would have also prevented the establishment of *Sphagnum* blanket bog. But without determining the source-area of the Ispani-II micro-charcoal record (e.g. Umbanhowar and McGrath, 1998), it remains unclear whether these significant fires were confined to the wetland itself or occurred more widely.

After 1900 cal. yr BP, when burning appears to have declined, both the settlements and agricultural lands around Ispani-II wetland were largely abandoned. This provided *Fagus* an opportunity to migrate from the mountains to colonise the lowlands, since it has difficulty invading closed forest (Huntley and Birks, 1983). *Pterocarya* also began migrating slowly out of riverine refuges onto the coastal plain. *Castanea* gradually disappeared from the coastal lowlands because of its dislike of waterlogged soils, its great economic value and susceptibility to disease when coppiced (Dolukhanov, 1966; Huntley and Birks, 1983). The Romans appear to have introduced olives and walnuts to cultivation in Western Georgia at this time, and throughout the ensuing millennia forest cover was denser than at any other period during the last 5600 years.

The landscape around Ispani-II remained in a state of relative stability from 1900 cal. yr BP until the 20th century. Then forest cover was all but destroyed and replaced with plantations of tea, citrus, tung tree, *Cryptomeria* and others (Ketskhoveli, 1959; Walter, 1974). Many swamps were drained and the Ispani-I bog was cut extensively for peat (Badenkov et al., 1990; Joosten et al., 2003). All of these changes, of course, are the result of the broad-scale human impacts that accompanied Stalin’s push for rapid agricultural development and collectivisation beginning in the 1920s and 1930s.
Sea level changes and peatland development

Five-and-a-half thousand years ago, through the lower part of the *Castanea* phase, Ispani-II existed amongst alder swamps. A drying phase or a stagnant lagoon phase followed, around 5000 years ago (875-800 cm), wherein *Trapa*, *Spirogyra*, *Ceratophyllum*, *Pediastrum* and *Tetraploa* were important. An overall decline in wetland taxa in the upper part of the *Castanea* phase, when taken with the low organic content of the sandy sediments, suggests that groundwater levels fell and the site was surrounded by well-drained alluvial flats up until 4500 cal. yr BP.

An abrupt rise in the water-table at the beginning of the transitional phase restored alder swamps to their former extent, and an increase in *Callitriche*, *Iris pseudacorus*-type and *Potamogeton* indicates the presence of a shallow open-water fen in the Ispani-II marshlands. The next stage (600-500 cm) began mid-way through the transitional phase with the retreat of *Alnus* swamp forest and the short-lived appearance of *Sphagnum*, the latter swiftly yielding to grasses, sedges and *Osmunda*, indicating a disturbed sedge or reed swamp.

![Figure 7.7. Sea level changes at Ispani-II and the abandonment of coastal settlements (arrows). Dashed curves represent sedimentary and biotic responses to coastal subsidence and sea level change, shown in relation to the sea level curve of Tvalchrelidze et al. (2004) for Georgia and Chepalyga’s (1984) scheme for the Black Sea as a whole. M = modern invasive phase.](image)
This stage ended around 1900 cal. yr BP with a second abrupt rise in water-tables, initiating the growth of *Sphagnum* blanket mire (*Fagus-Carpinus* phase). At first this was probably paludal species like *Sphagnum palustre*, but following the *Pterocarya* invasion around 1000 cal. BP, peat made of hummock species (e.g. *Sphagnum imbricatum* and *S. papillosum*) accumulated and continued forming rapidly up to the present, modern invasive phase.

During the period covered by the Ispani-II pollen diagram, three major relative sea level changes occurred: the New Black Sea transgression between 6500 and 4500 cal. yr BP; the Phanagorian regression from 4500 to 2000 cal. yr BP; and the Nymphaean transgression of 2000-1000 cal. yr BP (Chepalyga, 1984). In Colchis, the timing, amplitude and impact (Figure 7.7) of these events diverges to some extent from the regional pattern because of rapid tectonic subsidence and local geomorphology (Dzhanelidze, 1980; Kaplin and Selivanov, 2004; Tvalchrelidze et al., 2004).

Archaeological evidence for coastal subsidence and sea level change comes from the Ispani peatland itself. A Neolithic to middle Bronze Age settlement was uncovered during the excavation of a drainage canal in the 1970s (Mikeladze and Baramidze, 1976). This settlement was buried beneath four metres of peat and wooden dwellings were well preserved in the waterlogged, anoxic conditions (Dzhanelidze, 1980). Interestingly, the earlier dwellings at Ispani were built directly on the ground, but later houses were supported upon wooden piles. This trend is reflected in several late 3rd millennium BC coastal sites in Colchis (Tsetskhladze, 1997). Dzhanelidze (1980) considers it a reaction to changing sea levels during the New Black Sea transgression, which built up new coastal dunes, impeding the drainage of the Colchis lowland and leading to extensive paludification and peat-bog formation. Eventually rising groundwater overwhelmed these settlements on piles, and they were abandoned in favour of more elevated ground (Dzhanelidze, 1980; Tsetskhladze, 1997).

The sudden demise of *Castanea*-dominated forests around 4500 cal. BP at Ispani-II is most likely the result of rising water-tables at the end of the New Black Sea transgression, since chestnut is very sensitive to changes in soil moisture (Grove and Rackham, 2001). Likewise, the abandonment of coastal settlements and expansion of *Pterocarya* during the *Fagus-Carpinus* phase can be linked to the
Nymphaean transgression between 2000 and 1000 cal. BP. At Ispani-II, sea level rises had immediate and lasting consequences for the coastal environment and vegetation (Figure 7.7), whereas marine regressions had little impact. Paludification was thus the dominant impetus for late Holocene vegetation change in lowland Colchis.

It must be remembered, however, that the Colchian people had been manipulating the hydrology of the marshy lowlands by constructing embankments, drains and artificial hillocks since the 3rd millennium BC (Kushnareva, 1997; Tsetskhladze, 1994). Inadvertently, these drainage works, along with burning and deforestation, created ideal conditions for the growth of *Sphagnum* mosses. Like many European blanket mires, the *Sphagnum* peat of Ispani-II is underlain by a charcoal layer that provides not only a legacy of anthropogenic deforestation and burning, but may also have altered mire hydrology to favour *Sphagnum* growth (Moore, 1993). On the balance of archaeological, geomorphological and palynological evidence, there are grounds for regarding the Ispani *Sphagnum* bogs as cultural artefacts. It is perhaps no coincidence that the area of Colchis that had the greatest coastal population concentration during the 1st millennium BC is also the area that subsequently developed the greatest area of *Sphagnum* bogs.

**Conclusions**

Based on the palynological evidence presented here, four stages of landscape change around Ispani-II are recognised: the chestnut-dominated open woods of the mid-Holocene *Castanea* phase, the shrubby, marshy landscapes of the transitional phase, the afforestation and stability of the beech-hornbeam phase, and the deforested agricultural landscapes of the 20th century. These results call into question the idea that the Black Sea coast was entirely and densely forested throughout the Holocene.

In a perpetually-moist climate, such as that of southern Colchis, Holocene fluctuations in temperature and precipitation may have had minor impact on forest composition. If one accepts that dense forests dominate lowland Colchis in the absence of disturbance, then forest successional changes would have occurred through gap-phase regeneration, a process of gradual replacement rather than sudden change. It seems unlikely that the rapid and fundamental vegetation changes revealed by the
Ispani-II material were determined solely by regional climatic variations. This is supported by the asynchronous limits of the ‘Castanea’ phase of Holocene vegetation development in the Colchis lowland and the lack of any correspondence between the Ispani-II record and those presented in previous chapters. The lack of climatic response is hardly surprising in a supposed glacial refugium where, by definition, the climate has been comparatively stable through much of the Quaternary.

Instead, I argue that vegetation dynamics were strongly influenced by relative sea level changes and human activities. The Bronze Age rise and fall of chestnut woods undoubtedly reflected groundwater variations controlled by coastal subsidence and sea level change. Throughout the 1st millennium BC, the axe and fire were the main agents of vegetation change: in the hands of villagers and farmers, these tools were sufficient to alter the direction of climate-driven successional pathways. But, in turn, the inexorable transgression of the Black Sea stamped its mark on the vegetation of Colchis, and not until the tractor replaced the ox in the 20th century do we once again see the ascendancy of human impact.
CHAPTER EIGHT
HOLOCENE PALAEOVEGETATION MAPS OF GEORGIA

Introduction

The foregoing chapters have dealt in detail with the vegetation history of individual sites, tracing the development of different plant communities in temporal terms. The aim of this chapter is to incorporate these records into a broader spatial analysis of the history of the study area’s vegetation, by mapping the frequency of the most important pollen types from every location for various periods. The resulting maps provide a starting point for understanding the palaeoecology of the taxa involved, for examining changes in their distribution and abundance due to climatic, edaphic, anthropogenic and other factors, and for reconstructing the palaeovegetation at various moments in time.

The approach adopted here is very similar to Huntley and Birks’ (1983) Atlas of Past and Present Pollen Maps for Europe. The main difference is that ‘isopoll’ maps are not used here. This is because they can be misleading where the terrain is rugged and distribution of sites patchy. Instead, pollen frequency is represented by graduated symbols placed on the geographic location of each study site; a method used by Lennart von Post, the ‘father’ of palynology (von Post, 1924, cited in Faegri and Iversen, 1989).

The maps were constructed using a database of pollen spectra from 39 cores including 232 fossil spectra. Modern pollen data were collated from 164 samples of lake and wetland sediment (Figure 8.1, Table 8.1); moss- and soil-derived pollen spectra were carefully avoided. Modern and fossil data come from the pollen data in this dissertation, from published pollen diagrams and from unpublished data generously provided by Jacqueline van Leeuwen, Erika Gobet and Brigitta Ammann at the Institute of Plant Sciences, Bern. While some unpublished data were available in raw counts, pollen percentages from published diagrams had to be measured by hand, introducing a minor source of error.

Samples were selected for each 1000-year interval for the last 14,000 years. I adopted a calibrated timescale to allow the vegetation history to be compared to
archaeological and historical data that do not use the radiocarbon timescale. This, of course, introduces a source of dating error, but this is probably less significant than the errors generated in assigning ages to poorly dated pollen diagrams. Dating was by linear interpolation between dated levels. Where few dates were available, I occasionally used reliable biostratigraphic markers (i.e. the Pleistocene-Holocene boundary, the expansion of *Juglans*) as an age control.

Figure 8.1. Location map of pollen sites used in mapping and analysis. Site numbers refer to Table 8.1.

<table>
<thead>
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<th>No.</th>
<th>Site, sample no.</th>
<th>Type</th>
<th>Sub-region</th>
<th>Lat.</th>
<th>Long.</th>
<th>Elev.</th>
<th>°C</th>
<th>From</th>
<th>To</th>
<th>Source</th>
</tr>
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<td>Core</td>
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<td>41.28</td>
<td>1750</td>
<td>3</td>
<td>3000</td>
<td>0</td>
<td>(Kvavadze and Rukhadze, 1989)</td>
</tr>
<tr>
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<td>Abkhazia</td>
<td>43.27</td>
<td>41.23</td>
<td>2750</td>
<td>-</td>
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<td>40.82</td>
<td>-20</td>
<td>-</td>
<td>-</td>
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<td>(Kvavadze and Connor, 2005)</td>
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<tr>
<td>4</td>
<td>Akhaltsikhe 183 Surface</td>
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<td>42.93</td>
<td>1345</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(Klopotovskvaya, 1973)</td>
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<td>44.02</td>
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<td>10</td>
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No.
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Site, sample no.
Bezymianka 1
Bezymianka 2
Bluzovoe
Bolshoi Khodzhal
Chamlukh
Cheliagele
Cherepanov 1-4
Chili Tba 1-3
Devis Tba
Didajaris Tba A
Didajaris Tba B
Ertso
Gagra 471
Gagra 607
Gomnis Tba 1-2
Gomnis Tba 3
Gudauta 120
Gudauta 55
Imera
Imera 1-4
Imnati
Ispani I
Ispani II-A
Ispani II-B
Ispani II-C
Jvari
Jvari 1
Kakhisis Didi Chaobi
Kakhisis Didi Chaobi 2
Kartsakhi

Type
Surface
Surface
Core top
Surface
Core
Core
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Core top
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Surface
Core
Core top
Core top
Core top
Core
Core top
Surface
Core top
Surface
Core

Sub-region
Abkhazia
Abkhazia
NW Caucasus
Abkhazia
Abkhazia
Racha
S Georgia
E Georgia
Racha
Ajara
Ajara
E Georgia
Abkhazia
Abkhazia
S Georgia
S Georgia
Abkhazia
Abkhazia
S Georgia
S Georgia
Colchis
Colchis
Colchis
Colchis
Colchis
E Georgia
E Georgia
S Georgia
S Georgia
S Georgia

Lat.
43.63
43.63
43.63
42.98
43.18
42.47
41.57
41.82
42.42
41.68
41.68
41.95
43.23
43.27
41.77
41.77
43.08
43.08
41.65
41.65
42.10
41.85
41.87
41.87
41.87
41.83
41.83
41.73
41.73
41.25

Long.
40.53
40.53
41.13
41.92
41.03
43.10
44.37
44.68
43.30
42.50
42.50
44.97
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40.27
43.35
43.35
40.62
40.62
44.22
44.22
41.82
41.78
41.80
41.80
41.80
44.73
44.73
43.30
43.30
43.30

Elev.
2485
2548
2884
2510
1650
1100
1430
1130
1380
1850
1850
1200
5
0
1850
1800
0
0
1610
1610
2
2
2
2
2
571
570
1780
1800
1800

52
53
54
55
56
57
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82
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84
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86
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88
89
90
91

Kazbegi
Keli 1-2
Keli 3-4
Keli 5-7
Khachal east lake
Khachal pool 1-3
Khachal west lake
Kobuleti 39
Ktsiis Zeda Vake
Kumisi
Kumisi 2-4
Kvartsevoe
Lagodekhi lakes 1
Lagodekhi lakes 2-3
Lagodekhi lakes 4
Lagodekhi lakes 5-6
Lashkhrashi
Lisi
Lisi 1-7
Luganskoe
Malyi Khodzhal
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Pasinler CL
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<td>N Caucasus</td>
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<td>Western Georgia 21 Surface</td>
<td>Colchis</td>
<td>42.60</td>
<td>42.68</td>
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<td>Western Georgia 7 Surface</td>
<td>Svaneti</td>
<td>42.88</td>
<td>43.15</td>
<td>1520</td>
<td>-</td>
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<td>Zresi Core top</td>
<td>S Georgia</td>
<td>41.40</td>
<td>43.43</td>
<td>1700</td>
<td>-</td>
</tr>
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<td>S Georgia</td>
<td>41.40</td>
<td>43.43</td>
<td>1700</td>
<td>-</td>
</tr>
</tbody>
</table>

Key to abbreviations: Central C. – Central Caucasus; Lat. – latitude (decimal degrees); Long. – longitude (decimal degrees); $^{14}$C – number of radiocarbon dates (v – varve ages); From – basal age in $^{14}$C yr BP; To – most recent sample age (0 = modern).

Radiocarbon-dated pollen diagrams from the study area are the exception rather than the rule: 42 published pollen diagrams (apart from those used in this analysis) could not be used because they lack any independent chronological control. For the dated sites combined, 127 dates were available, an average of 3.3 per core and a median of 2, which highlights the discrepancy between a few well-dated sites and many poorly-dated ones (Table 8.1). This comes from the generally inorganic nature of sediments in the study area and the inaccessibility of accelerator mass spectrometer (AMS) facilities. The available radiometric dates were accepted as correct representations of the age of the pollen. In some cases, $^{14}$C ages are clearly erroneous, so this is taken into account in the discussion below.

As for sample selection, the sample nearest to each 1000-year interval was read from the diagram. The sample was rejected if it appeared anomalous or where high Asteraceae percentages suggested pollen degradation. The next closest sample was then used. Samples were not ‘smoothed’ with the surrounding samples because this was often impractical. A drawback of this approach, apart from dating uncertainty, is that rare taxa are often missed.

The pollen sum was calculated from the total of tree and shrub pollen reported in each diagram. The reason for doing this was to be able to compare pollen diagrams
calculated from a dryland pollen sum with those calculated from an arboreal sum only. Trace proportions marked with a ‘+’ sign were assigned a value of 0.5%. Proportions were then recalculated to a total of 100%. Grass and herb (non-arboreal) pollen percentages were calculated individually from a sum including trees, shrubs and the non-arboreal pollen type of interest.

Finally, the data were mapped using geographic co-ordinates based on published site descriptions. Maps were plotted using ArcGIS software (ESRI, 2005) and a Georgia base map kindly provided by Dr Lawrence Crissman, director of the ACASIAN database, Griffith University (Crissman, 1995).

This chapter is organised in three sections: the first one deals with the regional history of individual pollen taxa through the last 14,000 years, the second part is a reconstruction of Georgia’s vegetation history, while the third part is an attempt to derive quantitative climatic estimates for the past 12,000 years.

