University of Albertaa

Holocene Climate and Culture Change in the Lake Baikal Region, Siberia

by

Dustin White ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment
of the requirements for the degree of Doctor of Philosophy

Department of Anthropology

Edmonton, Alberta
Spring 2006

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Library and
Archives Canada

Published Heritage
Branch

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque et
Archives Canada

Direction du
Patrimoine de l'édition

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 0-494-14061-5
Our file Notre référence
ISBN: 0-494-14061-5

NOTICE:
The author has granted a non-exclusive license allowing Library and Archives Canada to reproduce, publish, archive, preserve, conserve, communicate to the public by telecommunication or on the Internet, loan, distribute and sell theses worldwide, for commercial or non-commercial purposes, in microform, paper, electronic and/or any other formats.

The author retains copyright ownership and moral rights in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

AVIS:
L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, publier, archiver, sauvegarder, conserver, transmettre au public par télécommunication ou par l'Internet, prêter, distribuer et vendre des thèses partout dans le monde, à des fins commerciales ou autres, sur support microforme, papier, électronique et/ou autres formats.

L'auteur conserve la propriété du droit d'auteur et des droits moraux qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.

Canada

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

ABSTRACT

This research is part of a multidisciplinary collaboration investigating Holocene culture change and continuity among hunter-gatherers in the Lake Baikal region of southern Siberia. Archaeological data have demonstrated two distinct periods of social complexity, as evidenced by the use of large formal cemeteries dating to the Early Neolithic Kitoi and Late Neolithic–Early Bronze Age Serovo-Glazkovo periods, separated by a *ca.* 1000-year interval spanning the 7th millennium before present in which large mortuary sites are entirely absent. Evidence further suggests that cultural groups on either side of this Middle Neolithic hiatus differed in such fundamental areas as subsistence, diet, mobility, social and political relations, and genetic affiliation. The causal factors underlying this 'biocultural discontinuity' are still unknown, though thus far have been attributed to various social processes. Regional climate change, however, may have played a contributory role by acting as a stimulus for environmental fluctuations which required the development of new adaptive strategies by resident hunter-gatherer groups. The present study is designed to examine this middle Neolithic discontinuity within the context of changing climatic and environmental conditions during the Holocene.

Given the relative scarcity of detailed paleoecological investigations currently available from the Lake Baikal area, a major objective of this research was to document and interpret previously unstudied, high temporal resolution biostratigraphic sequences to add further to the growing record of Holocene climate and environmental change in the region. Field studies were carried out in areas which have received rather limited

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

investigation, including sites in the upper Lena (Basovo site) and lower Selenga (Burdukovo site) river valleys. A multi-proxy research strategy was used to reconstruct the environmental significance of radiocarbon dated pedogenic cycles recorded in alluvial and aeolian depositional contexts, along with the associated records of macro- and micro-fossil datasets. Due to their extraordinary abundance and diversity at the study sites, particular emphasis is given to the Holocene successional history of land and freshwater molluscs. Results from these new data, in combination with other local and regional paleoecological proxy records, are used to examine the potential relationship between climate and environmental variability and culture change during the Baikal Neolithic.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

ACKNOWLEDGEMENT

I thank the following people and institutions for their contributions to this research. Foremost, Andrzej Weber and the Baikal Archaeology Project, who gave me carte blanche to chase snails in Siberia. The Social Sciences and Humanities Research Council of Canada, Canadian Circumpolar Institute, Killam Trust, and the University of Alberta's Faculty of Graduate Studies and Research and the Department of Anthropology also generously supported this work. To Richard Preece and the University Museum of Zoology Cambridge, for imparting much needed malacological expertise and for introducing me to Jochen Gerber, Simon Parfitt, Beata Pokryszko, J.G.J. Kuiper, Claus Meier-Brook, and Russel Coope, who all kindly provided taxonomical wisdom. Many thanks also to my fellow garmoshka brother Hugh McKenzie, and to Vladimir Bazaliiskii and Irkutsk State University, Mikhail Kuzmin and the Institute of Geochemistry RAS, Alexander Shchetnikov, Gennady Ufimtsev, and the Institute of the Earth's Crust RAS, Charlie Schweger, Andy Bush, Nat Rutter, Peter Crown, Alan Bryan, Ruth Gruhn, Karlis Muehlenbachs, Anson Mackay, Kostya Dlussky, Art Bettis, Andrea Hiob, Darren Shaw, Mike Metcalf, Vitaly Bogdanoff, Denis Parygin, and Ekaterina Dubova for their many contributions to the development and completion of this research. Thanks also to the many people in Siberia and Mongolia who I met during the course of my travels in the Baikal region and beyond. You have given me unimaginable experiences and memories for a lifetime. And finally, to Shari Newman, for her unconditional support and belief in me over the years.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

TABLE OF CONTENTS

CHATER 1 – INTRODUCTION

CHAPTER 2 – GEOGRAPHIC BACKGROUND

CHAPTER 3 – MATERIALS AND METHODS

CHAPTER 4 – THE BASOVO SITE, UPPER LENA RIVER VALLEY: RESULTS AND INTERPRETATIONS

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

CHAPTER 5 – THE BURDUKOVO SITE, LOWER SELENGA RIVER VALLEY: RESULTS AND INTERPRETATIONS

CHAPTER 6 – HOLOCENE CLIMATE AND ENVIRONMENTAL CHANGE AND NEOLITHIC BIOCULTURAL DISCONTINUITY IN THE LAKE BAIKAL REGION: DISCUSSION

CHAPTER 7 – CONCLUSIONS AND FUTURE RESEARCH

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

LIST OF TABLES

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

LIST OF FIGURES

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

LIST OF PLATES

SCANNING ELECTRON MICROSCOPY (SEM) IMAGES OF TERRESTRIAL AND AQUATIC MOLLUSCS FROM THE BASOVO AND BURDUKOVO SITES

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

LIST OF APPENDICES

APPENDIX A: BASOVO AND BURDUKOVO SITE STRATIGRAPHIC DATA

APPENDIX B: BASOVO AND BURDUKOVO MOLLUSC RAW COUNTS

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

CHAPTER 1

Introduction

Problem Statement

The Baikal Archaeology Project (BAP) is a multidisciplinary collaboration investigating long-term culture change and continuity among Holocene boreal forest hunter-gatherers in the Lake Baikal region of southern Siberia (Weber and McKenzie, 2003; Figure 1.1). Results from this international research program have demonstrated an intriguing hiatus or 'biocultural discontinuity' in which two distinct periods of social complexity, as evidenced by the use of large formal cemeteries dating to the early Neolithic and late Neolithic periods, are separated by a *ca.* 1000-year interval spanning the 7th millennium before present (calibrated years BP) in which large mortuary sites are entirely absent. Archaeological data further suggest that cultural groups on either side of this middle Neolithic gap differed in such fundamental areas as subsistence, diet, mobility, social and political relations, genetic affiliation, and worldviews. The causal factors underlying this hiatus are still unknown, though thus far have been attributed primarily to various social processes. Regional climate change, however, may have played a contributory role by acting as a stimulus for environmental fluctuations which required the development of new adaptive strategies by resident hunter-gatherer groups. As part of the BAP collaboration, the present study is designed to examine this middle Neolithic discontinuity in the Lake Baikal region within the context of changing climatic and environmental conditions during the Holocene.

Background and Research Approach

<u>Lake Baikal Neolithic Culture History</u>

A century of archaeological research in the Baikal area has revealed a unique and rich record of Neolithic hunter-gatherer culture change. In addition to more traditional

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

investigations of habitation sites and associated artifactual assemblages, the recovery of both abundant mortuary data and human osteological material from the region has offered unparallel insights into the biological and social make-up of prehistoric Subarctic foraging populations. With the discovery of new archaeological records and the application of more systematic analytical protocols, Neolithic culture history models developed for the area have undergone a series of reinterpretations over the last few decades, aptly summarized in Weber (1995).

The most significant recent developments in our understanding of Neolithic culture change in the Cis-Baikal region (*i.e.*, the area immediately west of Lake Baikal) have undoubtedly come from the extensive radiocarbon dating of cemetery complexes (Weber, 1995; Weber *et al.*, 2002, 2005). This work alone has redefined the chronological order of identified cultural groups while simultaneously invalidating many of the earlier Cis-Baikal culture history models. Further, these new temporal data and associated mortuary evidence have revealed more subtle characteristics related to the degree of continuity between regional cultural sequences, which previously remained unrecognizable largely due to the absence of systematic and well dated site records. This new model of Neolithic hunter-gatherer culture change developed through the BAP collaboration is briefly summarized below, setting the context for later discussion of early–middle Holocene climate and environmental change as potential contributing factors for the middle Neolithic biocultural discontinuity in the Cis-Baikal region.

Period	***Culture/Mortuary Complex***	***Radiocarbon (^{14}C) Age BP***	***Calibrated (cal) Age BP***	***Calibrated (cal) Age BC***
Late Mesolithic	Early Kitoi	*ca.* 8000–7000	*ca.* 8800–7800	*ca.* 6800–5800
Early Neolithic	Late Kitoi	*ca.* 7000–6100	*ca.* 7800–6900	*ca.* 5800–4900
Middle Neolithic	Hiatus	*ca.* 6100–5300	*ca.* 6900–6200	*ca.* 4900–4200
Late Neolithic	Early Serovo-Glazkovo	*ca.* 5300–4800/4400	*ca.* 6200–5400/5000	*ca.* 4200–3400/3000
Bronze Age	Late Serovo-Glazkovo	*ca.* 4800/4400–3300	*ca.* 5400/5000–3000	*ca.* 3400/3000–1000

Early Neolithic

Unlike many other areas in the world where the term 'Neolithic' signifies cultural attributes such as large settlements and plant and animal domestication, in Siberia the onset of the Neolithic period is recognized primarily by the first appearances of pottery

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

and ground stone tools and ends with the introduction of metallurgy (Weber *et al.*, 2002). In the Lake Baikal region, subsistence and lithic technologies spanning the Mesolithic–Neolithic transition are otherwise relatively indistinguishable, suggesting that cultural changes during this time were rather gradual (Weber, 1995). This late Mesolithic–early Neolithic period corresponds to the Kitoi cultural complex in the Cis-Baikal and represents an interval of growing social complexity in the region evidenced by the extended use of a few relatively large cemeteries in the Angara River valley (*e.g.*, Lokomotiv, Kitoi, and Ust'-Belaia) and on the southern Lake Baikal coast (*e.g.*, Shamanka II), as well as several smaller mortuary sites in both the upper Lena River valley (*e.g.*, Makrushina) and Little Sea region (*i.e.*, west-central coast) of Lake Baikal (*e.g.*, Shamanskii Mys and Khotoruk).

Archaeologically, Kitoi graves are identifiable by relatively deep pits with few stone furnishings and the frequent use of red ochre (Weber *et al.*, 2002). Accompanying grave goods often show evidence of social inequality, with males generally interred with both a greater number and range of artifacts compared to females, however individual site patterns show some variability (Weber *et al.*, 2002). Artifact assemblages commonly found in Kitoi graves include a variety of utilitarian (*e.g.*, composite fishhooks, points, green nephrite knives, ground stone adzes, scrapers, pestles, abraders, cores, flakes, prismatic blades for composite tools, and a number of organic tools) and non-utilitarian (*e.g.*, tooth pendants, anthropomorphic and zoomorphic figurines, and inorganic ornaments such as calcite rings and beads) items, however pottery vessels are rarely present at Kitoi mortuary sites (Weber *et al.*, 2002; Bazaliiskii, 2003).