Such a task has not previously been attempted in the Caucasus region. This is in spite of a long history of diverse palynological investigation there. Continental-scale reconstructions, such as those provided by Peterson (1983) and Tarasov et al. (1998), are too coarse to give a detailed impression of vegetation change in the Caucasus. Kvavadze and Rukhadze (1989) and Kvavadze et al. (1992) have reconstructed the Holocene vegetation and climate of Abkhazia, but a general overview of Georgia’s vegetation history, from the arid steppes to the coastal swamps, is notably lacking. The Holocene history of individual pollen taxa is poorly known, with one exception (Kvavadze and Connor, 2005). The aim of this chapter, then, is to incorporate the pollen data presented in previous chapters into a broader regional context.

**Holocene changes in the distribution and abundance of major pollen taxa**

The distribution and abundance of pollen taxa reflect, on a regional scale, spatial variations in the composition of plant communities. Within this context, the past behaviour of each individual pollen type tells us much about temporal changes in plant species’ altitudinal range, population expansions and contractions, migrations and extinctions (Huntley and Birks, 1983; van der Knaap et al., 2005). With a clear understanding of the ecology of the species represented, we gain a clearer insight into
the factors (climatic, edaphic, anthropogenic, etc.) that influenced the distribution and abundance of plants in the past.

Each of Georgia’s main pollen types is discussed in some detail, with reference to the ecology of its parent plants, its pollen representation, and the history of the taxon in the study area over the last 14,000 years. Rather than present this exhaustive ecological and palaeoecological information here, I have placed it in Appendix A and give a synopsis below.

In the broadest of terms, the history of each pollen type can be grouped into one of five temporal categories: (A) those that peaked during the late Pleistocene, (B) those that were most abundant at the beginning of the Holocene, (C) those that rose to prominence in the early-mid Holocene, (D) taxa that were most prevalent during the mid Holocene, and finally, (E) those that have increased in the last few millennia (Table 8.2).

<table>
<thead>
<tr>
<th>Group</th>
<th>Maximum abundance</th>
<th>Pollen types</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Late Pleistocene</td>
<td>Ephedra, Juniperus, Artemisia, Chenopodiaceae</td>
</tr>
<tr>
<td>B</td>
<td>Early Holocene</td>
<td>Betula, Corylus, Salix, Rumex</td>
</tr>
<tr>
<td>C</td>
<td>Early-mid Holocene</td>
<td>Abies, Carpinus betulus, Fagus, Tilia, Ulmus/Zelkova</td>
</tr>
<tr>
<td>D</td>
<td>Mid Holocene</td>
<td>Castanea, Quercus, Hedera, Ilex</td>
</tr>
<tr>
<td>E</td>
<td>Late Holocene</td>
<td>Juglans, Olea, Ostrya-type, Picea, Pinus, Pterocarya, Plantago</td>
</tr>
</tbody>
</table>

**Group A – Late Pleistocene**

Group A includes shrubs and herbaceous plants that are characteristic of semidesert-steppe vegetation today. *Ephedra* and *Juniperus* are xerophytic conifers, most abundant in the arid scrub vegetation of Eastern Georgia, although *Juniperus* is much more widespread and some species occur in forests and alpine vegetation. *Artemisia* and Chenopodiaceae are herbaceous plants that are well adapted to aridity and are prevalent in lowland semidesert-steppes, as well as being somewhat weedy.

All of these taxa peaked during the late Pleistocene, when the climate was presumably much more arid than it is today. If pollen data are any guide, there appears to be a relationship between *Juniperus* and Chenopodiaceae on the one hand, and *Ephedra* and *Artemisia* on the other. *Juniperus* and Chenopodiaceae declined during the Younger Dryas, while *Ephedra* and *Artemisia* expanded greatly (cf. Carrión and van Geel, 1999). All four taxa were much reduced through the early
Holocene. The mid Holocene triggered an expansion in *Juniperus* and Chenopodiaceae and a decline in *Ephedra* and *Artemisia*. Chenopodiaceae and *Artemisia* have expanded through the late Holocene in some places (Figure 8.2).

The history of these four taxa suggests that desert-steppe vegetation was distributed in the continental parts of the Caucasus during the late Pleistocene. The association between *Ephedra* and *Artemisia* is perhaps most easily explained by increased air humidity and reduced temperature, compared to the period in which *Juniperus* and Chenopodiaceae were dominant. This hypothesis could also explain why *Juniperus* and Chenopodiaceae increased through the mid Holocene, when the climate may have been relatively warm and dry. The late Holocene expansion of Chenopodiaceae and *Artemisia* is probably the result of widespread localised disturbance. It is less clear what impact humans have had on the two gymnosperms: *Juniperus* is killed by fire and promoted by grazing, while *Ephedra* appears to be the opposite.

**Group B – Early Holocene**

Group B includes several small trees, shrubs and a herb that share the common characteristic of being light-demanding; they are overshadowed by larger growing deciduous trees and are often found at forest edges. *Betula* and *Corylus* are small trees and shrubs that are a minor component in most mixed forests. Some *Betula* species are dominant trees at the upper tree line and *Corylus* are most prevalent in the understorey of deciduous forests. *Salix* are moisture-loving trees and shrubs, often found along watercourses. *Rumex* are grassland herbs regarded as good indicators of open vegetation and grazing (Behre, 1986; Huntley and Birks, 1983). *Salix* and *Rumex* both have poor pollen production, so their history is somewhat patchy.
Figure 8.2 (a). The modern distribution of Chenopodiaceae pollen in the study area.
Figure 8.2 (b). Changes in Chenopodiaceae (Group A) pollen abundance in Georgia through the last 14,000 years.
Figure 8.3 (a). The modern distribution of *Betula* pollen in the study area.
Figure 8.3 (b). Changes in Betula (Group B) pollen abundance in Georgia through the last 14,000 years.

All four taxa were present during the late Pleistocene in Georgia. Betula, it seems, was even present at relatively high altitudes, allowing it to expand rapidly in
the mountains once the Younger Dryas came to an end (Figure 8.3). *Corylus* and *Salix* followed soon after, competing with *Betula* for light and space in early Holocene woods. *Rumex*, which was present in the Pleistocene flora, also expanded considerably in the treeless parts of the study area. The four Group B taxa declined during the early-mid Holocene as more competitive deciduous trees moved in to supplant them (see Group C, below). In general, all four remained relatively scarce until the late Holocene, when they experienced a pronounced resurgence.

The woods that spread over the mountain slopes during the earliest millennia of the Holocene were unlike anything that is seen today. These woods must have been quite open in structure and short in stature. As in northern Europe, their composition was determined by the speed at which *Betula, Corylus* and *Salix* colonise new areas. The major difference in the Caucasus was that these pioneer taxa only dominated at higher elevations, since the lowlands were already home to forest refugia. The late Holocene rise of *Betula, Corylus, Salix* and *Rumex* is almost certainly the result of widespread forest disturbance at lower and middle elevations.

**Group C: Early-mid Holocene**

The pollen types that fall into Group C all represent trees of mixed deciduous, mesophytic forests. *Abies nordmanniana*, although a conifer, is a common component of deciduous forests. *Carpinus betulus* and *Tilia* are widespread and usually sub-dominant in Caucasian forests, while *Fagus orientalis* is the most important forest dominant in the South Caucasus region. *Ulmus* and *Zelkova* have diverse ecological tolerances and are discussed separately in Appendix A. All of these Group C taxa grow together in mixed forests, especially in the more humid parts of Georgia; they avoid the droughty, continental areas of Eastern Georgia.

Group C taxa were present in Pleistocene refugia in the Black Sea lowlands. In these forests, *Abies* seems to have been a major contributor. Through the early Holocene *Abies, Fagus, Carpinus betulus* and *Tilia* expanded slowly out of the lowlands to establish in the middle and upper forest belts. *Fagus orientalis* was the slowest to migrate, such that it became widespread only 7000 years ago (Figure 8.4). The mid Holocene was unfavourable to these taxa in the semi-arid parts of Georgia, and elsewhere *Fagus orientalis* reached such a level of dominance that *Carpinus*
*Carpinus betulus* and *Tilia* declined. During the late Holocene, *Carpinus betulus* and *Fagus orientalis* have increased in some places. The distribution of *Abies*, on the other hand, has become much more restricted.

Group C taxa expanded to replace the pioneer taxa of Group B during the early-mid Holocene. Their expansion was mitigated by possible early Holocene aridity and, for *Fagus*, the inability to disperse seed over large areas. In some places in Southern Georgia, it seems that fire was at least partly responsible for displacing Group C taxa during the mid Holocene, at a time when the climate may have also become less amenable to these taxa. The widespread late Holocene decline of *Abies* can be attributed to the increasing role of fire in forest vegetation. On the other hand, the abandonment of open land in both Eastern and Western Georgia has allowed *Fagus* and *Carpinus betulus* to increase their spread in the lower forest belt.

Those taxa that peaked during the mid Holocene are thermophiles, lending support to the idea that the mid Holocene was a time of increased temperatures (at least seasonally) across the Caucasus region. *Castanea sativa* is a tree with a fragmented distribution in the South Caucasus, growing mostly on warm, south-facing slopes in the foothills around the Colchis Lowland (Western Georgia) and the Alazani Valley (Eastern Georgia). *Quercus* species are much more widely distributed, occurring in middle elevation forests across the region, but dominating woodland vegetation where summers are hot and droughty. Highland oak (*Quercus macranthera*) is a subalpine species common in Southern Georgia and Armenia. *Hedera* and *Ilex* are evergreens confined to low-altitude Colchic forests and occur mostly in the west of the country.
Figure 8.4 (a). The modern distribution of *Fagus* pollen in the study area.
Figure 8.4 (b). Changes in *Fagus* (Group C) pollen abundance in Georgia through the last 14,000 years.
Figure 8.5 (a). The modern distribution of *Quercus* pollen in the study area.
Figure 8.5 (b). Changes in *Quercus* (Group D) pollen abundance in Georgia through the last 14,000 years.
Group D – Mid Holocene

*Castanea* and *Quercus* were present at low altitudes during the late Pleistocene – *Castanea* in the west and *Quercus* in the east. Both taxa expanded during the early-mid Holocene, but it was only during the mid Holocene that they became dominant in several pollen records (Figure 8.5). *Hedera* and *Ilex* likewise displayed a maximum distribution in Colchis and Abkhazia during the mid Holocene. All four taxa declined between 4500 and 3000 years ago and have not regained their former importance in the vegetation in recent times.

Changing climates have exerted a profound influence on the histories of *Castanea, Quercus, Hedera* and *Ilex*. Milder winters would be expected to benefit Group D taxa over others. In Southern Georgia, the onset of milder temperatures in the mid Holocene, accompanied by slightly drier conditions, may have encouraged *Quercus* to dominate. Warmer temperatures in Colchis may have assisted the spread of *Castanea, Ilex* and *Hedera* there. Colder winters through the late Holocene reduced Group D taxa considerably, but in many circumstances this factor alone is insufficient to explain the decline of *Quercus* and *Castanea*. These trees are very much intertwined with human history, having long been exploited by humans for fuel, timber, food and fodder. Past human activity is thought to have reduced their populations to a significant degree, since they occupy soils favoured for agriculture (Dolukhanov, 1966). On parts of the coastal plain, *Castanea* was set back by paludification during the late Holocene (see Chapter Seven).

Group E – Late Holocene

This last group includes an assortment of taxa that achieved maximum abundances in the late Holocene. *Juglans* and *Pterocarya* are large thermophilous trees of the Juglandaceae family found in lowland gallery forests and, in the case of *Juglans*, more commonly in cultivation. *Picea* and *Pinus* are cold-tolerant coniferous trees, distributed in the upper forest belt; *Picea* is less drought-tolerant than *Pinus* and is hence associated with Western Georgia. *Ostrya*-type pollen represents *Carpinus orientalis*, a tree or shrub found in the forest understorey, but most abundant in scrub and shibliak communities. *Olea europaea* is the common olive, native to the circum-
Mediterranean region, and *Plantago* represents grassland herbs that occur widely in open vegetation, especially pastures.

Although these seven taxa peaked during the late Holocene, some of them were also locally abundant during the late Pleistocene and early Holocene. *Juglans, Pterocarya, Picea* and *Pinus* were present in lowland refugia of Western and Eastern Georgia during the late Pleistocene. *Juglans* and *Pterocarya* were probably dominant trees on some floodplains in Eastern Georgia, but declined during the early Holocene to the point of local extinction. *Picea* and *Pinus* were likewise much reduced. *Ostrya*-type increased with the early Holocene advance of forest trees, but faded rapidly into the background. Around 4000 years ago, *Picea, Pinus* and *Ostrya*-type began to expand (Figure 8.6). Two thousand years ago they were joined by *Juglans, Pterocarya* and *Olea europaea* and all these taxa increased at an accelerated pace more recently. If the pollen records are indicative of plant abundance, then *Picea, Pinus, Pterocarya* and *Carpinus orientalis* are more common now than at any time during the entire Holocene.

Several hypotheses could help explain these patterns. For *Picea* and *Pinus*, cooler winter temperatures during the late Holocene may have assisted their late expansion through the mountain forests of Georgia. This hypothesis has some merit, but fails to explain why thermophiles like *Pterocarya, Juglans, Olea europaea* and *Ostrya*-type expanded at the same time at lower altitudes. For *Juglans* and *Olea europaea*, the most straightforward explanation is that people planted them. Most archaeobotanical finds of *Juglans* post-date the Hellenistic Period (Lisitsyna and Prishchepenko, 1977; Rusishvili, 1990), suggesting that walnuts were introduced to cultivation via contact with Greece and Rome. It is probable that olives were similarly introduced.

Human activities during the late Holocene could have also contributed to the rise of *Carpinus orientalis, Pterocarya* and *Plantago*, as well as *Picea* and *Pinus*, through the abandonment of pastures and fields (favouring *Pterocarya* and *Carpinus orientalis*), deforestation (favouring *Plantago* and *Picea*) and forest fire (favouring *Pinus*). Although a climatic change seems the most probable reason for the late Holocene expansion of *Picea* and *Pinus*, they and other taxa have also benefited from recent changes in human economy and land-use.
Figure 8.6 (a). The modern distribution of *Picea* pollen in the study area.
Figure 8.6 (b). Changes in *Picea* (Group E) pollen abundance in Georgia through the last 14,000 years.
Other taxa, including *Acer, Alnus, Frangula, Pistacia, Rhododendron, Rosaceae, Vitis, Poaceae and Cerealia*-type, have histories that do not easily fit into one of the five categories above. They are discussed in detail in Appendix A.

Each of the categories provides an insight into the climatic and ecological conditions prevailing at various stages through the past 14,000 years. During the late Pleistocene, tree lines were depressed by cold winters and aridity; forests were confined to the Black Sea lowlands in Western Georgia and the floodplains of Eastern Georgia. Increasing moisture during the early Holocene led to the rapid colonisation of the mountains by pioneer species such as *Betula* and *Corylus*, but these were quickly supplanted by *Fagus, Carpinus* and other mesophiles. The mid Holocene appears to have been somewhat warmer – *Quercus* expanded at all altitudes, and *Castanea* increased in the lowlands. Conditions changed again in the late Holocene, as these thermophiles retreated and cold-tolerant conifers widened their distribution. Many mid-late Holocene changes, however, bear the obvious imprint of human activity.

*Palaeovegetation Maps for Georgia – 14000 cal. yr BP to the present*

The histories of the individual taxa discussed above have considerable ecological and geographical value. They allow us to trace changes in altitudinal or spatial distribution, population expansions and contractions, migrations and extinctions. But plants do not exist in isolation. Their movements may be important to the composition of plant communities, but may have little impact on the structure of the vegetation. Hence, in this section, an attempt is made to reconstruct the past vegetation of the study area using the available pollen data.

**Method**

There is no one, incontrovertible method for the reconstruction of past vegetation. Most attempts are relatively subjective, relying on a knowledge of the present vegetation, how it relates to present soils and hydrology, comparing the present vegetation to the pollen signature it produces, and then applying all this
knowledge to the interpretation of palaeoecological, archaeological or other historical data to give an approximation of how the landscape may have looked in the past (Malmer and Regnell, 1986). The spatial scale of interest, which may range from the environs of an archaeological site to a whole continent, largely determines how this past vegetation is then mapped (e.g Malmer and Regnell, 1986; Prentice et al., 2000).

In recent decades palynologists have made a concerted effort to quantify their observations. Up until the 1960s, most analysts relied on “qualitative, intuitive interpretation of pollen diagrams”, paying little attention to the need to link modern plant communities to pollen spectra (Wright, 1967, p. 322). Since then a great deal of work has examined the relative pollen productivity of various trees and other plants (Andersen, 1970; Andersen, 1973; Bradshaw, 1981; Bunting, 2003, and references therein), providing a numerical basis for interpreting pollen spectra in terms of the composition of the vegetation that produced it. The problem of pollen source area has so far frustrated attempts to accurately reconstruct vegetation mosaic from pollen data, but considerable progress has been made both in understanding pollen source area and in modelling landscape openness (Davis, 2000; Gaillard and Berglund, 1998; Prentice, 1985; Sugita, 1993; Sugita et al., 1999). Because of the great complexity of interactions between different pollen types within the one pollen sum, a common approach has been to analyse surface samples and compare these semi-quantitatively with fossil pollen assemblages (see Birks and Birks, 1980, p. 237-255).