Subsistence adaptations interpreted from these and other site data indicate that the Kitoi had small annual ranges and low group residential mobility combined with high individual mobility (Weber *et al.*, 2002). Narrow spectrum foraging activities resulted in a diet focused primarily on the harvesting of fish as well as ungulates (*e.g.*, red deer, roe deer, moose, and reindeer), and seasonal food supplies may have been erratic (Weber *et al.*, 2002). This high dependency on aquatic resources is believed to have fostered the extended use of home bases in areas with abundant and predictable seasonal fisheries (*e.g.*, many Kitoi settlements are located near the mouths of major tributaries) (Weber *et al.*, 2002). Further, it is hypothesized that this more selective or specialized use of

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

subsistence resources may have made these populations susceptible to even small-scale changes in the natural environment (Weber *et al.*, 2002). Evidence of Kitoi demography indicates the existence of large local communities (*i.e.*, high nucleation) with low regional population densities (*i.e.*, sites distributed primarily in the Angara River valley), and limited interaction between neighboring groups (*i.e.*, socially closed communities) (Weber *et al.*, 2002). Kitoi population stagnation and even decline is suggested by the end of the early Neolithic period (Weber *et al.*, 2002). Analyses of mtDNA from skeletal remains (Mooder *et al.*, n.d.), along with craniometric data (Weber, 1995), indicate that early Neolithic Kitoi populations were biologically discontinuous with subsequent hunter-gatherer groups in the Cis-Baikal region.

Middle Neolithic

The end of the late Kitoi period (*ca.* 6900 cal yr BP) marks the onset of an intriguing *ca.* 1000-year gap or hiatus in the use of large formal cemeteries by Neolithic hunter-gatherer groups in the Cis-Baikal. This discontinuity in mortuary behavior was revealed through extensive radiocarbon dating of human skeletal remains from a number of sites in the area. Of the *ca.* 400 new radiocarbon determinations from regional cemeteries, none have bridged this middle Neolithic hiatus in the Cis-Baikal mortuary record (Weber *et al.*, 2005). Rather, these data have confirmed the existence of a millennium-long gap, if not longer, in formal cemetery use separating two distinct periods of mortuary complex development associated with the pre-hiatus Kitoi and post-hiatus Serovo-Glazkovo groups. Further, according to Weber *et al.* (2005), "since the formal use of cemeteries by hunter-gatherers is almost invariably a result of growth in social complexity linked to relative sedentism and the intensification of subsistence activities, including increased reliance on fishing, it is reasonable to suggest that the lack of cemeteries during the Middle Neolithic represents some sort of reversal of such trends". It is hypothesized that for some still unknown reason(s), late Kitoi groups abandoned large local settlements and the practice of formal cemetery use, as well as established subsistence modes and sociopolitical organizations, and dispersed into smaller groups spread out across the broader Baikal region (Weber *et al.*, 2005). The processes surrounding changes in Kitoi adaptations form the basis of on-going

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

multidisciplinary investigations by a number of BAP researchers. These issues will be assessed in greater detail from an environmental perspective later in this dissertation.

Late Neolithic–Bronze Age

By *ca.* 6200 cal yr BP, the development of large mortuary complexes once again becomes a distinguishing feature on the Cis-Baikal landscape. This post-hiatus period of growth in social complexity is associated with the Serovo-Glazkovo culture. While still broadly grouped as a single cultural complex, new radiocarbon evidence suggests that the Serovo period is slightly but distinguishably older, dating to the late Neolithic, and represents an incipient stage in the development of social complexity which continued to increase throughout the Bronze Age Glazkovo period (Weber *et al.*, 2005). Serovo and Glazkovo interments are often found together at the same cemeteries, and given the continuity in age, similarity in mortuary protocols, and close biological affinities, these data all indicate the *in situ* development of this cultural complex (Weber *et al.*, 2005). Principal Serovo-Glazkovo cemeteries in the Cis-Baikal region include Ust'-Ida, Serovo, Ponomarevo, Bratsk, Semenovo, and Shumilikha in the Angara River valley, Verkholensk, Obkhoi, and Makrushina in the upper Lena River valley, and Sarminskii Mys, Khuzir, Khuzir-Nuge VI, Khuzir-Nuge XIV, Kurma XI, and Uliarba in the Little Sea region of Lake Baikal.

Serovo-Glazkovo cemetery complexes are distinguished archaeologically by relatively shallow (*i.e.*, *ca.* 0.5 m deep) and elongated grave pits lined and filled with stone slabs, more patterned grave orientations, common use of fire in graves, and the frequent occurrence of grave disturbances (*i.e.*, looting), particularly during the Bronze Age Glazkovo period (Weber *et al.*, 2002). Artifacts interred during burials suggest more equitable social organization compared to the early Neolithic Kitoi group (Weber *et al.*, 2002). Typical Serovo-Glazkovo grave goods include lithic and bone knives, harpoons, and composite tools, bifacial stone knives, polished slate and green nephrite knives, clay vessels, and various adornments (*e.g.*, pendants and figurines) (Weber *et al.*, 2002). By the early Bronze Age, copper and bronze artifacts, nephrite and calcite discs, and fewer, though stylistically different, pottery remains become more commonly associated with Cis-Baikal mortuary practices (Weber *et al.*, 2002).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Preliminary interpretations of these and other data from habitation sites suggest that Serovo-Glazkovo subsistence adaptations included large annual ranges with relatively high group residential mobility and comparatively low individual mobility (Weber *et al.*, 2002). Dietary preferences were based on a broad spectrum foraging strategy focused on ungulates and aquatic resources such as fish and seal, and these diversified and more flexible subsistence activities produced sustainable seasonal food supplies (Weber *et al.*, 2002). Demographic trends suggest small local communities with high regional population densities spread out rather evenly across the area, with interactions between social groups being more common than during the early Neolithic Kitoi period (Weber *et al.*, 2002). Substantial population growth is evident at least during the early post-hiatus period (Weber *et al.*, 2002). Genetic and osteological data indicate both that the Serovo-Glazkovo people were quite similar to one another and that these populations were biologically discontinuous with the pre-hiatus Kitoi (Mooder *et al.*, n.d.; Weber, 1995).