Statistical methods have also been applied to match fossil spectra with modern analogues in the vegetation (e.g. Anderson et al., 1989; Overpeck et al., 1985), thus removing the bias associated with subjectively comparing modern and fossil pollen spectra. This method runs into difficulty where no modern analogue has been found for the particular pollen spectrum in question and is an especial problem in heavily human-impacted landscapes (Birks, 1973; Webb, 1973; Webb, 1980).

An alternative approach involves linking individual pollen types to the plants that produce them and the environments in which these plants are found. The most ambitious example of this is the BIOME project, which relates each pollen taxon to possible plant functional types and thence to biomes, assigning each fossil pollen spectrum to a biome via a matrix of probabilities (Prentice et al., 1996). This method circumvents the problem of finding modern analogues for pollen spectra because it relies on plant functional types and not pollen taxa per se (Prentice et al., 1996). The
method has been applied to produce palaeovegetation maps of Europe (Prentice et al., 1996), the Former Soviet Union (Tarasov et al., 2000; Tarasov et al., 1998), China (Yu et al., 1998), North America (Williams et al., 1998), Africa and most of the Northern Hemisphere (Prentice et al., 2000).

At the continental scale, the BIOME reconstructions are convincing representations of the present day vegetation. It is more difficult to assess their applicability at the sub-regional scale: a certain “noisiness” is produced in mountainous areas and along biome boundaries (Prentice et al., 1996, p. 191). It comes as no surprise that some of the reconstructed biomes for the Caucasus, with its complex relief and varied vegetation, do not accord to the present vegetation (Tarasov et al., 1998). This may have as much to do with the quality of the original dataset as it does with the errors inherent in the model.

Pollen data in this dissertation will shortly be incorporated into a BIOME model for the Eastern Mediterranean-Black Sea-Caspian Sea region, but until this is completed, I have adopted the same approach used by Huntley (1988) to construct palaeovegetation maps for Europe. This method uses TWINSPAN to classify pollen data into ecologically meaningful and similar groups, and mapping to trace the movements of these groups through time. It has an advantage over some other multivariate methods in that it does not assume that fossil pollen spectra will have a modern analogue. It merely identifies the prevailing trend in the data and classifies pollen spectra according to similarities in their composition. The indicator species and thresholds produced by the analysis have ecological and biogeographical meaning and can be used subsequently to classify other pollen spectra.

The dataset described at the beginning of this chapter was reduced to include only those pollen diagrams where both arboreal and non-arboreal pollen were reported. This is because of the importance of taxa like Poaceae in mountain grasslands and Chenopodiaceae and Artemisia in semideserts and steppes. An attempt to use arboreal pollen alone failed because of the prevalence of long-distance-transported Pinus and Alnus pollen in treeless environments. I excluded Cerealia-

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10 Eastern Mediterranean-Black Sea-Caspian Corridor Biomes, the palynology working group of IGCP project 521, coordinated by Drs C. Cordova and P. Mudie:

www.bridge.bris.ac.uk/projects/EMBSECBIO
type pollen from the analysis because few palynologists in the study area have
counted or reported it. The Sagarejo and Bazaleti records (Gogichaishvili, 1990) were
also excluded because they skewed the result considerably; they appear to be outliers
perhaps because of fluvial pollen transport or redeposition. TWINSPAN pseudo-
species cut levels were set to 1, 2, 4, 10, 20, 30, 40, 60 and 80% to ensure that major
taxa were selected as indicators and to reduce the influence of chance occurrences.

The data are presented on a base map of Georgian bioclimatic zones. This
map was produced from a digital elevation model and climatic data using the
IsoCluster algorithm in ArcGIS software (ESRI, 2005). This yielded sixteen groups
based on similarities in elevation, temperature and rainfall (Figure 8.7). These groups
were then extrapolated to the entire landscape of Georgia through a maximum
likelihood classification. The resulting map (Figure 8.8) shares broad similarities with
Ketskhoveli’s superbly detailed Map of Reconstructed Vegetation Cover (AN GSSR,
1964; Ketskhoveli, 1959), but is not intended to replace it. Instead it provides a useful
bioclimatic backdrop for examining vegetation changes at individual sites.

Figure 8.7. Average rainfall, elevation and temperature values for Georgian bioclimatic zones shown
in Figure 8.8.
Figure 8.8. Bioclimatic zones of Georgia. Major vegetation units corresponding to each zone are given in parentheses.
Figure 8.9. TWINSPAN classification dendrogram for the Georgian pollen dataset.

Table 8.3. TWINSPAN classification of pollen taxa (eigenvalue = 0.71)

<table>
<thead>
<tr>
<th>Euxinian and Euro-Siberian provinces</th>
<th>Irano-Turanian province</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abies</td>
<td>Hippophae</td>
</tr>
<tr>
<td>Alnus</td>
<td>Ilex</td>
</tr>
<tr>
<td>Betula</td>
<td>Picea</td>
</tr>
<tr>
<td>Carpinus betulus</td>
<td>Pinus</td>
</tr>
<tr>
<td>Castanea</td>
<td>Pterocarya</td>
</tr>
<tr>
<td>Corylus</td>
<td>Rhododendron</td>
</tr>
<tr>
<td>Fagus</td>
<td>Tilia</td>
</tr>
<tr>
<td>Frangula</td>
<td>Ulmus and Zelkova</td>
</tr>
<tr>
<td>Hedera</td>
<td>Quercus</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Classification

The major TWINSPAN division in the data set, explaining 23% of variance, separates samples high in *Alnus* from those with more Chenopodiaceae, Poaceae, *Quercus* and *Ostrya*-type (Figure 8.9). In biogeographical terms this divides the moist Euxinian and Euro-Siberian botanical provinces from the more arid Irano-Turanian province (sensu Zohary, 1973). The pollen taxa best associated with these provinces are given in Table 8.3. The Euxinian group is split from the Euro-Siberian by its greater representation of *Carpinus betulus* and *Ulmus-Zelkova*. The Euro-Siberian group is characterised by comparatively high proportions of *Picea* and *Pinus* and is generally associated with higher altitudes.

The Irano-Turanian group is divided on the basis of *Ephedra*, *Artemisia* and Chenopodiaceae proportions. The group with more of these taxa is a steppe and semidesert group, while the other group has analogues in oak forests, xerophyte scrub and mountain grasslands.
Eight sub-groups have been chosen for mapping because these most simply and accurately reflect broad patterns in the study area’s present-day vegetation. The groups are:

1. Glacial desert-steppe (no modern analogue)
2. Semidesert-steppe
3. Oak-xerophyte group (oak forest, open woods and xerophytic scrub)
4. Mountain grassland
5. Mixed forest group (beech, hornbeam, elm, fir and chestnut forests)
6. Alder swamp-forest
7. Subalpine vegetation
8. Coniferous forest group (forests and open woods of pine and spruce)

The present-day map of these groups (Figure 8.10), despite some gaps, clearly portrays the major vegetation types in the study area. Alder swamps are located on the Black Sea coast, and above these is a zone of mixed deciduous forest, with alpine vegetation on the Main Caucasus and Anticaucasus Ranges. The coniferous forests of the Akhaltsikhe-Bakuriani area are clearly delineated, and east of these we pass over the treeless mountain grasslands of the South Georgian Uplands, through the narrow oak forest belt, along the xerophytic lower tree line into the semidesert-steppe region of Eastern Georgia.

Around 9% of the samples have a pollen signal that is not entirely consistent with their present-day vegetation, and these are listed in Table 8.4. In general, the misclassifications are easily explained by long-distance pollen transport in mountain areas, by the site having a larger pollen source area than accounted for in the vegetation description provided by the authors, the mixing of pollen from different altitudinal vegetation belts, or by sampling surface sediments from lake edges rather than the centre. The misclassifications tend to push the pollen-based vegetation units upwards because of pollen transport to higher elevations (cf. Prentice et al., 1996).
The palaeovegetation maps that follow are limited by the paucity of sites in the late Pleistocene, early Holocene and the arid parts of the study area, as well as problems with dating where there are few absolute dates available. Not all vegetation types will be captured in the samples examined, and the successional transitions between some of them will be missed because of the 1000-year time interval chosen. Nevertheless, I believe they provide a good overview of the general stages of late Quaternary palaeovegetation development in the study area.

Table 8.4. Misclassified pollen-vegetation relationships.

<table>
<thead>
<tr>
<th>Site and sample no.</th>
<th>Source</th>
<th>Pollen-based vegetation</th>
<th>Observed vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagodekhi 6</td>
<td>KE</td>
<td>3. Oak-xerophyte group</td>
<td>7. Subalpine</td>
</tr>
<tr>
<td>Cherepanov 2-3</td>
<td>C</td>
<td>4. Mountain grassland</td>
<td>3/2. Oak forest, mountain grassland</td>
</tr>
<tr>
<td>Immati core top</td>
<td>N</td>
<td>5. Mixed forest group</td>
<td>6/5. Alder swamps, mixed forests</td>
</tr>
<tr>
<td>Lisi 2</td>
<td>KS</td>
<td>5. Mixed forest group</td>
<td>4/2. Mountain grassland, steppe</td>
</tr>
<tr>
<td>Lagodekhi 1, 2, 4, 5</td>
<td>KE</td>
<td>5. Mixed forest group</td>
<td>7. Subalpine</td>
</tr>
<tr>
<td>Akhaltsikhe 183</td>
<td>K</td>
<td>8. Conifer forest group</td>
<td>4. Mountain grassland</td>
</tr>
<tr>
<td>Ktsisi Zeda Vake</td>
<td>M</td>
<td>8. Conifer forest group</td>
<td>4. Mountain grassland</td>
</tr>
<tr>
<td>Nariani</td>
<td>M</td>
<td>8. Conifer forest group</td>
<td>4. Mountain grassland</td>
</tr>
<tr>
<td>Kartsakhi</td>
<td>M</td>
<td>8. Conifer forest group</td>
<td>4. Mountain grassland</td>
</tr>
</tbody>
</table>


Figure 8.10. Present-day reconstructed vegetation at pollen sites in Georgia.
Palaeovegetation maps for Georgia – 14,000 to 1,000 years before present. Symbols are the same as those used in Figure 8.10.

**Figure 8.11.** Palaeovegetation maps for Georgia – 14,000 to 1,000 years before present. Symbols are the same as those used in Figure 8.10.

**Palaeovegetation development from 14,000 cal. yr BP to the present**

During the late Pleistocene, from 14,000 to 11,500 cal. yr BP, mixed deciduous forests grew in the Black Sea lowlands, providing refuge to thermophilous
trees in *Abies*-dominated vegetation (Figure 8.11). At the same time in Southern Georgia the landscape was one of hyper-arid semidesert-steppe, a community that apparently extended far to the west, into what is today the ‘humid mountain zone’ where *Picea* forests grow.

In the early Holocene the mixed deciduous forests in Abkhazia changed to alder forests, perhaps as *Abies* and other trees migrated upslope and the lowlands were paludified by rising watertables fed by glacial meltwater. Glacial desert-steppe vegetation persisted into the early Holocene at several sites in Southern Georgia, suggesting that the climate remained arid until after 10,000 BP, when desert-steppes gave way to grasslands and alpine meadows.

Nine thousand years ago, steppic vegetation had vanished from the study sites. A grassy oak-xerophyte community populated the Tsalka Plateau. Further west, on the moist slopes of the Trialeti Range, subalpine meadows gave way to mixed deciduous forests, while in Abkhazia and Colchis, alder forests and mixed forests were probably widespread.

At 8000 cal. yr BP we can begin to see the differentiation of the vegetation on geographical lines – the mixed deciduous forests of Western Georgia and the oak woodlands of the East, both hemmed in by subalpine vegetation on the surrounding high mountains. This situation changed surprisingly little during the next few thousand years. Apart from the appearance of alder swamps at various locations in Colchis, the vegetation of the mountains remained stable from 8000 BP until after 5000 BP.

At 5000 BP, coniferous forest appears on the maps for the first time, in the mountains of Ajara. By 4000 BP, this community had spread eastwards at the same time as mountain grassland vegetation appeared in Southern Georgia and areas of subalpine vegetation had expanded to encompass some sites formerly in mixed deciduous forest.

A thousand years later the area of *Alnus* swamps along the Black Sea coast had grown considerably as sea levels rose. Mountain grasslands expanded on the Tsalka Plateau, and subalpine vegetation in the Bakuriani and Javakheti areas. Coniferous forest appeared briefly at Salkanalla in the North Caucasus.
Two thousand years ago the landscape of the entire study area had changed dramatically. No longer did it resemble the simple divisions of the early Holocene. Oak-xerophyte vegetation disappears from the map, replaced by steppe vegetation at lower altitudes and mountain grasslands in elevated places. Coniferous forest invaded the Bakuriani area, formerly home to mixed forests and subalpine meadow vegetation. ‘Subalpine’ vegetation appears at one site on the sea coast, probably as a result of deforestation or fluvial pollen transport. Only in Abkhazia does the vegetation remain the same.

By 1000 cal. yr BP, mountain grasslands had enveloped the highlands of Southern Georgia, grading into steppe vegetation in the east and open pine forest in the Javakheti region. The Colchis coastline was completely paludified and mixed forests confined to the piedmonts and mountainsides. The last 1000 years saw the expansion of alder swamps and subalpine vegetation in Abkhazia, the re-invasion of coniferous forests in the Bakuriani area, and the re-establishment of oak-hornbeam forest near Tbilisi.

Several points of interest emerge from this analysis. Firstly, the desert-steppes of the late Pleistocene lingered on in the continental parts of the study area for at least a thousand years after the Holocene began. This suggests a slow change from hyper-arid to more humid conditions. Secondly, deciduous trees were dominant in forests almost everywhere during the early-mid Holocene, with coniferous forest appearing only 5000 years ago in Ajara and subsequently spreading through Southern Georgia. It seems that the spread of conifers was stalled by conditions during the early-mid Holocene and accelerated during the late Holocene. Thirdly, the late Holocene appears to have been a time of rapid and fundamental reorganisation in Georgia’s vegetation. For example, the Tsavkisi site (Chapter Five), classified as oak-xerophyte vegetation for most of its 8000-year history, changed to steppe 2000 years ago and mountain grassland 1000 years ago, before reverting to oak-xerophyte in recent years. A drawback of this classification is that it cannot adequately describe the density of past vegetation units, such that the oak-xerophyte group includes oak forest as well as arid scrub and highland savanna. Such nuances are better accentuated by the numerical analyses in previous chapters.

In the following section, the same dataset is used to provide some insight into the reasons for Georgia’s changing palaeovegetation. By estimating past climatic
parameters, the relative roles of climate, human impact and other factors in explaining vegetation change can be more objectively evaluated.

**Holocene climatic change in Georgia – a modelling experiment**

A significant branch of recent palaeoenvironmental research has aimed to reconstruct quantitative estimates of past climate from palaeoecological data (e.g. Cheddadi et al., 1998; Guiot, 1990; Magny et al., 2001; Peyron et al., 2000; Prebble and Shulmeister, 2002; Seppä and Birks, 2001; Solovieva et al., 2005). In all of these studies, the modern analogue is the cornerstone of the reconstruction.

But it must be admitted that in spite of its attractiveness, the modern analogue technique has many inherent problems. Reconstructing climatic parameters carries the assumption that modern pollen spectra are in equilibrium with the current climate and that fossil pollen spectra were in equilibrium with past climate (Birks and Birks, 1980; Jackson and Williams, 2004). The modern analogue technique is also unable to adequately address problems of palaeoecological ‘convergence’ and ‘divergence’ (Jackson and Williams, 2004), where different vegetation units may produce similar pollen assemblages due to pollen representation and taxonomic factors (convergence) or when the same vegetation unit produces pollen assemblages that differ due to source-area and fossilisation factors (divergence). And the problem of ‘no-modern-analogue’ pollen spectra is well documented (Anderson et al., 1989; Jackson and Williams, 2004; Overpeck et al., 1985).

In areas where vegetation dynamics are well understood, some authors have avoided the no-analogue problem by using forest simulation models. By comparing simulated palaeovegetation with fossil pollen data, these models can be ‘tuned’ to accurately estimate past climatic parameters (e.g. Hall and McGlone, 2001).

Vegetation dynamics, in a modelling sense, are poorly understood in the Caucasus region, so the modern analogue technique provides the most appropriate method for palaeoclimatic reconstruction. Despite its constraints and assumptions, the climatic trends that can be produced from pollen data are very useful for hypothesis testing. Pollen-derived precipitation and temperature trends can be compared to similar reconstructions derived from other proxies, such as chironomids, tree rings, geochemistry and stable isotopes. In the future, comparisons such as these
will bring about a more refined understanding of the palaeoclimate and help to both inform and improve reconstructions based on pollen data.

**Method**

For the purposes of estimating past climatic parameters, I have adopted an approach that combines ordination scores and elevation data in a model based on non-parametric multiplicative regression (McCune and Mefford, 2004). Rather than being a direct method, which links pollen spectra to modern analogues via a distance metric, this method attempts to circumvent problems of no-analogue, divergent and convergent spectra by linking past spectra to *gradients produced by modern analogues*. It can therefore be conceptualised as an indirect method.

**Figure 8.12.** DCA ordination of the Georgian pollen dataset. Result for axes 1 and 2 (left) and axes 1 and 3 (right).

To begin with, the data set described in this chapter was reduced to a few relevant trends using detrended correspondence analysis (DCA – see Chapter Three). This provided ordination scores for each fossil and modern sample. The result is shown in Figure 8.12. Next, correlations between the modern sample scores and environmental variables were sought. Precipitation was positively correlated with DCA axis 1 ($r^2 = 0.55$); July and January temperature were positively correlated with DCA axis 2 ($r^2 = 0.10$ and $0.08$) and negatively correlated with DCA axis 3 ($r^2 =$
Temperature reconstructions, therefore, must be viewed with much more scepticism than rainfall estimates.

The next stage of the method involved the habitat-modelling computer program Hyperniche (McCune and Mefford, 2004). This program builds non-linear models of species abundance based on predictors. In this case, the predictor variables were input as modern DCA scores, while the response was the modern climate dataset (AN GSSR, 1964). The model form selected was Local Mean Non-Parametric Multiple Regression (LM-NPMR) with a Gaussian weighting function (McCune and Mefford, 2004).

Hyperniche searches for models that best fit the relationship between the ordination scores and climatic variables. Selection of the ‘best’ model involved a trade-off between goodness-of-fit and parsimony: often a model with a lower $xR^2$ (cross-validated $R^2$) value and broader tolerance gave a better prediction from patchy data. The selected models (Figure 8.13, Table 8.5) were then used to estimate palaeoclimatic parameters for fossil pollen data based on site elevation and ordination scores. Data were mapped in ArcGIS (ESRI, 2005) and points were interpolated by kriging based on the exponential semivariogram model (Johnston, 1998), which seems to be the most appropriate model for pollen dispersion (cf. Davis, 2000).

**Figure 8.13.** NPMR models used to derive palaeoclimatic estimates from DCA scores and elevation. The graphs are three-dimensional response surfaces, showing modelled values (on the vertical axis) compared to predictors (diagonal axes).
Table 8.5. Predictors used in the selected models, tolerances of each, and correlation coefficients for the three models. ANS: Average Neighbourhood Size (a measure of model flexibility).

<table>
<thead>
<tr>
<th>Model</th>
<th>Predictors (and tolerances)</th>
<th>ANS</th>
<th>Fit (xR^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual precipitation</td>
<td>Axis 1 (36.2), Axis 2 (68.6) and Elevation (458)</td>
<td>16.5</td>
<td>0.81</td>
</tr>
<tr>
<td>July temperature</td>
<td>Axis 3 (29.6) and Elevation (305)</td>
<td>18.8</td>
<td>0.72</td>
</tr>
<tr>
<td>January temperature</td>
<td>Axis 1 (60.3), Axis 2 (68.6) and Elevation (305)</td>
<td>16.3</td>
<td>0.68</td>
</tr>
</tbody>
</table>

**Results**

Scatterplots of observed climatic parameters versus predicted values are shown in Figure 8.14. Predicted rainfall values are quite close to the rainfall data obtained from the Georgian Atlas (AN GSSR, 1964).\(^{11}\) Most overestimates relate to high *Picea* percentages in the Akhaltsikhe Basin of Southern Georgia. Underestimates occur at sites where Chenopodiaceae are disproportionately common due to long-distance pollen transport (in alpine sites) and local disturbance (in forested sites). Temperature predictions are overestimated in some treeless sites because of pollen transport from lower altitudes; temperatures are underestimated in places where conifer pollen is dominant. On the strength of correlations between observed and predicted data, temperature predictions are considered less reliable than rainfall. Nonetheless, correlation coefficients produced by this method are equivalent to those in studies that employ the ‘best modern analogue’ technique (Cheddadi et al., 1998; Guiot, 1990; Magny et al., 2001). Each of the reconstructed climatic parameters is discussed below.

![Scatterplots of modelled versus observed climatic parameters for modern data. Dotted line on each graph indicates a one-to-one relationship.](image)

**Figure 8.14.** Scatterplots of modelled versus observed climatic parameters for modern data. Dotted line on each graph indicates a one-to-one relationship.

\(^{11}\) Data in the Georgian Atlas are modelled from a discontinuous network of meteorological stations and may not be entirely accurate representations of climate at a given point. Despite this constraint, these data are still the best available for Georgia as a whole.
Rainfall

Figure 8.15 shows reconstructed precipitation patterns for the last 12,000 years. The reconstructed pattern for the present-day, accounting for the patchy distribution of sites, quite closely resembles the actual pattern (Figure 2.6). A certain loss of detail can be ascribed to interpolation between data points, which does not take altitudinal variations into account. The high rainfall zone of Western Georgia, and especially the mountain slopes of Ajara and the Main Caucasus Range are clearly portrayed. The arid lowlands of Eastern Georgia are also accurately delineated in this reconstruction. Somewhat less certainty surrounds the gradation between the arid and humid zones, as there are no lake or wetland pollen sites in the Shida Kartli and Imereti regions.

If we turn now to the reconstructed history of rainfall for the Holocene, 12,000 years ago arid conditions prevailed across Southern Georgia with somewhat moister climates in the Black Sea refugium. Late-glacial rainfall values are higher than expected and this is probably due to the Local Mean estimator in the model. Aridity waned through the early Holocene, with a pattern resembling the modern one established between 9000 and 8000 BP. The lead up to the mid Holocene saw a partial contraction of the arid zone, with higher rainfall penetrating further eastward than it does today. By 5000 BP, however, the distinction between the humid west and arid east had sharpened.

Over the next few thousand years, the rainfall pattern in Western Georgia appears to have moved from the south to the north, producing drier conditions in Ajara 3000 years ago. Increased precipitation is predicted for 2000 BP, with higher rainfall throughout Western Georgia. The Mediaeval Period saw a contraction of the humid zone and a consequent expansion of the drier zone westward, producing much steeper precipitation gradients in Western Georgia. A similar pattern is reconstructed for the present-day, with a return to high rainfall values in Ajara.

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12 The Local Mean estimator tends to compress values at the extreme ends of the predictor variables’ range, such that high and low DCA scores (e.g. late Pleistocene) tend to be pushed closer to those in the centre. When the analysis was re-run using a Local Linear estimator instead, the lack of analogues for the late Pleistocene resulted in negative rainfall estimations in some cases and lower $xR^2$ values.
Figure 8.15. Reconstructed rainfall patterns in Georgia for the last 12,000 years (in mm.a$^{-1}$). Dots indicate sampling locations.
Figure 8.16. Reconstructed January temperature patterns in Georgia for the last 12 ka (in °C). Dots indicate sampling locations.
Figure 8.17. Reconstructed July temperature patterns in Georgia for the last 12,000 yr (in °C). Dots indicate sampling locations.
Temperature

As mentioned, less certainty is attached to modelled estimates of temperature. The present-day pattern for January (Figure 8.16) agrees well with observations for each of the pollen sites, especially in the generally colder winters experienced in the continental highlands of Southern Georgia compared to milder temperatures along the Main Caucasus Range. Modelled values just below freezing for the lowland of Eastern Georgia and above freezing for the Colchis coastline are likewise in accordance with observed temperatures.

The modelled changes in Holocene January temperatures are much more subtle than rainfall variations and probably much less reliable. With this in mind, the modelled data yield late Pleistocene and early Holocene temperatures very similar to or higher than present values. This could be an artefact of the late Holocene increase in *Picea* and *Pinus*, which are the most important indicators of low winter temperatures in the modern context. These two taxa are all but absent in pollen spectra of late Pleistocene to early Holocene age, artificially elevating modelled temperatures. Yet the temperature reconstructions given by Davis et al. (2003) also show elevated early Holocene temperatures for southeastern Europe based on pollen data, so the trend cannot be dismissed out of hand.

The data suggest that warmer winters prevailed in lowland Western Georgia through the early Holocene, peaking in about 6000 BP. Since that time, the pattern of elevated winter temperatures in Western Georgia has shifted southward, leading to cooler winters in Abkhazia, though this too may be an artefact of site distribution. Modelled temperatures for the late Holocene indicate progressive cooling, with modern values the coldest for the entire Holocene. The magnitude of this change is greatly overstated by recent increases in *Pinus* and *Picea* pollen throughout the study area, increases that can be explained in terms of human impact and edaphic changes as well as colder winter temperatures.

July temperatures should be slightly more reliable than January values. Estimates for the present-day (Figure 8.17) are reasonably close to the observed pattern, with low temperatures (below 16 °C) in the mountains and high temperatures (above 24 °C) in the semidesert lowlands. Past estimates show little change through
the early Holocene, but a gradual increase in summer temperatures around 7000 BP. The mid Holocene, according to these data, appears to have been a time of reduced thermal gradients across Georgia, i.e. slightly cooler summers along the Black Sea coast and slightly warmer summers further inland. This pattern was reversed during the late Holocene, especially 2000 years ago, when the difference between the cold highlands and warm lowlands was more pronounced. Like the January temperature estimates, July values seem to indicate a temperature increase in the inland part of Western Georgia and a decrease in Southern Georgia through the last thousand years.

**Local trends**

Maps of reconstructed climate are useful for tracing major spatial shifts over time, but give only a coarse indication of change at individual sites. By applying the same models to pollen data from previous chapters, palaeoclimatic trends can be reconstructed for the Tbilisi area, Tsalka Plateau and Black Sea coast. This has already been attempted for the Tbilisi and Tsalka sites in Chapters Five and Six, although the trends produced by weighted averaging were difficult to interpret because temperature, rainfall and forest cover were all interrelated. And yet these trends were produced from complete pollen assemblages and with reference to good modern analogues in Southern Georgia; as such they provide a semi-independent proxy for assessing the palaeoclimatic models put forward in this section.

Figure 8.18 shows reconstructed palaeoclimatic trends for four sites with long Holocene records – Aligol, Imera, Ispani and Tsavkisi. Rainfall trends for the two Tsalka Plateau sites, Aligol and Imera, are very close, indicating aridity through the late Pleistocene, a gradual increase in rainfall through the early Holocene, peaking 6000 years ago, before declining 5000-3500 years ago, then rising again until 2000 years ago and fluctuating subsequently. Interestingly, the Tsavkisi trend follows this one not at all. Rather than decreased rainfall 5000-3500 years ago, it exhibits increased values, and declines thereafter. In this respect the Tsavkisi rainfall trend is closer to the trend reconstructed for Ispani, on the Black Sea coast.

The same can be said for July temperature estimates, which for Tsavkisi and Ispani seem to follow rainfall trends. To an extent, summer temperatures in the lower altitude sites (Ispani and Tsavkisi) have been far more changeable than those
reconstructed for the highlands (Aligol and Imera). Conversely, January temperature estimates suggest that the highlands were subject to much more variation in winter temperatures than lower altitudes. And there is a surprising correlation between summer temperatures and rainfall lower altitudes on the one hand and winter temperatures and rainfall in the highlands on the other; such that hot summers and wet conditions at lower altitudes seem to accompany warmer winters and dry conditions in the highlands. Cool summers and dry conditions at lower altitudes accompany cold winters and wet conditions in the highlands.

Figure 8.18. Modelled Holocene palaeoclimatic trends based on pollen data from Southern Georgia, presented in order of altitude. Figures in parentheses beside site names are present-day reconstructed values. Vertical scales for each climatic parameter are given at left (vertical scale on the Ispani rainfall curve has been reduced by ten times). The dotted lines are Weighted Averaging environmental trends from Chapters Five and Six included for comparison.
This unexpected correlation warrants further discussion. It is very possible that it arises from the model itself: that the use of DCA ordination axes somehow creates an artefactual relationship where none exists. It is hard to discredit this idea without independent palaeoclimatic data for the Caucasus. Another explanation might be that pollen assemblages produced by vegetation at different altitudes are sensitive to different seasonal aspects of the climate. *A priori*, one might expect vegetation at the upper tree line to be more sensitive to freezing winters than vegetation at the lower tree line, which is more sensitive to desiccation by high summer temperatures.

Data presented in Chapters Five and Six (Figures 5.23 and 6.20) also suggest that the Tsalka Plateau sites have a different history of temperature and rainfall compared to Tsavkisi near Tbilisi. Warmer temperatures across the study area could result in higher rainfall and lake levels on the wooded slopes near Tbilisi because of the rain-producing convection currents they generate. In the sunny Tsalka Plateau grasslands, warmer temperatures may increase summer evaporation, producing relatively dry conditions (and low lake levels, as shown in Chapter Six). It seems very probable that the ‘rainfall’ parameter in pollen-based palaeoclimatic estimates includes a significant precipitation-to-evaporation component (cf. Magny et al., 2001).

Much uncertainty surrounds these reconstructed trends and their interpretation. Late Pleistocene estimations are particularly difficult to accept, although in relative terms they probably reflect the direction of change. The modelling method presented here is experimental and to my knowledge has not been used previously in the palynological literature; better results may have come from applying the method to a simpler region, where palynological difficulties associated with mountainous and semi-arid environments are minimised and the climatic dataset is more reliable. And because these reconstructions are all based on the same pollen dataset, there is a danger of constructing circular arguments in support of past climatic changes. It is very difficult to disentangle the late Holocene conifer ingression, for instance, from possible human impacts and the effects of progressive soil impoverishment.

I merely offer these reconstructions as a possible model for Holocene climatic change in Georgia. As such, they are testable hypotheses, and I hope that in future
alternative sources of palaeoclimatic data from the Caucasus will be brought to both inform and improve them.

**Conclusions**

The foregoing chapter attempts to chart a course through the Holocene vegetation history of Georgia, from the late Pleistocene’s upland deserts and lowland refugia, via the early-mid Holocene’s advancing forests and expansion of thermophiles in the mid Holocene, through the rapid vegetation changes of the mid-late Holocene to the varied, anthropogenic landscapes of today.

The maps confirm the widespread aridity and high seasonality of the late Pleistocene, the more moderate, humid climate of the early-mid Holocene, followed by warmer mid Holocene conditions and more variable, generally cooler climates during the late Holocene. Climate change has thus exerted a profound influence on the course of vegetation development over the past 14,000 years.

But the present-day complexity of the study area’s vegetation must be explained, in part, by the long and varied impact of humans. Through burning, grazing, cropping and felling, humans have disrupted the successional pathways of the beech forests of Western Georgia and the oak woods of Eastern Georgia, giving rise to a number of plant communities that seem to have been absent during the early and mid Holocene.

In the following chapter, the comparative roles of climate change and human impacts on vegetation development in Southern Georgia will be evaluated in the light of independent palaeoclimatic and archaeological data.
‘During the Holocene, human activity has become one of the major influences on the vegetation cover. Its role has increased unremittingly, especially in recent times. Extensive areas are now covered in cultural vegetation. The most fertile forest and steppe soils were developed the earliest, particularly under oak trees and in oak-hornbeam woods. Virgin steppe soils have vanished. And, with the irrigation of ever-expanding areas of Eastern Transcaucasia, semideserts formerly used as winter pastures are increasingly displaced by agriculture. Forest areas have been reduced, and their structure and composition have changed.’ (Dolukhanov, 1966, p. 228).

Dolukhanov was one of the few botanists to acknowledge the long and varied impact of human activities on Caucasian vegetation. His view stands in stark contrast to the majority, for whom human impact is conceptualised as a very recent phenomenon (Badenkov et al., 1990; Gulisashvili, 1964; Ketskhoveli, 1959; Nakhutsrishvili, 1999; Sakhokia, 1961; Sosnovskii, 1915; Tumajanov, 1971; Walter, 1974).

And yet evidence from around the world suggests that the antiquity and extent of past human impacts may have been severely underestimated by ecologists and historians alike. Grove and Rackham (2001) have eloquently argued that the Mediterranean landscape is not the result of recent and catastrophic human impact, but the diverse and colourful product of a long symbiosis between vegetation, humans, livestock and fire. Andrič and Willis (2003) analysed pollen data from different floristic regions in Slovenia, showing that the early Holocene vegetation was
remarkably uniform; only when human impact intensified did the vegetation of different areas diverge to create today’s rich and distinct landscape mosaic. In the semi-arid rangelands of Western Asia, Roberts (2002) has suggested that humans had a hand in delaying early Holocene forest expansion by burning the vegetation, thus preserving open landscapes since prehistoric times. Essentially the same argument has been invoked to explain the persistence of fire-promoted moorland vegetation in southwest Tasmania, where the climate and soils are capable of supporting rainforest of much greater biomass (Fletcher and Thomas, in press). On the Australian continent, biomass burning has a relationship with human history that began as early as 140,000 years ago (Kershaw, 1994; Moss and Kershaw, 2000; Singh and Geissler, 1985). In Indonesia, humans may have been burning the vegetation some 200,000 years ago (Wang et al., 1999).