The origin or "homeland" of late Neolithic–Bronze Age (*i.e.*, post-hiatus) cultures in the Cis-Baikal region and the processes leading to this period of renewed social complexity are still unanswered questions and remain a focal point of BAP research. Genetic and osteological evidence points to the immigration of a new population(s) into the Cis-Baikal region sometime following the abandonment of large settlements and cemetery complexes by late Kitoi groups at the end of the early Neolithic. It is still unclear however, where the ancestral homeland(s) was for the Serovo-Glazkovo culture. Weber (1995) has reported cranial features and pottery styles present in the late Neolithic Cis-Baikal which show some similarities with records from the upper Yenisey Basin to the west. Goriunova *et al.* (2004) also note similarities between late Glazkovo mortuary traditions in the Cis-Baikal with those of west Siberian cultural complexes. Further, sitting graves, characterized by individuals interred in a generally upright posture with flexed legs, are present in the Baikal area during the early Bronze Age period, and this practice is also known from across northern Eurasia, including central Kazakhstan and eastern Mongolia (Kharinskii and Sosnovskaia, 2000; Okladnikov and Larichev, 1968; Turkin and Kharinskii, 2004; Volkov, 1975). Interestingly, genetic evidence suggests a link between Serovo-Glazkovo in the Cis-Baikal with a *ca.* 2300-year-old Xiongnu (or

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Hun) cemetery population from the Egyin Gol in northern Mongolia (Mooder *et al.*, n.d.; Keyser-Tracqui *et al.*, 2003). In general however, few archaeological comparative studies have been undertaken across the broader region. These and other questions surrounding the enigmatic middle Neolithic biocultural discontinuity in the Cis-Baikal are subjects of continued study.

Research Approach and Significance

The climatic and environmental context of hunter-gatherer culture change and continuity in the Lake Baikal region has yet to be adequately evaluated as a possible contributing factor leading to the archaeologically identified middle Neolithic hiatus. In previous studies, relative ecological stability has been assumed for the Cis-Baikal Neolithic (Weber *et al.*, 2002). Results from a number of recent investigations however indicate that the dynamic cultural processes transpiring in the Lake Baikal region during the middle Holocene were contemporaneous with significant climatic and environmental changes occurring both locally and across continental east Asia (An *et al.*, 2000; Andreev and Klimanov, 1999; Andreev *et al.*, 1997; Bezrukova *et al.*, 1996, 2005a, 2005b; Blyakharchuk, 2003; Blyakharchuk and Sulerzhitsky, 1999; Blyakharchuk *et al.*, 2004; Demske *et al.*, 2005; Dorofeyuk and Tarasov, 1998; Fedotov *et al.*, 2004; Feng *et al.*, 2005; Fowell, *et al.*, 2003; Grunert *et al.*, 2000; He *et al.*, 2004; Horiuchi *et al.*, 2000; Karabanov *et al.*, 2000; Kataoka *et al.*, 2003; Kremenetski *et al.*, 1997, 1998, 2003; Krivonogov *et al.*, 2004; MacDonald *et al.*, 2000; Peck *et al.*, 2002; Peteet *et al.*, 1998; Prokopenko *et al.*, 2005; Rhodes *et al.*, 1996; Takahara *et al.*, 2000; Tarasov *et al.*, 1997, 2000, 2004; Velichko *et al.*, 1997, 2002; Wang *et al.*, 2004a, 2004b). While these paleoecological data are still somewhat limited in spatial and temporal resolution, it is apparent that, at least chronologically, a correlation exists between climate and cultural changes in the Lake Baikal region. Whether or not causality played any specific role in climate-culture interactions remains unclear. Such links between changes in environmental conditions and hunter-gatherer adaptations are well documented in the ethnographic and archaeological literature (Binford, 2001; Kelly, 1995), but establishing clear relationships between climate and environmental changes and cultural responses

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

requires a resolution in data that is often unobtainable in many paleoecological and archaeological site contexts.

Given these challenges, the present study is designed to reconstruct the Holocene environmental history of the Lake Baikal region and surrounding areas through the integration of various multi-proxy paleoecological records, and then use these data to contextualize Neolithic cultural dynamics in the Cis-Baikal. Considering the relative scarcity of detailed paleoecological investigations available from the Baikal area, a major focus of this research is to document and interpret previously unstudied, high temporal resolution paleoenvironmental sequences in the region to add further to the growing, though still limited, record of Holocene climate and environmental change. These new field data, in combination with other regional paleoclimate proxy records, will then be used to examine how changing environmental conditions had at least the potential to induce shifts in both local ecological systems and subsistence resources, which could have then initiated a range of responses in the adaptive behaviors of resident Neolithic hunter-gatherer groups. These changes in turn may have played a contributing role in reconfiguring levels of social complexity on the Cis-Baikal landscape.

To this end, field studies were carried out in areas around Lake Baikal which have traditionally received rather limited scientific investigation, including sites in the upper Lena (Basovo site) and lower Selenga (Burdukovo site) river valleys. Fieldwork and subsequent laboratory analyses were guided by a multi-proxy research strategy in order to reconstruct floodplain biostratigraphic records in as much detail as possible. The focus of these studies is to establish the environmental significance of radiocarbon dated pedogenic cycles recorded in alluvial and aeolian depositional contexts, along with the associated sequence of macro- and micro-fossil datasets. Due to their extraordinary abundance and diversity at the study sites, particular emphasis is given to the Holocene successional history of land and freshwater Mollusca.

Molluscs are often identifiable to species level and modern studies have shown many taxa to be relatively sensitive indicators of local habitat conditions, including dominant vegetation types, the degree of ground moisture, various characteristics of water bodies, and human disturbances (Lowe and Walker, 1997; Goodfriend, 1992). Thus the autecology and spatial distribution of living species allow inferences about past

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

environmental conditions based on temporal changes in fossil assemblages. While Holocene molluscan sequences have become a common proxy record in site paleoecological reconstructions in Europe (Kerney *et al.*, 1980; Limondin-Lozouet and Preece, 2004; Meyrick, 2002; Meyrick and Preece, 2001; Preece, 1980; Preece and Bridgeland, 1999; Preece and Day, 1994; Preece and Robinson, 1984; Preece *et al.*, 1986), such an approach has yet to be undertaken in Siberia. Thus the data from field research presented in this dissertation offer both a rare and scientifically unique record and illustrate the potential of a new proxy archive for documenting Holocene environmental changes in the Lake Baikal region. Additionally, the integration of these new malacological data with results from other regional paleoclimate records establishes a framework both for reconstructing the environmental context surrounding Neolithic hunter-gatherer culture change and continuity in this remote part of the world and to begin evaluating the role that regional and local climatic and environmental variability played in the observed biocultural discontinuity during the region's middle Neolithic period, thus contributing to the broader research goals of the Baikal Archaeology Project collaboration.

Organization of Study

The dissertation is organized into seven chapters. Following this Introduction, a brief geographic background of the Lake Baikal region and the field sites investigated for this research is presented in Chapter 2, which also includes a review of the Holocene climatic and environmental history of continental east Asia (*i.e.*, Siberia, Mongolia, and adjacent areas). Chapter 3 outlines the materials and methods employed during field and laboratory analyses, including the taxonomic considerations used in the identification of molluscan species. This is followed in Chapters 4 and 5 by the presentation of research results and interpretations of the Basovo and Burdukovo site records, respectively. In Chapter 6, these data are compared and discussed within the context of other published local and regional climate change reconstructions. The collective record of early–middle Holocene environmental change is then evaluated to formulate several new research questions linking regional climatic shifts as possible factors contributing to the middle Neolithic biocultural discontinuity in the Cis-Baikal. Finally, Chapter 7 concludes the

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

dissertation with a brief summary of research contributions and outlines a few recommendations for both future malacological research and environmental and culture change studies in the Lake Baikal region.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Figure 1.1. Geographic location of the Lake Baikal study area within Asia (modified from http://www.lib.utexas.edu/maps/middle_east_and_asia/asia_ref04.jpg).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

CHAPTER 2

Geographic Background

Study Area

Lake Baikal Region

Lake Baikal (456 m asl), the world's most voluminous (23,015 km^3) and deepest (1642 m) fresh-water lake (Mackay *et al.*, 2002), is located between 52°–56° north latitude and 104°–110° east longitude in the center of the Asian landmass (Figure 1.1). This part of south-central Siberia is a geographically diverse area known as the Baikal Mountain Region (Kozhov, 1963), consisting of the Cis-Baikal and western Trans-Baikal areas (Figure 2.1). Cis-Baikal includes the regions to the north and west of Lake Baikal, encompassing the Angara drainage down to Ust'-Ilimsk, the drainage of the upper Lena River down to Kirensk, and the western islands and coasts of the lake itself (Michael, 1958; Weber, 1995). Western Trans-Baikal includes the areas to the south and east of the lake, extending from the eastern and southern coastlines to the Vitim River drainage and south to the Mongolian border. A brief geographical background of the Lake Baikal region is described below, following Galazii (1993), Shahgedanova (2002), and Weber (2003). More detailed descriptions of the geographic setting of the Basovo and Burdukovo study areas are provided in subsequent sub-sections of this chapter. Finally, the chapter concludes with a review of the Holocene climatic history of the Lake Baikal region and surrounding areas, thus setting the context both for the integration of results from new paleoecological field data, and later discussion of the potential role of climate and environmental change in regional Neolithic cultural sequences.

As part of the seismically active Baikal Rift Zone, the mountainous character of the region is defined by a series of ranges which border the deep structural depressions in which Lake Baikal resides. These include the Primorskii (1100–1700 m asl) and Baikalskii (1100–2650 m asl) ranges along the western coast, the Barguzinskii (1100–

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

2100 m asl), Ulan-Burgasy (1100–1800 m asl), and Khamar-Daban (1100–2400 m asl) ranges along the eastern and southern coastlines, and the Eastern Sayan (1100–3400 m asl) range which lies to the west of the southern tip of Lake Baikal (Figure 2.1.). Topography decreases in elevation away from these mountain ranges, and in the Cis-Baikal includes the foothills and valleys of the southern Central Siberian Plateau (400–1500 m asl) and the eastern and northern slopes and valleys of the Eastern Sayan, and in western Trans-Baikal includes several lower SW-NE oriented ranges and intermontane depressions. The orientation of mountain ranges to prevailing atmospheric circulation has a significant affect on local climatic conditions and associated vegetation complexes, accounting in part for the relatively high degree of micro-environmental variability throughout the area.

The modern climate of the region is distinctly continental, characterized by long, cold, dry winters and short, warm, and moderately wet summers. These conditions result primarily from the dominance of the Siberian anticyclone (*i.e.*, high pressure) in winter and the Inner Asiatic depression (*i.e.*, low pressure) in summer. Generally, annual temperatures average *ca.* 20°C in July and *ca.* –26°C in January. Thermal conditions in the coastal zone around Lake Baikal however are strongly influenced by the large and relatively warm water mass, which acts both to lower summer temperatures and raise winter temperatures by *ca.* 10–15°C compared to surrounding areas. Precipitation across the region has an irregular spatial distribution, ranging from as little as *ca.* 150–200 mm along the central west coast of Lake Baikal up to *ca.* 1300 mm at higher elevations. Precipitation totals are highest during the summer months, reaching a maximum during July. Snow accumulation is also quite variable across the region during the winter. Permafrost is mapped as 'discontinuous' to the north and south of Lake Baikal and as part of the 'massive-island' and 'island' zones to the west and east.

Vegetation complexes in the Baikal region are relatively diverse for a Subarctic landscape, and include alpine-tundra, taiga, forest-steppe, and steppe environments. Alpine areas are host to a variety of mosses, lichens, grasses and meadows, and willow, with limited forests. Local treeline elevations vary considerably depending on geographic position, but generally range between *ca.* 1300–1800 m asl. Taiga is the most widespread vegetation complex in the region today, dominated by pine (*Pinus sylvestris*),

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

larch (*Larix sibirica*), and 'cedar' (*Pinus sibirica*) forests, along with an admixture of fir (*Abies sibirica*), spruce (*Picea obovata*), birch (*Betula*), and aspen (*Populus*). In the Cis-Baikal, forest-steppe and steppe environments occur in localized moisture-deficient areas, including much of the upper section of the Angara River valley, parts of the Kuda and Manzurka drainages in the upper Lena River valley, and along the west-central coast of Lake Baikal and neighboring Ol'khon Island. In western Trans-Baikal, forest-steppe and steppe is common throughout the Selenga River valley and the intermontane depressions of its tributaries, including the Dahuria area near the Mongolian border, as well as in the Barguzin River valley in the north.