On a larger scale, the global fire simulations by Bond et al. (2005) have demonstrated that many of the world’s ecosystems would cease to exist in the absence of fire. And Ruddiman (2003) has put forward the controversial suggestion that biomass burning beginning with early Eurasian agriculture slowly added carbon to the atmosphere, causing the global climate to diverge from the path expected by insolation effects and palaeoclimatic analogy. The greenhouse effect thus began 8000 years ago. Following pandemics of bubonic plague, he argues, the afforestation of abandoned farmland sequestered enough carbon that temperature variations such as the Little Ice Age, to a surprising extent, can be explained in anthropogenic terms (Ruddiman, 2003).

Fire looms large in all of these studies. In many parts of the world, fire histories have been instrumental in understanding past changes in the vegetation, and particularly in identifying phases of human impact (e.g. Carrión and van Geel, 1999; Clark and Royall, 1995; Dodson and Mooney, 2002; Edwards, 1988; Naveh, 1990; Patterson et al., 1987; Tinner et al., 1998; Willis et al., 1998; Yasuda et al., 2000). In Europe, fire histories are yet to be fully embraced in palaeoenvironmental research. This seems almost incomprehensible, since as early as 1941 Johannes Iversen used charcoal analysis to demonstrate that Neolithic people cleared European forests with fire (Iversen, 1941). This is the well-known landnám phase that often followed the ‘elm decline’. With some notable exceptions, few European researchers since
Iversen’s day have paid much attention to the ecological role of fire (Tinner et al., 2005).

Unfortunately, this has led to the widespread perception that fire is bad, destroys habitats and turns forest into desert (Grove and Rackham, 2001). The neglect of fire history has also severely impeded our knowledge of past human impacts in Western Asia. Most pollen diagrams from this region lack charcoal records (see van Zeist and Bottema, 1991), leaving open the question of how, when and if early agriculturalists cleared the land for the planting of crops. The Caucasus is no exception – there are no published fire histories from this region of great botanical and archaeological significance – yet fire is an important agro-pastoral tool in the Caucasus today.

One of the earliest European botanists to visit Georgia, Joseph de Tournefort, was given to remark that, in the highlands of Southern Georgia, “all manner of Trees have been long banish’d…” (Tournefort, 1718, p. 227). This chapter draws heavily upon the archaeological and historical record of this ancient region to place the vegetation and fire histories of Southern Georgia in context, and in so doing, answer the question of how, when and if its trees were banished. This history is not without its problems: like any history it is selective in its scope; there are many uncertainties in relation to chronology and dating; good early Holocene data are lacking, while historical data for the late Holocene are often too detailed for fair comparison with the palaeoenvironmental record. Nonetheless, in the prophetic words of the archaeologist Charles Burney, “seeing through a glass darkly is surely better than not seeing at all” (Burney and Lang, 1971, p. 24). In that spirit I present the following discussion, which is arranged in archaeological periods for the sake of convenience and because the relationship between environmental change and cultural change is often more suggestive than might at first appear.

**Upper Palaeolithic (c. 30,000 – 8,500 BC)**

The Palaeolithic takes in the great sweep of time from the appearance of hominids in the South Caucasus some 1.8 million years ago to the earliest centuries of

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the Holocene (Gabunia and Vekua, 1995). Perhaps the most significant cultural event through this time was the arrival of modern humans in the Caucasus region some 32,000 years ago and the displacement of Neanderthal populations (Tushabramishvili et al., 2002). These Upper Palaeolithic hunters established themselves in caves in the foothills and lowlands of Western Georgia, where the climate must have been more amenable to human habitation than further east where, as yet, Upper Palaeolithic finds are lacking (Kiguradze and Menabde, 2004; Vekua and Lordkipanidze, 1998).

Various authors have suggested that, at the last glacial maximum, snow lines were depressed by 800-1000 m along the Main Caucasus Range (Tsereteli and Maisuradze, 1976), valley glaciers descended to an altitude of 1000-1500 m above sea level in the west (compared to 2300-2700 m today), and to 1800-2400 m (2500-3200 m today) in the more arid east (Janelidze et al., 2000; Serebryanny, 1984; Tsagareli, 1964). Tree lines in Western Georgia were perhaps depressed to 600-800 m above sea level (Kvavadze et al., 1992), pushing forest vegetation into the foothills and lowlands. Several Upper Palaeolithic sites in Western Georgia were thus located near the upper tree line; a fact reflected in faunal assemblages comprising both forest and steppe taxa: wild goat, bison, Caucasian tur, cave bear, wild boar, hamster, deer, auroch, mouflon, horse and others (Bendukidze, 1979; Tsereteli et al., 1982; Vekua and Lordkipanidze, 1998). Other Upper Palaeolithic faunal assemblages are dominated by just one species, for example Capra caucasica, comprising 85% of remains at Ortvale Klde (Tushabramishvili et al., 2002; Vekua and Lordkipanidze, 1998). Modern humans seem to have been more selective in their diet than the Neanderthal populations they replaced (Tushabramishvili and Vekua, 1977) and some caves were perhaps occupied only seasonally for the hunting of specific highland prey (Vekua and Lordkipanidze, 1998). This brought humans into frequent conflict with other cave-dwelling carnivores – cave bears, cave hyenas and wolverines – all of which became extinct in the Caucasus during the late Pleistocene and early Holocene (Bendukidze, 1979; Dolukhanov, 1980). Many large herbivores, notably aurochs, bison, roe deer and moose, also became much less abundant in Georgia at the Pleistocene-Holocene transition (Bendukidze, 1979). Palaeolithic humans in the

14 Very few glacial features in the Caucasus have been dated, so their exact age is unknown.
Caucasus probably exerted a strong and highly selective impact on the fauna, using the foothill cave sites to hunt in the open landscapes inhabited by large mammals.

It would not be surprising, however, if the majority of Upper Palaeolithic human populations were clustered around the Black Sea coast. At its lowest stand, the sea level stood between 90 and 155 metres below its present level and the Black Sea was in fact a huge freshwater lake (Ballard et al., 2000; Chepalyga, 1984; Tvalchrelidze et al., 2004). In the Georgian sector of the Black Sea basin, the shelf drops off steeply, so the Pleistocene coastline was only a few kilometres distant from the present one in most areas, making seasonal hunting excursions to the mountains far from impossible. The coastline of this huge lake no doubt had a milder climate and more abundant plant and animal resources than elsewhere, and hence may have provided a focus for human habitation in the late Pleistocene.

Around 14,500 years ago, a global cycle of increased solar radiation began in the northern latitudes, triggering a northward movement in the inter-tropical convergence zone and higher rainfall in the Sahara (Burroughs, 2005). In Georgia, forests began to move upward and outward in Abkhazia (Kvavadze and Rukhadze, 1989), arid juniper savanna spread through the highlands of Southern Georgia and Armenia (Chapter Six) (Grichuk and Airapetian, 1976), and pine woodlands grew on the piedmonts of Eastern Georgia (Gogichaishvili, 1984b). This process was curtailed by the Younger Dryas, which pushed vegetation zones downslope and saw plants like Ephedra and Artemisia expand in desert-steppe vegetation. Some authors have suggested that the main characteristic of the climate of Western Asia at this time was a switch to conditions of hyper-aridity rather than of cold (Lemke and Sturm, 1997; Wick et al., 2003; Wright et al., 2003). Increasing aridity associated with the Younger Dryas is not evident in the palaeoclimatic trends reconstructed in Chapters Six and Eight, so some explanation is required.

The Younger Dryas was caused by a temporary interruption to the Gulf Stream, which carries warm water from the equatorial regions of the Atlantic Ocean northward to Europe. If the salinity of the Atlantic Ocean is diluted, or its connection to the Southern Ocean is cut off, the Gulf Stream loses its ability to transport heat to the North Atlantic, and Europe is plunged into glacial conditions (Broecker, 1994; Broecker, 1997; Knorr and Lohmann, 2003). As conditions in the North Atlantic currently have a strong influence on the winter climate of Western Asia (Cullen et al.,
2002), it follows that an interruption to the thermohaline circulation should have a considerable seasonal impact in the Caucasus.

I would argue that, instead of hyper-aridity during the Younger Dryas, the continental interiors of the Caucasus and adjacent regions experienced a climate of extreme seasonality. Deprived of the moderating influence of the North Atlantic, winters must have been very cold and dry. Summer conditions, however, were perhaps governed by the northward shift of the intertropical convergence zone and intensified monsoonal influences or thermal convection. Summers were thus hotter and perhaps more humid than now; a conclusion also arrived at independently by Roberts and Wright (1993).

The extraordinary seasonality and unpredictability of the late-glacial climate has been invoked to explain why agriculture was not adopted in Western Asia during the Pleistocene (Richerson et al., 2001). Yet Hillman et al. (2001) have argued that these were precisely the conditions that induced people into cereal cultivation, providing evidence of probable rye cultivation at Abu Hureyra around 13,000 BP. In theory, conditions of high seasonality would necessitate the collection of foodstuffs that could survive long periods of storage (Blumler, 1996). Climatic conditions at the terminal Pleistocene allowed the area of wild cereals to expand in the Fertile Crescent (Hillman, 1996) and the considerable amounts of cereal pollen in records from Southern Georgia suggest that this was a phenomenon of significant geographic extent (i.e. records from Lake Aligol: Chapter Six; Gomnis Lake: E. Gobet, unpubl. and Didajaris Lake: J. van Leeuwen, unpubl.). The Caucasus is known as a centre of crop plant diversity (Vavilov, 1992) and it is possible that these wild cereals grew amongst the wetland fringing vegetation (cf. Bottema, 1995) where moist soils provided a kind of refuge from aridity. Did Upper Palaeolithic humans encounter these wild cereal stands in their peregrinations across the highlands in search of game? While there is no direct evidence from the Caucasus that these wild plant resources were exploited during the late Pleistocene (Lisitsyna and Prishchepenko, 1977), in the pre-agricultural context, such evidence is likely to be very difficult to find (Harris, 1984).
When the Younger Dryas came to an end, the renewed strength of the Gulf Stream brought milder winters to the Caucasus region and vegetation belts responded with steady upward migration (Figure 9.1). Although rainfall increased at the
beginning of the Holocene, the climate remained somewhat dry for the first few millennia, a phenomenon that Wright et al. (2003) linked to high summer temperatures and drought produced by an orbital cycle of increased summer insolation. The widespread, early Holocene expansion of *Pistacia* in Western Asia has logically been interpreted as an indication of early Holocene dry climates with mild winters (Rossignol-Strick, 1995; Stevens et al., 2001; van Zeist and Bottema, 1991; Wick et al., 2003). As in the Younger Dryas, the prevalence of *Ephedra*, *Artemisia* and Poaceae during the early Holocene may mitigate against this hypothesis, since these three taxa are not especially favoured by summer drought, though they can tolerate dry winters (Chikov, 1983; El-Moslimany, 1990; Rossignol-Strick, 1995). Roberts and colleagues noted the apparent contradiction between the supposed droughty summers of the early Holocene on the one hand, and the presence of mesic tree species and high lake levels on the other (Roberts et al., 2001). Palaeoclimatic trends from Southern Georgia (Chapters Six and Eight) also suggest that the summer drought hypothesis may need revision.

A possible alternative explanation is that the peak in Northern Hemisphere insolation during the early Holocene produced high summer humidity across Western Asia through thermal convection. Relative to the present climate, the concentration of annual rainfall in the warmer months would have been conducive to the development of steppic grassland and savanna vegetation in the continental interiors of Western Asia. *Pistacia*, which “tolerates protracted winter drought, had little competition from the more drought-stressed oak” (Stevens et al., 2001, p. 753) and thus became abundant. High lake levels could be maintained by low evaporation rates during summer, even if the winter rainfall input were considerably reduced. For reasons yet unclear, rainfall in the Caucasus and Western Asia increased quite slowly through the first millennia of the Holocene (Lemke and Sturm, 1997). At lakes Van and Aligol, this led to the slow demise of *Ephedra* in the vegetation and the expansion of grasses, while at Didajaris Lake in the humid mountains of Ajara, woodlands of *Fraxinus* and *Quercus* began to expand (van Leeuwen, unpublished data).

In summary, the Upper Palaeolithic period was one of climatic extremes. Summers were hot; winters were cold and especially arid. Humans adapted to this seasonality by congregating in Western Georgia and exploiting resources over large areas, especially in the treeless uplands. Although a clear impact of humans on the
vegetation during the Upper Palaeolithic is difficult to discern, their impact on the fauna was much more clearly manifested. And compared to Western Europe at the same time, the Caucasus and much of Western Asia were home to considerable human populations; populations whose impact on the vegetation in the future would be considerable.

Mesolithic (c. 8500 – 7000 BC)

The period of the Caucasian Mesolithic was one of rapid environmental reorganisation throughout Western Asia. In Georgia, Mesolithic sites are not confined only to the Colchis lowlands and foothills, but are distributed through the highlands of Western Georgia, Southern Georgia, Armenia and Azerbaijan, and this is thought to represent a considerable population expansion (Kiguradze and Menabde, 2004).

Like the Upper Palaeolithic that preceded it, Mesolithic sites are concentrated in Western Georgia, but often at considerably higher altitudes (e.g. Tsona, 2100 m; Kudaro, 1600 m). Mountain caves that were abandoned during the coldest phases of the late Pleistocene were reoccupied during the Mesolithic (Dzhanelidze, 1980). Western Georgian Mesolithic sites are characterised by a suite of microliths and bone tools, and faunal remains indicative of forested surrounds (Bendukidze, 1979; Kushnareva, 1997). Evidently the climate in Western Georgia had changed to the point where forests had expanded up the mountain slopes from their Colchian refugia, but not to the point where their present altitudinal limit was achieved (Kvavadze and Rukhadze, 1989; Margalitadze, 1995; Margalitadze, 1998; Tumajanov, 1971). Afforestation occurred rapidly in Western Georgia and may explain the increasing role of foraging, fishing and gathering in the Mesolithic economy at the same time as hunting declined in importance at several sites (Kushnareva, 1997).

A second group of Mesolithic sites occurs in Southern Georgia. These are mostly open settlements and are centred on the broader Tsalka Plateau (Figure 9.2)(Kikodze and Koridze, 1978). All of these sites are nowadays situated in mountain steppe landscapes. They are differentiated from their Western Georgian counterparts in the almost exclusive use of obsidian in the manufacture of stone tools. Faunal remains here also differ from those in Western Georgia; the Tsalka sites have yielded assemblages that indicate the prevalence of open vegetation – wild horse,
onager, mouflon, aurochs, maral, Caucasian tur, gazelle and wild boar (Bendukidze, 1979). Pollen data from the Tsalka Plateau indicate that birch and hazel pioneer woodlands had begun to encroach on the uplands during the Mesolithic. In general, however, these environments remained relatively open, allowing Mesolithic people in Southern Georgia to continue hunting the same animals that had sustained their predecessors through the Upper Palaeolithic. According to Bendukidze (1979), human impact on Georgia’s fauna increased sharply during the Mesolithic and intensified through subsequent periods.

Figure 9.2. Map of Southern Georgia showing palynological sites and some of the archaeological sites mentioned in the text. Forest areas, modern settlements and the W-E transect in Figure 9.1 are also marked.

During the late Mesolithic the waning influence of Pleistocene cold and aridity allowed Georgia’s vegetation to anticipate its present form in several respects (Figure 8.11). While the Colchian landscape remained much the same as ever, mesic forests of elm spread in the mountains of Ajara (van Leeuwen, unpubl.), mixed woods of

15 *Cervus elaphus maral*
Corylus, Carpinus, Ulmus and Fraxinus established on the western flanks of the Trialeti Range (Margalitadze, 1995), and the same taxa became important around the Tsalka Plateau slopes and margins. In Eastern Georgia the early Holocene saw the disappearance of Pleistocene-relict populations of Pterocarya and Juglans from the Iori River gallery forests (Gogichaishvili, 1984b). These thermophiles probably became extinct because of localised changes in floodplain sedimentation and geomorphology associated with deglaciation of the Main Caucasus Range (Appendix A). If palaeoclimatic trends from Chapter Eight and Lake Van (Wick et al., 2003) are interpreted literally, temperatures and precipitation fluctuated and rose slowly during the Mesolithic, producing conditions that might ordinarily favour Pterocarya and Juglans.

Toward the end of the Mesolithic, the appearance of obsidian tools in Western Georgia gives certain proof of active trade connections between communities living in lowland Colchis and those in Southern Georgia, where the main obsidian sources are located (Kiguradze and Menabde, 2004; Kikodze and Koridze, 1978). The emergence of this obsidian-based lithic industry in the eighth millennium BC and stronger interconnections with peoples south of the Caucasus is regarded as an important precursor to the Neolithic in Southern Georgia (Kiguradze and Menabde, 2004).

Neolithic (c. 7000 – 4800 BC)

In the Caucasus, it is supposed that the earliest, aceramic Neolithic settlements appeared in the Black Sea lowlands of Western Georgia (Chataigner, 1995; Gogitidze, 1978; Kiguradze and Menabde, 2004; Nebieridze, 1972). Changes in material culture, economic subsistence and settlement types around 7000 BC point to a sedentary existence more in keeping with the Neolithic than the preceding Mesolithic (Kiguradze and Menabde, 2004). Neolithic Colchians eschewed the dankness of caves and instead established open-air settlements, often in close proximity to rivers (Chataigner, 1995). Usually these sites have only very thin layers of cultural accumulation, so organic remains have rarely been preserved. In a few places, soil discolouration left by post-holes suggest they built wooden or wattle-and-daub structures, rectilinear in plan (Kiguradze and Menabde, 2004). Archaeologists have distinguished two aceramic Neolithic traditions in Western Georgia on the basis of
stone tool assemblages: the Anaseuli tradition, developed in the Colchis lowlands with a reliance on flint and obsidian blades, and the Paluri tradition, a stone flake industry occurring in the highland zone (Grigolia, 1977; Kiguradze and Menabde, 2004).

Our picture of faunal exploitation in Western Georgia at this time is very limited and subject to considerable dating uncertainty. However, the appearance of domestic pig, sheep, cow and dog remains alongside red deer, roe deer and wild boar fossils in early Neolithic assemblages from Darkveti provide a glimpse of agricultural beginnings (Bendukidze, 1979; Nebieridze, 1978). Pig remains, in particular, suggest sedentary human populations and rich forest resources of beech mast and acorns (Kushnareva, 1997). At other sites, wild herbivores and fish remained the predominant catch of aceramic Neolithic humans (Dolukhanov, 1980; Kushnareva, 1997). Palynological evidence from both lacustrine and archaeological contexts attests to the widespread occurrence of forest vegetation and expanding role of oak, hornbeam, elm, chestnut and Zelkova in Western Georgia during the Neolithic (Kalandadze et al., 1977; Kvavadze and Connor, 2005; Kvavadze and Dzheiranashvili, 1989; Kvavadze and Rukhadze, 1989; Neishtadt et al., 1965). This occurred as the last vestiges of Pleistocene aridity faded away to produce a rainfall pattern of more or less modern character (Figure 8.15).

Interestingly, the establishment of near-modern climatic conditions in Western Georgia coincides with changes in the level of the Black Sea. Evidence for an abrupt flooding of the Black Sea with saline Mediterranean waters around 6000 BC (7150 $^{14}$C yr BP) comes from drowned strandlines, a change from freshwater to marine molluscs and other proxies (Ballard et al., 2000; Ryan et al., 1997; Uchupi and Ross, 2000). As well as impacting on the regional climate, it has been suggested that the rapid submergence of 100,000 km$^2$ of lowland landscapes may have contributed to the migration of Neolithic communities into adjacent regions (Ryan et al., 1997).

It may be more than coincidence that archaeological sites in Western Georgia see the first manifestations of the ceramic Neolithic around 6000 BC. These appeared initially along the northern coast of Colchis; spreading subsequently to encompass the entire Colchis lowland (Gogitidze, 1978; Nebieridze, 1972). With them came more obvious signs of sophisticated foraging, gathering and perhaps cultivation; suggested by occasional finds of grindstones, hoes and other implements (Kushnareva, 1997).
These communities produced a limited range of coarse ceramic jars, red or brown in colour and sometimes ornamented with simple, geometric patterns (Kiguradze and Menabde, 2004). Although macrofossil evidence is exceedingly scanty, Caucasian archaeologists believe that the early agriculturalists of Colchis grew or gathered millet and rye (Kiguradze and Menabde, 2004; Kikvidze, 1975) in preference to the traditional ‘founder’ crops of Western Asia – wheat, barley, flax and legumes (Zohary, 1996).

Leaving aside the Neolithic of Western Georgia, let us now turn our attention eastward. Until relatively recently it was assumed that Eastern Georgia became home to Neolithic communities somewhat later than Western Georgia, during the sixth millennium BC, when the so-called Shulaveri agricultural settlements began to appear on the alluvial soils of the Kura lowlands (Chataigner, 1995; Kushnareva, 1997; Munchaev, 1975). A recent re-examination of lithic assemblages suggests that the aceramic Neolithic is indeed represented in Southern Georgia: at Dmanisi, Lake Paravani and on the Tsalka Plateau at Beshtasheni (Kiguradze and Menabde, 2004). All of these open-air sites are located in the present-day mountain grassland zone at altitudes up to 2100 m. While little is known about them apart from their obsidian-based lithic industry in the Paluri tradition, they bridge the chronological gap between the Mesolithic sites and Shulaveri settlements. Regrettably, no palaeozoological or palaeobotanical material is preserved at these sites.

This, it would seem, is all that can be said of the aceramic Neolithic in Southern Georgia. But some startling evidence for occupation and human activity in this area comes from an unexpected source – the pollen records of Lake Imera and Tsavkisi Wetland. Sediments from these sites contain increasing amounts of microscopic charcoal from the early Neolithic onward, suggesting frequent and repeated burning. Fires in the landscape of Southern Georgia apparently peaked around 6000 BC, a date coincident with the emergence of the late Neolithic in Georgia (Figure 9.3). Any suggestion that these were natural fires can be quickly dismissed by examining the pollen records themselves – this increase in vegetation burning corresponds to a very pronounced expansion of mesic forest taxa across the whole of Georgia (while the local vegetation of Imera and Tsavkisi remained conspicuously open) and a steady increase in precipitation throughout the region (Chapter Eight)(Wick et al., 2003).
Figure 9.3. Fire records from Southern Georgia in relation to archaeological periods. Charcoal concentrations are shown above the line and influx below. The graphs indicate a Neolithic peak in burning, followed by a clear late Chalcolithic increase and a Bronze Age decline. Burning increased during the Classical Era and subsequent periods.

Roberts (2002) has recently and controversially put forward the suggestion that Neolithic humans deliberately used fire to delay the expansion of oak woodland in Western Asia. “In concert with a range of natural agencies,” he argues, Neolithic and Chalcolithic populations acted “to retard the establishment and spread of woodland at an ecotone where moisture stress would always have limited plant growth” (Roberts, 2002, p. 1009). Thus in the semi-arid rangelands of Western Asia, the ecological disjunction between increased precipitation and stalled afforestation is explained by humans manipulating the vegetation with fire. Here, in the semi-arid uplands of Southern Georgia, so ideally placed to test this assertion, is convincing evidence that Roberts’ hypothesis is correct.

The Neolithic desire to preserve open landscapes speaks volumes about the economy of that time. Even though we have no data on the subsistence strategies of the aceramic Neolithic people of the South Georgian Uplands, one might assume that they were primarily concerned either with hunting or livestock breeding. The great
abundance of dung fungal spores in zone T-1 of the Tsavkisi Wetland pollen diagram (see Figure 5.20) suggests that large herbivores were as common in that landscape during the Neolithic as at any time more recently. Whether wild or domestic, these animals provided a rich resource, and one that could be maintained with judicious use of fire. In this regard some things have changed little in Southern Georgia: herders today intentionally burn large tracts of the mountain plateaux each October to promote fresh grass growth in the following spring (Connor et al., 2004). And, like their Neolithic counterparts, today’s transhumant herders leave little trace of their seasonal camps when they return to the lowlands with their flocks and herds for the winter.

Figure 9.4. Some stone tools from early agricultural sites in Southern Georgia. The one on the left is from Khramis Didi Gora, the middle one from Gadachrili Gora and the black obsidian blade at right is from Imiris Gora.

At the beginning of the sixth millennium BC, ceramic Neolithic communities began to settle in the lowland valleys of the Kura and Araxes: in southeastern Georgia, northeastern Azerbaijan and northwestern Armenia. Unlike the situation in Western Georgia, the people of the Shulaveri culture established clusters of farmsteads that were intensely settled over long periods. The multi-layered accumulation of mud bricks and other cultural debris at these sites produced
conspicuous mounds that even today rise above the otherwise flat, alluvial plains (Connor and Sagona, in press; Kiguradze, 1986; Kiguradze and Menabde, 2004). The settlement types of the Shulaveri culture were much more closely linked to Anatolia than Colchis, which shared many features with the North Caucasian Neolithic (Kushnareva, 1997). Key late-Neolithic sites in Eastern Georgia include Shulaveris Gora, Imiris Gora and Khramis Didi Gora, which is the largest Neolithic site in the South Caucasus. Radiocarbon dated to the period from 5800 to 4600 BC, these sites are characterised by closely spaced agglomerations of dome-roofed, mud-brick roundhouses. Ceramics from the earliest levels of the Shulaveri settlements are notable for their rarity and crude manufacture (Kiguradze and Menabde, 2004). Obsidian and bone implements, in contrast, are distinguished by their number, diversity and quality (Figure 9.4).

The most celebrated aspect of the Shulaveri settlements is their clear evidence of agriculture. Several species of wheat, hulled and naked barley, rye, oats, millet, lentils, peas and beans have been identified in macrofossil assemblages from these sites (Lisitsyna and Prishchepenko, 1977; Rusishvili, 1990; Yanushevich and Rusishvili, 1984). It has often been claimed that these finds, particularly in relation to wheat, represent the independent development of agriculture in the Caucasus (e.g. Kushnareva, 1997; Lisitsyna, 1984; Lisitsyna and Prishchepenko, 1977). The appearance of domestic grape pips at Shulaveris Gora, Khramis Didi Gora and Shomu Tepe appears to support Georgia’s claim to be the home of wine-making and viticulture; but, as with wheat, this remains an open question. There is some merit in the idea that the Shulaveri settlements were originally sited to take advantage of wild cereal stands, and in such circumstances local domestication would be far from impossible (see Hillman and Davies, 1990). Evidence reported from some aceramic Neolithic sites in the Armenian highlands suggests that wild cereals and wild fauna were exploited prior to and during the adoption of domestic varieties (see Mellaart, 1975, p. 201). Against independent agricultural development in the Caucasus are the obvious material links between the Shulaveri and other contemporaneous cultures of Western Asia (Glumac and Anthony, 1992), as well as the fact that the crops sown by the Shulaveri communities were essentially the same as those planted further south (Zohary and Hopf, 1993). Until more archaeological work is undertaken with a greater attention to radiocarbon dating, this issue will remain unresolved. Suffice it to
say that the early agricultural settlements of the Shulaveri type have a strong local character no doubt influenced by the environment in which they developed.

The surroundings of the Shulaveri settlements are relatively well studied. Wild plant remains from Arukhlo and Imiris Gora are entirely those of herbs and forbs still common in the steppe vegetation – species of *Polygonum, Lithospermum, Sideritis, Trifolium, Papaver, Chenopodium, Amaranthus, Rumex* and various grasses (Lisitsyna and Prishchepenko, 1977). Pollen analysis of cultural deposits and irrigation ditches at these two sites showed Chenopodiaceae, Asteraceae, *Artemisia*, Lamiaceae and Poaceae to be the most common pollen taxa, with tree pollen all but absent (Dzhanelidze, 1980; Gogichaishvili, 1984a; Gogichaishvili, 1990). Faunal assemblages from the Shulaveri settlements contain abundant remains of domestic cattle, sheep, pigs and goats (Dzhanelidze, 1980; Vekua, 1984). Far fewer and more diverse were the remains of wild fauna: red deer, wild sheep, onagers, aurochs, wild horses, gazelles, wild boar and to a lesser extent birds, small mammals and tortoises (Bendukidze, 1979; Vekua, 1984). These three, independent lines of palaeoenvironmental evidence point to the persistence of open vegetation in the Kura River lowlands during the Neolithic.

The exceptionally rich pollen record from Tsavkisi Wetland exhibits some noteworthy changes around the time of the Georgian late Neolithic. Of particular interest is the substantial peak in *Triticum*-type (wheat) pollen coincident with a decline in grazing and fire (see Figures 5.20 and 9.3). This might suggest that cropping had extended well into the foothills, pushing the more established practice of herding to higher altitudes. Why would this be the case? Perhaps intense demand for cereals in the Shulaveri communities made cropping on the rugged foothills worthwhile. Or, as the orbital influence of higher summer insolation began to fade during the mid Holocene, summer drought became more common in Eastern Georgia’s lowlands and necessitated cultivation in more elevated places. Evidence for artificial irrigation is also known from this period (Mardaleishvili and Janelidze, 1984). Whatever the answer, it is clear that socio-economic, political or environmental events at the end of the Neolithic prompted a move away from a sedentary, agrarian lifestyle to one where herding assumed a greater role.
**Chalcolithic (c. 4800 – 3000 BC)**

It has been argued that a general cultural continuity stretched from the Caucasian Neolithic until the end of the Chalcolithic period around 3000 BC (Chataigner, 1995). During this period a socio-economic structure was gradually established that served highland communities of the subsequent Early Bronze Age. The Chalcolithic, or Eneolithic as it is also called, in Southern Transcaucasia includes the key site of Sioni, as well as Delisi, Berikldeebi, Alikemek Tepesi, Leila Tepe and Tekhut (Kiguradze and Sagona, 2003). A series of recurring cultural traits and patterns define the Chalcolithic of the eastern South Caucasus, known collectively as the Sioni culture (Menabde et al., 1978). This itself can be classified into two phases: an early Chalcolithic phase stretching from 4800 to 4000 BC, and a middle to late Chalcolithic phase covering the 4th millennium (i.e. 4000-3000 BC). It was the later of these two phases that gave rise to the ubiquitous Kura-Araxes culture, aspects of which begin to manifest more clearly from 3600-3500 BC (Kiguradze and Sagona, 2003).

Compared to the clustered distribution of Neolithic settlements, Chalcolithic sites are scattered more widely and at various altitudes. The two periods also differ architecturally. The multi-layered mound sites of the Neolithic gave way to Chalcolithic sites that were generally flat, pock-marked with bell-shaped and cylindrical pits, and poor in architectural remains – mostly small wattle-and-daub dwellings (Kiguradze and Sagona, 2003). Chalcolithic ceramics are characterised by a relative sameness of form and finish. Mostly jars and bowls, they were built by hand, usually from clay tempered with inclusions of grit, mica, grog or chaff. Chalcolithic ceramics from Georgia usually have either a pale finish (Sioni pottery) or are burnished to a lustrous black (Kiguradze and Sagona, 2003). It is the wide distribution of this red-black pottery that gives certain indication of strong cultural and socio-economic interactions among the highland communities of the South Caucasus and Eastern Anatolia through the Chalcolithic, the same interactions that saw Georgian obsidian traded throughout the region (Kiguradze and Sagona, 2003; Palumbi, 2003).

Complimentary palaeoecological analyses have shown that wheat, barley and grapes were probably the most commonly grown crops (Lisitsyna and Prishchepenko, 1977). In comparison to the Neolithic, however, the role of grain agriculture is
thought to have become subsidiary to livestock breeding, particularly the transhumant herding of sheep and goats (Dzhanelidze, 1980; Piotrovskii, 1955). Chalcolithic communities were by no means nomadic, but may have moved back and forth between lowland and highland pastures with the changing seasons (Kiguradze and Sagona, 2003). While expanding trade connections across the highlands may have encouraged the herding of livestock (a commodity that walks to market), it could also be argued that changing environmental conditions contributed to the shift toward a pastoral economy.

Numerous palaeoenvironmental analyses show that the region experienced a mid Holocene peak in precipitation between 4000 and 2000 BC (Chapter Eight)(Gogichaishvili, 1984b; Margalitadze, 1995; Margalitadze, 1998; Roberts and Wright, 1993; van Zeist and Bottema, 1991; Wick et al., 2003). Annual rainfall increased and temperatures rose during the Chalcolithic, leading to an upward migration of altitudinal vegetation belts perhaps hundreds of metres above their present level (Kvavadze and Connor, 2005; Kvavadze and Rukhadze, 1989; Margalitadze, 1998). Around Lake Van in Eastern Anatolia, oak woodland (forest-steppe) reached its maximum extent, corresponding to a peak in lake levels (Lemke and Sturm, 1997; Wick et al., 2003). Higher rainfall may have rendered lowland floodplains uninhabitable or unpredictable (cf. Oguchi and Oguchi, 1998), leading to a shift away from cereal-based agriculture.

In addition, orbitally driven changes in insolation led to the desiccation of the Sahara and the reorganisation of regional weather systems around this time (Goodfriend, 1991; Ritchie et al., 1985). The same probably had a significant impact on the seasonality of rainfall in semi-arid Southern Georgia. Even though annual rainfall was increasing through the Chalcolithic, much of this increase came from enhanced westerly airstreams originating in the North Atlantic (Roberts and Wright, 1993). In consequence, winters became milder and wetter, while summers became hotter and drier (see Chapter Eight). These conditions would have enhanced drought susceptibility and crop failure in the steppic lowlands. In such circumstances, the highland zone may have provided a more stable base for cropping and animal husbandry.