Basovo Site and the Upper Lena River Valley

The Basovo site (55°52'30.4" N, 105°47'01.7" E) is located within the upper Lena River valley of the Cis-Baikal, part of the Lena-Angara foothills region of the southern Central Siberian Plateau (Figure 2.1). The geographical background described in this section is taken from summarized translations of Boyarkin (1973), Dobrovolsky and Urusevskaya (1984), Irkutsk Meteorological Agency report (2002), Kuznetsov and Zharkov (1964), Maslov (1947), Reference Book for Climatology of the USSR (1949), and Romanchenko (1990).

The site is situated on the east bank of the Lena River at an elevation of *ca.* 345 m asl, with maximum elevations of surrounding hilly terrain reaching over *ca.* 1500 m asl. The topography in the area is formed primarily from bedded subhorizontal terrigenous-carbon-bearing rocks of Cambrian and Ordovician age. Cambrian rocks are represented by thinly-bedded argillites interlaid (up to *ca.* 1.5 m thick) with aleurolites, fine-grained sandstone, marl, and limestone, predominantly brown, red-brown, and purple-brown in color. Ordovician deposits have a more widespread occurrence in the area, comprising the valley divides and upper valley slopes. Rocks of this age occur as parallel- and obliquely-laminated, fine- and medium-grained sandstone, dolomites and limestone, with some aleurolites and argillites. Rock colors vary, but are primarily grey, red-brown, and cherry-brown. Quaternary deposits occur as thin mantles of colluvium along valley slopes and as alluvial sediments of the upper Lena River terrace complex and its tributaries. Modern soil cover in this area includes loamy-skeletal Eutric Brunisols

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

(Cryoeutric Cambisols) and Dystric Brunisols (Cryodystric Cambisols) on well-drained plateaus and slopes, along with clayey Gleyic Brunisols (Cryogleyic Cambisols) in poorly-drained areas and Organic Cryosols (Cryic Histosols) in depressions. Within river valleys, Gleyed Cumulic Regosols (Gleyic Fluvisols) dominate. Soil classifications follow the Canadian System of Soil Classification and the World Reference Base for Soil Resources, respectively (Soil Classification Working Group, 1998; International Society of Soil Science, 1998).

Average annual air temperature in the Basovo area is *ca.* –4.3°C (Figure 2.2a). January is the coldest month of the year, averaging *ca.* –26°C, with minimum air temperatures reaching up to *ca.* –50°C during the winter season. Average temperatures below 0°C occur for *ca.* 195–200 days annually, with continuous frosts lasting for *ca.* 140–160 days. Frosts first occur by early-September and last until mid-May. Warmest annual air temperatures are recorded during July (average July temperature *ca.* 17°C) with daily highs averaging between *ca.* 22–24°C, and maximum air temperatures can reach up to *ca.* 36°C. Average daily air temperatures over 0°C and 10°C are *ca.* 160–165 and *ca.* 70–80 days, respectively. Humidity patterns also follow a well defined seasonal regime, with two-thirds of annual precipitation accumulating between June and August (Figure 2.2a). Annual precipitation totals in the river valleys range between *ca.* 300–400 mm and reach up to *ca.* 600 mm at higher elevations. Maximum rainfall totals generally occur during the months of July and August, with a combined average of *ca.* 150 mm. Snow cover is formed by mid-October and lasts until late-April to early-May. Average snow depth in open areas during February is *ca.* 40–47 cm and ranges between *ca.* 50–55 cm in sheltered areas during the first half of March.

The upper Lena River is characteristic of those throughout eastern Siberia, with a well-defined cycle of spring flooding associated with the rapid rise of water levels (averaging *ca.* 3–5 m) (Figure 2.2b). Approximately 80 % of drainage occurs during the spring and summer months and more than *ca.* 90 % of suspended sediment/drift is deposited during the spring high water period. During disintegration, drift ice build-up is common and can lead to rapid catastrophic rises in water levels (up to *ca.* 7 m). River ice generally forms in mid-November with annual ice breakup occurring in mid-April to early-May.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Vegetation complexes in the vicinity of Basovo are characteristic of mountain-taiga forest, consisting of mature stands of pine (*Pinus sylvestris*), larch (*Larix sibirica*), and spruce (*Picea obovata*), along with birch (*Betula alba*), aspen (*Populus*), willow (*Salix*) and alder (*Alnus*) underbrush, and forest herbage. The floodplain and part of the lower slopes in the vicinity of the Basovo settlement are abandoned arable lands that have acquired steppic-features characterized by the predominance of grasses, wormwood (*Artemisia*), and herbage, including meadow foxtail (*Alopecurus pratensis*), milfoil (*Achillea*), plantain (*Plantago*), and chamomile (*Matricaria*). Red clover (*Trifolium pratense*) and shade horsetail (*Equisetum pratense*) appear in moist depressions along the floodplain. Abandoned farmland and historical clearance of forest along valley slopes adjacent to the Basovo settlement indicates the former occurrence of more intensive local land-use strategies in the area than exists today.

Burdukovo Site and the Lower Selenga River Valley

The Burdukovo site (52°07'13.2"N, 107°29'.29.3"E; elevation *ca.* 490 m asl) is located along the east bank of the Selenga River in western Trans-Baikal (Figures 2.1). The geographical background presented below is a brief summary of translated excerpts from Bazarov (1968), Chita Hydro-meteorological Observatory reports (1966, 1974), Dobrovolsky and Urusevskaya (1984), Preobrazhenskiy *et al.* (1959), Snitsarenko (1983), and Zhukov (1960).

The site is situated near the juncture of the Eastern Khamar-Daban and Ulan-Burgasy mountain ranges. These uplifts are part of the eastern mountain chain of the Baikal rift basin, which is cut by the Selenga River near the settlement of Tataurovo. Maximum elevations of local surrounding topography reach *ca.* 1300–1400 m asl, with ridge-lines averaging *ca.* 900 m asl. Geological formations are part of the early Paleozoic Barguzin intrusive complex, composed primarily of biotite, biotite-hornblende, and gneissous granites, as well as syenites, granodiorites, pegmatites, and diorite porphyrites. Exposures of boulder-pebble conglomerates with tufogene cement of the Cambrian Tataurovo suite and conglomerates with sandstone interlayers of the Jurassic Baikal suite are also present in the area. Quaternary deposits occur as thin mantles of colluvial sediments along valley slopes, as alluvial sediments of the Selenga River terrace complex

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

and its tributaries, and as sandy aeolian sequences that contain buried soils. Modern soil development along valley bottoms consists of sandy loam and loamy meadow soils characteristic of Gleyed Cumulic and Gleyed Cumulic Humic Regosols (Mollic Fluvisols), and upland plateaus and valley slopes are dominated by Eutric Brunisols (Eutric Cambisols).

Average annual air temperature in the region is *ca.* –1.7°C, with an average minimum of *ca.* –8.3°C and an average maximum of *ca.* 4.8°C (Figure 2.3). Annual precipitation at higher elevations (*ca.* > 1000 m asl) averages about 300–350 mm, exceeding levels in the river valley by *ca.* 100 mm. The seasonal humidity regime is marked by moderate precipitation totals from June to August (*ca.* 2/3 of annual total), with annual precipitation levels reaching a minimum during the months of February and March (Figure 2.3). Snow cover forms in mid-November and lasts until the beginning of the melting period in early-April. Spring flooding starts during the first half of April, reaches a maximum in early-May, and typically ends during the second half of May. River discharge during the period from April to September constitutes *ca.* 83.4 % of the annual total, with *ca.* 12.5 % occurring between October and November and *ca.* 4.1 % between December and March. Annual discharge rates near Burdukovo average *ca.* 935 m^3/sec, reach *ca.* 5350 m^3/sec during the spring flood season, and increase up to *ca.* 7700 m^3/sec during flooding brought on by rain events. The annual range of river water level oscillation in the area averages *ca.* 0.60 m, with the highest recorded level reaching *ca.* 6.45 m during a major ice-jamming event in 1968. By mid-November the river freezes, which lasts *ca.* 150–170 days before spring break-up in mid-April when ice-jamming is common.

Vegetation complexes along this part of the lower Selenga River valley bottom are composed of halophyte meadows, which include *Puccinellia tenuiflora*, *Hordeum macilentum*, and *Alopecurus brachystachyus*, along with stands of willow (*Salix* sp.), bird cherry (*Padus avium*), and blood-red *Crataegus sanguinea.* Forested valley slopes in the surrounding area are dominated by pine (*Pinus sylvestris*) and larch (*Larix sibirica*, *Larix dahurica*) with an admixture of birch (*Betula pubescens*), along with herb underbrush composed of *Pulsatilla flavescens*, *Anemone crinita*, and *Carex pediformis*.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Holocene Climate History

Background

The Holocene climate history of northern Eurasia has traditionally been based on the Blytt-Sernander classification scheme, originally developed in the late 19th Century for northern Europe from paleobotanical analyses of Scandinavian peat bogs (Lowe and Walker, 1997). This model was subsequently extrapolated over broad regions by various scientists in attempts to correlate large-scale climate and environmental changes thought to be synchronous across Eurasia, thus serving as a convenient conceptual framework in the absence of high resolution and well-dated site records over much of this vast area. Indeed, many Russian scientists continue to utilize a modified version of the Blytt-Sernander model for categorizing climatic sequences during the Holocene (after Khotinskiy, 1984).

Period	***Inferred Climate***	***Radiocarbon (^{14}C) Age BP***	***Calibrated (cal) Age BP***
Sub-Atlantic	cool/wet	*ca.* 2600–present	*ca.* 2750–present
Sub-Boreal	warm/dry	*ca.* 4600–2600	*ca.* 5300–2750
Atlantic	warm/wet	*ca.* 8000–4600	*ca.* 9000–5300
Boreal	warm/dry	*ca.* 9200–8000	*ca.* 10,500–9000
Pre-Boreal	cool/dry	*ca.* 10,300–9200	*ca.* 11,500–10,500

According to Khotinskiy (1984: 179), "a modified Blytt-Sernander scheme, which adequately reflects the character of global climatic fluctuations, was adopted as the chronologic-paleogeographic standard of the Holocene..... [and the u]se of this scheme as an international standard could significantly facilitate correlation and comparison of Holocene paleogeography throughout the world". However, the wide application of the Blytt-Sernander climate chronology across northern Eurasia, let alone the world, has been justifiably criticized by a number of researchers. Wright and Barnosky (1984: xviii) correctly point out that this classification scheme "is used to define both chronologic (time-parallel) and climatic units, thereby making an assumption *a priori* that climatic events were synchronous and that the resulting vegetation response (at least of the local component) was immediate across Europe and Asia". Further, given that vast areas of Asiatic Russia have yet to be adequately studied and that many of the available paleoecological site records are based on limited radiocarbon determinations, an assumption of both synchronicity and similarity in climatic trends is an insufficient basis

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

for meaningful continental-scale reconstructions. A number of new high resolution studies from across northern Eurasia indicate a more asynchronous (*i.e.*, time-transgressive) pattern in climatic and environmental conditions during the Holocene than was previously recognized. Such temporal and spatial variability thus calls into question the applicability of a single continental-scale classification scheme for Holocene climate change in Eurasia. Given these deficencies, results and discussions presented in this dissertation will not be referenced to the Blytt-Sernander model, despite its continued prevalence among many Russian scientists. Rather, temporal units of the Holocene have been informally sub-divided into early (11,500–7000 cal yr BP), middle (7000–3500 cal yr BP), and late (3500 cal yr BP to present) periods for generalized use within the text.