The extension of forest vegetation and upward migration of tree lines clearly posed an economic challenge to highland communities as arable land was gradually
consumed by woodland. Chalcolithic farmers responded to this afforestation in the same way as their Neolithic predecessors had – with fire. Charcoal records from across the Tsalka Plateau to the hills of Tbilisi clearly demonstrate the degree to which humans were deliberately maintaining open landscapes, battling against forests to sustain their pastoral economy (Figure 9.3). It should be emphasised that these fires were not indiscriminate, nor were they universal. There is no suggestion that Chalcolithic farmers destroyed established areas of forest. Their interest was in sustaining an agro-pastoral system of ancient inheritance, and this was achieved by using fire (and the livestock themselves) to prevent afforestation. Toward the end of the Chalcolithic, the effort expended in maintaining open pastures seems to have intensified. Then, as the period came to a close around 3000 BC, the fires that had burned with ever-increasing frequency and intensity through the preceding millennium were abruptly snuffed out.

Archaeologists speak of a regional ‘collapse’ around 3000 BC that saw the abandonment of some sites and loss of complexity at others (Kiguradze and Sagona, 2003). This seems to have been more a political or economic event than a cultural one, for the same traits that emerge during the latter part of the Chalcolithic are carried through uninterrupted to the Early Bronze Age. It seems that a significant reorganisation of the region’s political and economic sphere occurred around 3000 BC. In places, pastures that were so assiduously maintained during the Chalcolithic were overrun by trees during the Bronze Age. Fire was banished from the landscape and even grazing seems to have declined. All of these changes relate not to any abrupt climatic event, but to a technological one – the arrival of Bronze Age metallurgy.

**Early and Middle Bronze Age (c. 3000 – 1500 BC)**

The Early and Middle Bronze Ages have been the subject of great archaeological interest over the past few decades, giving rise to the definition of a series of ‘cultures’ known, in chronological order, as Kura-Araxes, Martkopi, Bedeni and Trialeti (Burney and Lang, 1971; Glumac and Anthony, 1992; Kuftin, 1941; Kushnareva, 1997; Marro and Hauptmann, 2000; Munchaev, 1975; Rubinson, 1977; Sagona, 1984; Sagona, 2004a; Sagona, 2004b; Smith and Rubinson, 2003;
By 3000 BC, the communities of farmers and stock-breeders that emerged during the late Chalcolithic were fully established across the highlands of the South Caucasus and eastern Anatolia. The distribution of these sites in Georgia in many ways resembles present-day settlement patterns, with a significant emphasis on highland environments.

Despite some clear regional traits, the Kura-Araxes cultural assemblage is overwhelmingly homogenous, suggesting a high degree of social cohesion across the mountain rangelands (Sagona, 1984). This cultural assemblage in Georgia included a diversity of architectural styles, ranging from wooden-framed, free-standing rectangular houses with wattle-and-daub walls to more typically Near Eastern, mud-brick dwellings of rectilinear or circular plan. Within these varied forms, the internal use of space was remarkably uniform, each with a centrally placed terracotta hearth set into the floor. The universal occurrence of red-black, burnished pottery of this time is considered the hallmark of the Kura-Araxes culture (Burney and Lang, 1971). Metallurgy also developed at this time, attested by bronze artefacts such as axes, spearheads, earrings, dress-pins and other ornaments.

Around 2500 BC, the communities of Southern Georgia began to adopt elaborate burial customs that contrasted starkly with the simple inhumations favoured by the Kura-Araxes culture of the Early Bronze Age (Sagona, 2004a). Monumental barrow tombs (‘kurgans’) were constructed for the burial of important persons, suggesting fundamental changes in social structure. Burial chambers were either dug into the ground and covered with planks or built entirely of oaken logs (Gobejishvili, 1980; Sagona, 2004a). In each case the chamber was covered with a tumulus of stone and earth rising up to 15 m high, making these mounds prominent features in the otherwise flat landscapes of Martkopi, Bedeni and Tsalka. The burials themselves were accompanied by symbols of power and wealth, including vessels of precious metal, jewellery, pottery, weaponry, furs, fabrics and wheeled vehicles (Sagona, 2004a). The most elaborate examples of this mode of burial are the later Trialeti kurgans from the highland Tsalka Plateau. Amongst the opulent funerary offerings was an embossed silver goblet, with depictions of humans and animals in a style thought to reflect the Tsalka Plateau’s elevated standing in sphere of trade and exchange stretching as far as Assyria and the eastern Mediterranean (Rubinson, 2003; Sagona, 2004a).
While the mortuary architecture and customs of the Middle Bronze Age are well known, the same cannot be said of the economy of the period (Kushnareva, 1997). This is largely attributable to the apparent absence of settlements, though it could be argued that this ‘absence’ is in fact a chronological misinterpretation (Sagona, 2004a). The perceived lack of settlements has promoted the idea that Middle Bronze Age communities were transhumant rather than sedentary (Kushnareva, 1997; Puturidze, 2003). Although this is possibly a regional phenomenon, recent evidence from Sos Höyük in eastern Anatolia suggests, conversely, that this period may have seen increased sedentism; evidence that includes more permanent architecture and a high proportion of cattle and pigs in faunal assemblages (Howell-Meurs, 2001; Sagona, 2004a; Sagona and Sagona, 2000).

More than previous periods, the Early and Middle Bronze Age were characterised by increased temperatures across the length and breadth of Georgia. Warm and relatively dry conditions in the highlands were accompanied by equally warm but wetter conditions at lower altitudes (Chapter Eight). These varied conditions promoted the expansion of oak savanna on the Tsalka Plateau and dense oak-ash forest above Tbilisi. The *Quercus* maximum in Southern Georgia, however, comes at least 1000 years later than its equivalents at Lake Van in eastern Anatolia and Lake Zeribar in Iran (van Zeist and Bottema, 1991; Wick et al., 2003). This considerable migrational lag cannot be adequately explained in terms of the palaeoclimatic. Instead it was human activity that delayed oak’s expansion in Southern Georgia, namely widespread burning and grazing during the previous Chalcolithic period.

The absence of vegetation fires during the Bronze Age (Figure 9.3) argues in favour of a new method of vegetation management. Forest cover trends from the Tsalka Plateau (Chapter Six) indicate that tree cover did not blanket the highlands, but fluctuated considerably during the Early Bronze Age, when the development of metal tools allowed woodland to be maintained, moulded and utilised without the need for landscape-scale fires. Axe in hand, a Bronze Age farmer was able to shape the vegetation in a much more selective way than his Chalcolithic ancestors could do with fire. Any doubt that these people could have had such a wide-ranging impact should be allayed by remembering that they had the labour wherewithal to build the kurgans, the largest of which were artificial mounds of 21,000 cubic metres of stone and earth,
contained oak-lined burial chambers up to 175 square metres in area, and had paved ritual roads several hundred metres long leading westward to the chamber entrance (Gobejishvili, 1978; Kushnareva, 1997; Narimanishvili, 2004; Puturidze, 2003).

A valuable insight into prehistoric wood exploitation comes from a pioneering macrofossil analysis of the Beshtasheni fortress on the Tsalka Plateau (Yatsenko-Khmelevskii and Kandelaki, 1941). The site contained 45% oak and 30% fir macrofossils during the Middle Bronze Age, a pattern wholly consistent with the pollen evidence. Chalcolithic assemblages, in contrast, were predominantly (60%) of alder, a fire-enhanced streamside tree. A similar shift from exploitation of riverine taxa during the Chalcolithic to woodland taxa during the Bronze Age is recorded at Sos Höyük (Longford, 2005). In both these studies, the authors concluded that deforestation of riversides forced Bronze Age folk to exploit woodlands farther from their settlements.

I regard this deforestation hypothesis as only partly applicable to Southern Georgia for several reasons. One is the growing complexity and diversification of Middle Bronze Age economies (Puturidze, 2003), which saw greater specialisation in crafts such as metallurgy, carpentry and pottery. I find it difficult to accept that a society that could build the kurgans and had sturdy axes to hand would willingly cut poor quality wood like alder in preference to oak. Secondly, the emergence of metallurgy itself must have had a profound impact on wood use. Smelting in the prehistoric context required large amounts of wood charcoal, and for this purpose trees like *Carpinus* were probably sought after since they take well to coppicing and their wood burns very hot (Gardner, 2002; Rackham, 2001). It may be no coincidence that *Carpinus* pollen all but disappears from the Tsalka Plateau records during the Bronze Age. Oak, on the other hand, was more valued for construction, as its almost exclusive use in building kurgan burial chambers attests (Burney and Lang, 1971; Gobejishvili, 1980). Thirdly, pollen evidence clearly shows that oaks were relatively abundant in Bronze Age landscapes, so their exploitation seems entirely natural. The prior exploitation of alders and willows may relate simply to their relative abundance

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16 At Sos Höyük, Salicaceae dominate Chalcolithic assemblages (76%). Middle Bronze Age levels contained less Salicaceae (18%) and more *Pinus* (42%) and *Quercus* (24%) (Longford, 2005).
in the largely treeless highland environment of the Chalcolithic, their proximity to riverside settlements and their ease of collection in the absence of metal tools.

In conclusion, the Early to Middle Bronze Age saw the emergence of a new relationship between society and environment. This occurred as populations became more sedentary, economic activities diversified, farming intensified, and metallurgical innovation changed the way vegetation density was managed. The use of timber and joinery in the kurgans and their wheeled vehicles reveals a level of sophistication in this craft hitherto unprecedented. As for the kurgans themselves, one could indeed ask whether they were powerful statements of land tenure placed ostentatiously in the partially wooded plateau landscape (Connor and Sagona, in press).

**Late Bronze and Iron Ages (c. 1500 – 400 BC)**

The Late Bronze and Iron Ages, more than any other period, were afflicted by climatic changes that had a profound impact on the distribution and economy of prehistoric settlements. Pollen and isotopic records from across the region indicate a progressive and lasting decrease in both temperature and precipitation from the beginning of the second millennium BC (Chapter Eight) (Lemke and Sturm, 1997; Roberts et al., 2001; Wick et al., 2003). Coniferous trees on the Tsalka Plateau responded to this climate change positively, displacing the oaks that had been so widespread during the Early and Middle Bronze Age. On the hills above Tbilisi, oak-ash forest gave way to open vegetation. Even in southern Colchis the climate became less humid. On the Main Caucasus Range, glaciers reactivated around 1000 BC (Serebryanny, 1984; Serebryanny and Orlov, 1982).

Climate change has often been invoked as a factor in the destabilisation of socio-economic structures (Burroughs, 2005; Diamond, 2004). Perhaps the most celebrated example is the collapse of the Akkadian Empire around 2200 BC, an event some have linked to a sudden and sustained aridification event in Mesopotamia (Cullen et al., 2000; Dalfes et al., 1997). In Southern Georgia, there are signs that the climatic instability of the second millennium BC brought about changes in the human sphere. Not least amongst these is the widespread abandonment of the highlands that had been the focus of so much activity during the Early and Middle Bronze Age (Burney and Lang, 1971). Settlements of the Late Bronze and Iron Ages in Southern
Georgia were instead concentrated in the lowland valleys and piedmonts, where the climatic conditions may have been more amenable to farming (Furtwängler et al., 1998; Kvavadze, 1999c; Kvavadze and Todria, 1992; Pitskhelauri, 1979; Pizchelauri, 1984). Compared to the Middle Bronze Age, when the scarcity of weapons is thought to signify relatively peaceable political relations (Burney and Lang, 1971; Lang, 1966, p. 46), the Late Bronze and Iron Ages saw a dramatic increase in weaponry manufacture – swords, daggers, arrowheads, axes, maces and the like (Abramishvili, 2003).

Gogichaishvili (1990), in reviewing the available pollen data from the lowlands of Eastern Georgia, concluded that human impact on the vegetation intensified dramatically during the Late Bronze and Iron Ages. Her conclusion is reaffirmed by pollen data from Tsavkisi Wetland showing the destruction of oak-ash forests and their replacement with open steppe-phrygana vegetation. Livestock grazing on the foothills around Tbilisi must have been exceedingly intense during the Late Bronze and Iron Ages, as the extraordinary abundance of dung fungal spores and phrygana pollen demonstrates (see Figure 5.20). The demise of wild fauna in Eastern Georgia, especially onagers, aurochs, beavers, wild horses, moose, Caucasian tur and wild goats, was to a large degree attributable to intensified human impacts during the mid to late Holocene (Bendukidze, 1979). Human impact on the Tsalka Plateau at this time is less obvious because populations had largely abandoned the highlands. Even so, high proportions of *Triticum*-type pollen in the Imera record may indicate that Iron Age highlanders had resorted to growing wheat in shallow lake basins where a source of water could be assured. Around Lake Aligol it seems that the lack of human activity allowed pine and fir trees to consolidate into a forest – the densest vegetation in all its Holocene history (see Figure 6.21). Yet this afforestation was all too brief, cut short by destructive fires that had long been in abeyance on the Tsalka Plateau. In their wake, fire-sensitive fir trees were eradicated from the landscape.

The Late Bronze-Iron Age phase of intensive human impact in Georgia corresponds to changes occurring around the same time in southwestern Turkey. A good deal of palaeoenvironmental research has been devoted to unearthing the causes of impact events known collectively as the ‘Beyşehir Occupation Phase’ (Bottema and Woldring, 1990; Eastwood et al., 1998; Eastwood et al., 1999; Roberts, 1990; Roberts et al., 1997; Vermoere et al., 2002). Because the beginning of the phase corresponded
more or less with the eruption of Santorini around 1600 BC (Guichard et al., 1993), some questioned whether the deposition of volcanic ash provided the impetus for the forest clearance and cultivation episodes recorded in pollen diagrams. Although tephra deposition temporarily affected lake productivity, the Beyşehir Occupation Phase did not begin in many places until centuries later, pointing to political instability as a probable trigger for deforestation and cultivation (Eastwood et al., 1998; Roberts et al., 1997). At the same time, deforestation in eastern Anatolia is indicated by increased sedimentation in the Euphrates (Kuzucuoglu, 2003), the almost wholesale loss of woodland fauna in vertebrate assemblages at Sos Höyük (Howell-Meurs, 2001) and a decreasing proportion of woodland taxa in macrobotanical data from the same site (Longford, 2005; Newton, 2004). This clearly was a very widespread pattern of human impact.

Around 1200 BC, the Hittite Empire of Anatolia crumbled under the repeated depredations of the ‘Sea Peoples’, ushering in the so-called Anatolian Dark Age and unleashing a cascade of political reorganisations that reverberated across the Near East (Lang, 1966). It has been argued that colder, drier climates across Europe and the Mediterranean during the second millennium BC led to crop failure and famine in the Sea Peoples’ homelands, driving them out en masse in search of new territory (Burroughs, 2005). Southern Georgia was by no means immune from the political ramifications of this regional event (Lang, 1966). Nor was it immune from subsequent invasion of the Scythians, who laid waste to much of Eastern Georgia in the seventh century BC; nor indeed the imperial reach of the Achaemenid Empire of Persia in the fifth century BC (Tsetskhladze, 2003). Climatic change compounded political instability by forcing populations to congregate in the lowlands and foothills, where such population pressures seem to have taken a substantial toll on the vegetation and fauna. As in more recent times, people of the highlands responded to the destabilisation of their political and economic structures by once again taking up the ancient practice of herding.

Contacts with Greece and Rome (400 BC – 330 AD)

So much has been written on historical-era Colchis and Iberia that it is not possible to review here the extent of their labyrinthine interactions with the Greeks,
Romans, Achaemenids, Urartians, Armenians, Medes, Pontians, Albanians, Cimmerians, Scythians and other neighbouring peoples during the 1st millennium BC (see Braund, 1994; Burney and Lang, 1971; Lang, 1966; Salia, 1983). Suffice to say that these cultures had both direct and indirect influences on the culture of Georgia of the time, through migrations not only of artistic ideas, but of ethnic groups as well (Knauß, 2005; Tsetskhladze, 2003). The date of 400 BC is a convenient starting point as it coincides with Xenophon’s march through the highlands of Anatolia and the southwestern Caucasus, the weakening of Persian control in Eastern Georgia, and, most importantly, the rise of the Iberian Kingdom in that region (Lang, 1966). Southern Georgia at this time was a frontier zone between the Armenians and Iberians, lying within the territory of the latter.

The date of 400 BC is also significant in the palaeoenvironmental record, for it was around this time that fir trees were burnt out from the surroundings of Lake Imera (Chapter Six). This initial fire was followed by a series of even more intense blazes through the following centuries that obliterated pine woodland from that sector of the Tsalka Plateau altogether. Although it is difficult to tie these fires to particular historical events, the impact of war should not be overlooked – especially the imperial expeditions of Xenophon, Alexander and Pompey. It was in 66 BC that Pompey invaded Georgia with his army, on a campaign ostensibly to rid the Roman Empire of the troublesome Eupator of Pontus, Mithridates VI. One contemporary source recorded that the Georgians put up fearsome resistance to the Roman legionaries, who “drove the barbarians into a dense forest. These people are terrible forest fighters, hiding in the woods and darting out unexpectedly. Pompey surrounded this forest with his army, set it on fire, and pursued the fugitives when they ran out” (Appian, 1913, 15: 103, my italics). Of course, it cannot be claimed that the Lake Imera fires were the result of Pompey’s campaign, the movements of which are largely unknown (Braund, 1994, p. 161 ff.), but the almost regional increase in fires through this turbulent period (Figure 9.3) forces us to consider that fire may have been as much an instrument of war as it was a tool of farming. War’s indirect impact, far from the

17 Although no charcoal record is available for the Gomnis Lake pollen diagram, fir and beech declined rapidly there (Margalitadze, 1971; Gobet, unpubl.) around the same time as the Lake Imera fires, suggesting widespread human impact in Southern Georgia.
battlefields, was probably the same – by promoting transhumance and pastoralism, war also promoted the torching of forests on a large scale.

Somewhat cool climates persisted in Southern Georgia throughout the 1st millennium BC. In the highlands, precipitation rose gradually during this period, but in the lowlands the opposite trend is observed (Chapter Eight). Judging from dung spores preserved in the Tsavkisi and Jvari sediments, this period was one of intense grazing on the piedmonts about Tbilisi. At the very end of the first millennium BC, it appears that the climate again became warmer and wetter across Georgia. At once the pastures surrounding Tsavkisi Wetland were abandoned and enveloped by dense regrowth forests of hornbeam. Was it this warmer, wetter climate that brought about such a fundamental shift in vegetation and land-use? The answer, it seems, is no; for the Lake Jvari record shows convincingly that grazing and burning continued in some piedmont areas unabated, maintaining the openness of the vegetation. Climatic factors, at best, played a minor role. Because the wholesale transformation of the Tsavkisi landscape coincides directly with the appearance of walnut and olive pollen, there can be little doubt that socio-economic and cultural factors were at play.

By the first century AD, the Kingdom of Iberia had assimilated many of the trappings of Graeco-Roman life. The geographer Strabo (ca. 64 BC – 25 AD) gives a description of the Iberians that reveals much about their agricultural economy, settlements, cultural references, and their political alliances with the mountain tribes:

“‘The greater part of Iberia is so well built up in respect to cities and farmsteads that their roofs are tiled, and their houses as well as their market places and other public buildings are constructed with architectural skill… The plain of the Iberians is inhabited by people who are rather inclined to farming and to peace, and they dress after both the Armenian and Median fashion; but the major, warlike portion occupy the mountainous territory, living like the Scythians and the Sarmatians,18 of whom they are both neighbours and kinsmen;”

18 Scythians and Sarmatians are elsewhere called “nomads of the north” (Strabo, 1928).
however they engage also in farming” (Strabo, 1928, XI, 3, 1-3).

Archaeological excavations have since validated much of Strabo’s description (see Braund, 1994, p. 205 ff.; Lordkipanidze, 1994b, p. 158 ff.). The substantial, two-storied villa at Dedoplis Gora is but one example. Its buildings were constructed of mud-brick with large wooden beams supporting a tiled roof. Auxiliary structures contained querns and ovens for baking bread, pithoi for wine storage, various farming implements (ploughs, hoes, etc.), an armoury store, as well as abundant and skilfully crafted ceramics, glassware and ornaments. Macrofossil remains included wheat, millet, peaches, cherries, grapes and nuts (Gagoshidze and Tsotselia, 1991).

Around the ancient Iberian capital of Mtskheta, the strongholds of Harmozice19 and Seusamora mentioned by Strabo have also been excavated, revealing not only substantial fortifications, but also a Roman bath-house and large civic buildings (Figure 9.5). Extraordinarily rich and abundant finds from the nearby necropolis of Samtavro indicate a population strongly influenced by surrounding cultures and with a high degree of social stratification (see Apakidze et al., 1958; Braund, 1994; Lordkipanidze, 1994b).

In my opinion, the rapid expansion of forest and orchards near Tsavkisi Wetland reflects a changing social landscape. The ancient Iberians had shown their readiness to adopt elements of Greek and Roman culture, much as they had assimilated Persian influences earlier. Evidently, some Iberian farmers responded to this by abandoning pastoralism and growing imported fruit trees like walnuts and olives. Compared to pastures, walnut groves carry much stronger overtones of sedentism, land ownership and prosperity, and it was these three characteristics that seem to have been the hallmarks of the Iberian Kingdom in the 1st century AD.

19 Evidently a corruption of the Georgian Armaz-tsikhe, meaning ‘fortress of Armazi’. Armazi was the Georgian equivalent of Ahura-Mazda, the fire god of Zoroastrian religion, who was revered above all other gods in the pantheon of ancient Iberia (Burney and Lang, 1971).
9: HUMAN IMPACT

Figure 9.5. Axonometric projection of the remains of the bath complex at Bagineti (Harmozice), 1st century AD (source: Apakidze et al., 1958, p. 176).

From Christianity to the Middle Ages (330 AD – 1400 AD)

The adoption of Christianity as the state religion of Iberia makes a convenient starting point for the next phase of its history, for this decision by the then Iberian king, Mirian, had far-reaching effects on Georgia’s culture, literature, language, political alliances and the structure of its feudal monarchy (Lang, 1966). It also marks the beginning of a long and complex stretch of history in which Georgia weakened as a political entity, falling under Persian suzerainty from 378 AD and having its monarchy dissolved during the 6th century. Persian domination was followed by the capture of Tbilisi by the Greeks in 627 AD and then Arabs in 655 AD.

The Georgians and their fellow Christians in Armenia, despite their oppression, succeeded in preserving their Church, language and sense of identity through these turbulent years. During the 8th century, Arab forces swept through the whole of Georgia, leaving such a wake of destruction that a contemporary source records: “Now at that time the lands of Kartli, Armenia, and Ran had been devastated, and there were no dwellings nor food at all for men or beasts.” (Thomson, 1996, p. 245). A more evocative description, notable for its attitudes toward fires and forests, is given of the aftermath of the Turkish invasion of 1080 AD:

“They consumed the land and massacred everyone wherever he might escape – to forests, cliffs, caves, or
holes in the ground. In those times there was neither sowing nor harvest. *The land was ruined and turned into forest*; in place of men, beasts and animals of the field made their dwelling there... *Fire, an unaccustomed adversary*, consumed all dwellings” (Thomson, 1996, pp. 310-311, my italics).

In geopolitical terms, Georgia remained a frontier and vassal state for most of the first millennium AD. Then, during the reign of King David the Builder toward the end of the 11th century, Georgia rose to prominence as a political force in the region, annexing parts of Armenia and regaining Tbilisi from the Muslim emirs who had controlled it for centuries past (Burney and Lang, 1971). What many consider to be Georgia’s ‘Golden Age’ followed during the reign of Queen Tamar (1184-1213). This period saw Georgia’s sphere of influence grow to encompass almost the entire Caucasus region: from the North Caucasian tribes in the north, the Black Sea and Trabzon Empire in the west, the Caspian Sea in the east, to what are today northwestern Iran, Armenia and eastern Turkey in the south (AN GSSR, 1964). The beginning of the 13th century was the zenith of Georgian language, arts, culture and religion (Lordkipanidze, 1994a; Salia, 1983).

It is not my aim here to analyse the innumerable environmental changes that may or may not have influenced and been influenced by Georgia’s turbulent socio-economic situation during the Mediaeval. The data presented in this thesis provide insufficient detail to deal with this question except in the most general terms. Nevertheless, several points are of interest. The first concerns the charcoal record (Figure 9.3), which indicates that burning was more common in the vegetation from *ca* 330-1000 AD compared to the period *ca* 1000-1400 AD. A second point relates very much to this first; that is, the decline in burning during Georgia’s ‘Golden Age’ corresponds to an apparent reduction in rainfall at all altitudes (compare Figures 8.18 and 9.3). This suggests that it was not the flammability of the vegetation that contributed most to its ignition, but the prevailing political climate. As I have previously argued, episodes of political stability are characterised by stability in agro-

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20 It was around this time that the famous Georgian epic poem, *Vepkhistaqosani* (*The Knight in the Panther’s Skin*), is thought to have been penned by Shota Rustaveli (Rustaveli, 1966).
pastoral systems, whereas political instability favours transhumant pastoralism over sedentary agriculture. Landscape fires in Georgia today are lit most commonly by herders, rather than those who sow grain, cultivate the vine or tend their orchards.

Much has been written about the Mediaeval climate of northwestern Europe, which is thought to have been somewhat warmer than the previous and subsequent centuries (e.g. Bradley et al., 2003; Broecker, 2001; Hughes and Diaz, 1994; Lamb, 1965). In Southern Georgia, the Mediaeval climate was certainly different to its precedent, but the description ‘Mediaeval Warm Period’ is not entirely fitting here. While the Georgian Mediaeval seems to have seen slightly warmer winter temperatures on the Tsalka Plateau, the main characteristic of the climate was increased seasonal aridity, witnessed particularly in low lake levels at Imera and Bareti. At least for the highlands of Southern Georgia, the climate reverted to a state that more closely resembled its Early to Middle Bronze Age character (cf. Figure 8.18). It could be asked whether the same climatic conditions that saw the Trialeti Kurgan culture flourish in the highlands during the Bronze Age helped to foster Georgia’s Mediaeval prosperity in the important highland centres of Tsalka, Akhalkalaki, Timogvi and Vardzia.

The irruption of the Mongol hordes from Central Asia sounded the death knell for Georgia’s Golden Age (Allen, 1929; Lang, 1966). Between 1235 and 1240 AD the Georgian feudal lords each and separately came to terms with the Mongol leaders, thus ending the unification so hard won by David the Builder over a century before. Not until 1334 AD could the Georgian population throw off the burden of Mongol oppression and once again unite under King Giorgi the Brilliant (1314-1346 AD). Again, this period of autonomy was short-lived: in the year 1386 Tamerlane came to Georgia. The devastation his armies inflicted during this and subsequent campaigns was absolute – they massacred the population, burnt their cities, churches and villages, laid waste to vineyards, fields and orchards (Salia, 1983). At the dawn of the 15th century, after decades of brutal war and a catastrophic outbreak of the Black Death, Georgia was left defeated, depopulated and deforested.
Recent history (1400 AD – present)

Following Tamerlane’s campaigns, Georgia was divided amongst a number of its feudal lords and became the subject of prolonged Turkish and Persian territorial disputes over the next few centuries. Toward the end of the 16th century Russia also entered into this conflict; eventually Georgia sided with their Christian neighbours to the north against the Muslim Persians and Turks. Thus Georgia was subsumed by the Russian Empire during the 19th century and its successor, the Soviet Union, during the 20th (Salia, 1983).

![Figure 9.6. Dr Eliso Kvavadze standing beside an ancient pollarded Zelkova carpinifolia tree in the Babaneuri Reservation, Eastern Georgia. The diameter of this tree’s trunk is 1.22 m (breast height). Most of Babaneuri’s old, large Zelkova trees have been pollarded in the past.](image)

This more recent history played out in a climate somewhat cooler and wetter than the preceding Mediaeval. Permanent snow in the highlands of Southern Georgia described by the 18th century geographer Vakhushhi could be interpreted as evidence for the Little Ice Age (Dzhanelidze, 1980). Human impact on the vegetation
intensified and especially so in the forests along lowland rivercourses, on the Main Caucasus Range and in Colchis (Badenkov et al., 1990; Dzhanelidze, 1980; Ketskhoveli, 1959). Deforestation in these areas must have been sufficiently serious to warrant Georgian rulers employing forest guards and enacting forest protection laws from the beginning of the 15th century (Ketskhoveli, 1959, p. 345). At least in Southern Georgia, intense fires ensured that the land did not become “ruined and turned into forest” in Tamerlane’s wake (Figure 9.3).

Perhaps in consequence of deforestation near settlements, tree pollarding and coppicing were practised widely at this time (Ketskhoveli, 1959, p. 81 ff.). Poplars, willows, elms, ash and Zelkova trees were commonly pollarded on short rotation (Figure 9.6), oaks were often shredded to produce construction timbers, and other trees and shrubs were coppiced for fencing, brushwood and firewood (Ketskhoveli, 1957, p. 263 ff.). Such activities could well have their genesis in the ancient past, especially in Southern Georgia where wood was always scarce due to the dry climate and long history of burning and grazing.

The transformation of lowland landscapes during the Soviet period impacted heavily on their biota (Badenkov et al., 1990; Bendukidze, 1979; Dolukhanov, 1966). In Western Georgia, swamps were drained and turned over to intensive mechanised agriculture; in the arid lowland steppes of Eastern Georgia, irrigation converted vast winter pastures into collectivised agricultural fields.

Yet in the hills and highlands of Southern Georgia, the vegetation remained more or less in its prehistoric state, bitten down by livestock, felled and fired by villagers, so that when Joseph de Tournefort arrived there at the behest of Louis XIV, he observed a landscape little different to the present one – “full of Grass; but all manner of Trees have been long banish’d out of it” (Tournefort, 1718, p. 227).

In spite of all Georgia’s political vicissitudes, had he visited centuries or even millennia before, he may well have made the same observation.
CHAPTER TEN

CONCLUSIONS

This thesis has demonstrated the persistence of open landscapes in Southern Georgia through the last 14,000 years. The steppic and xerophytic plant communities that currently prevail in parts of Southern Georgia are not recent developments, but have existed in one form or another for the entire Holocene period. Paradoxically, when forests expanded throughout the Caucasus region during the early-mid Holocene, the landscapes of Southern Georgia remained stable, open and relatively treeless. This was in spite of a clear trend towards higher rainfall and temperatures.

I argue that the ecological void between the expected vegetation and the climate of that period was filled by Neolithic human populations. Through burning and grazing, Neolithic people preserved and maintained the open landscapes upon which their agro-pastoral economy depended. Not until the dawn of the Bronze Age, some 5000 years ago, did the emergence of metallurgy foster a new relationship with the vegetation. The axe allowed highland populations to mould and utilise the vegetation in a highly selective and deliberate fashion. Some parts of Southern Georgia responded to the extinguishment of landscape fires with rapid afforestation, while areas close to population centres remained conspicuously open. The increasing complexity of the Bronze Age economy thus manifested in the increasing heterogeneity of the vegetation.

The turbulent history of Southern Georgia in historical times brought dramatic changes to its plant communities. Moments of stability brought stability to agricultural systems and allowed the expansion of orchards, forests and fields; political instability on the other hand forced many to adopt transhumance and saw the widespread expansion of open vegetation and burning. To a significant degree, the heterogenous landscapes and various phytogeographical provinces of Georgia in the present-day can be directly attributed to the differential effects of human activity in time and in space, superimposed on a land of great bioclimatic diversity.

I hope that these conclusions will stimulate discussion on the causes of vegetation change in neighbouring regions and lead to a careful re-evaluation of the
pollen evidence. In particular, this study has shown that traditional interpretations of pollen data are likely to produce misleading results in a semi-arid environment. Changing lake levels have a strong bearing on the pollen source area, such that low lake levels are representative of local vegetation and high lake levels of more regional vegetation. This relationship is most vividly expressed in the ratio of tree pollen to non-tree pollen. While this ratio is commonly regarded as an indication of forest cover in humid regions, in the steppe lakes of Southern Georgia it is a much more reliable indicator of lake levels.

Other considerations include the interpretation of grass pollen, which is produced by both steppic and wetland vegetation, and the difficulties in detecting xerophyte scrub vegetation using pollen data. This thesis has highlighted the need for future research to include analysis of microscopic charcoal and fungal remains as an adjunct to radiocarbon-dated pollen data. Statistical methods, in particular, show great promise in aiding the interpretation of the often-cryptic pollen diagrams from semi-arid and mountainous environments. Even though trends may not be immediately apparent, changes in temperature and precipitation, forest cover and land-use can be effectively isolated from background noise using modern analogues.

Indeed, the Late Pleistocene seems to have been a time of intense aridity and seasonality, with a cold phase centred on the Younger Dryas. Moisture increased during the early Holocene, albeit slowly, so it was not until after 9000 years ago that rainfall came to resemble its present-day aspect. The mid Holocene seems to have been a time of increased temperatures and was followed by somewhat cooler and more variable conditions during the late Holocene. While climate has had a strong bearing on the course of Holocene vegetation change in Georgia, within the bounds of Southern Georgia human impact has always played the leading role.

Archaeologists have long concerned themselves with questions of the emergence of agriculture and subsequent changes in economic strategies. In Western Asia, this question has traditionally been examined through artefact, macrobotanical and faunal assemblages in archaeological sites. Perhaps we need to broaden our view of human interactions with the environment, and consider the ancient cultural landscape as our predecessors’ most significant and enduring legacy.
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