To set the background for later discussion, the following provides a review of published results from the most recent Holocene climate and environmental change studies available from the Lake Baikal region and surrounding areas (Table 2.1). Earlier investigations of the Holocene climatic history of northern Eurasia, by necessity, relied on relatively few sites and chronological controls in the development of environmental reconstruction models, particularly for eastern Siberia (*e.g.*, Khotinskiy, 1984). Geo-political changes in the post-Soviet era have both steadily increased the number of multi-national scientific programs working in the region and facilitated the introduction of new scientific methodologies. Results from these collaborations have led to more detailed site investigations and a concomitant expansion in our understanding of Holocene climate and environmental change across the region. These data, however, continue to lack adequate spatial coverage over this vast area, and in many cases site chronological controls are still rather limited. But the growing number of high resolution records (*e.g.*, smaller sampling intervals for proxy analyses and more radiocarbon dates for establishing temporal sequences) and the utilization of multi-proxy datasets increasingly permit more accurate site and sub-regional environmental reconstructions, thus providing greater insights into the spatial and temporal variability of Holocene climate change across northern Eurasia. All radiocarbon dates in this chapter are presented in calibrated (cal) years (yr) before present (BP), except where indicated otherwise. In cases where studies have published radiocarbon dates only in ^{14}C yr BP, calibrations have been approximated from tables in Stuvier *et al.* (1998).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Baikal Region

Over the last decade or so, Lake Baikal has become a focal point of paleoclimate research in Siberia due largely to the efforts of the Baikal Drilling Project. This collaborative research program, involving Russian, U.S., Japanese, and German scientists, was initiated to investigate the tectonic evolution and paleoclimatic history of the Baikal sedimentary basin through the comprehensive analyses of the lake's bottom sediments (Kuzmin *et al.*, 1993). These lacustrine deposits reach thicknesses of up to *ca.* 7500 m and represent millions of years of sedimentation uninterrupted by past glacial cycles (Hutchinson *et al.*, 1992), thus making the area an important archive for long-term climate change in continental Asia (Colman *et al.*, 1995; Kashiwaya *et al.*, 2003; Kuzmin *et al.*, 1993, 2000; Williams *et al.*, 2001). Despite difficulties in establishing high resolution age models for the late Quaternary sequence (Coleman *et al.*, 1996; Piotrowska *et al.*, 2004; Prokopenko *et al.*, 1999), pollen and diatom data from several Lake Baikal sediment cores have been used to reconstruct late Glacial and Holocene environmental changes in the region.

Demske *et al.* (2005) report pollen records from multiple core sites which detail regional vegetation changes following the last glacial period. These data, based on new radiocarbon chronologies derived from a pollen and spore concentration technique outlined in Piotrowska *et al.* (2004), show highest relative humidity values during the late Glacial with decreasing though still moderate humidity levels during the early Holocene, followed by generally drier conditions after *ca.* 6500 cal yr BP (Demske *et al.*, 2005). Relative temperature estimates indicate moderate though progressive warming over late Glacial conditions from *ca.* 10,000–7500 cal yr BP, followed by a *ca.* 1000 yr cooling interval (Demske *et al.*, 2005). The highest Holocene temperatures are indicated between *ca.* 6500–4300 cal yr BP (thermal maximum between *ca.* 6200–5700 cal yr BP) with a subsequent oscillating trend, though generally cooling, during the late Holocene (Demske *et al.*, 2005).

In a study by Karabanov *et al.* (2000), higher siliceous microfossil abundances present in Baikal sediments are correlated to both increased lake productivity and higher temperatures, which are indicated at *ca.* 9000 cal yr BP, between *ca.* 7800–6300 cal yr

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

BP, and again from *ca.* 4200–2550 cal yr BP, the latter interval interpreted as the Holocene thermal maximum. These data thus differ from Holocene temperature trends reported by Demske *et al.* (2005). In another coring project, Horiuchi *et al.* (2000) report paleoenvironmental changes spanning the last *ca.* 23,000 cal yr BP based on a series of multi-proxy analyses. However the limited chronological controls from this study permit only generalized temporal reconstructions for the Holocene interval. Additionally, a number of new analytical methods have been used to study Baikal sediments for Holocene climatic proxies, including oxygen isotope composition of diatom silica (Morley *et al.*, 2005) and organic pigments (Tani *et al.*, 2005). However, results from these rather experimental approaches are still preliminary and further investigation is needed for more definitive climatic interpretations of these data.

Given the vast size of Lake Baikal, Holocene climatic reconstructions derived from the lacustrine sedimentary record may be more indicative of average environmental changes across the broader region rather than a specific local signal. More locally representative paleoecological data are perhaps better reflected in biostratigraphic sequences reported along the eastern and southern coasts of the lake in Trans-Baikal. A number of studies in this area have produced Holocene environmental reconstructions based on palynological data from peat bogs, swamp sites, and small lakes (Bezrukova *et al.*, 1996, 2005a, 2005b; Krivonogov *et al.*, 2004; Kataoka *et al.*, 2003; Tarasov *et al.*, 2002; Takahara *et al.*, 2000). Results from these investigations provide complimentary proxy data to those obtained from bottom sediments of Lake Baikal.

Along the northeastern and eastern coast of Baikal, palynological data indicate that the initial expansion of postglacial spruce dominated forests occurred by *ca.* 14,000 cal yr BP, signaling an amelioration of climatic conditions and greater moisture availability in the region (Takahara *et al.*, 2000). Studies from Chivyrkui bog show that prior to *ca.* 12,500 cal yr BP the area was dominated by forest-tundra complexes with widespread steppe, and between *ca.* 12,500–11,400 cal yr BP a cold-dry climate became cool and more humid, evidenced by a further expansion of forests and the decline in steppe vegetation (Bezrukova *et al.*, 2005a). Spruce forests reached their maximum distribution in the region from *ca.* 11,400–10,500 cal yr BP and remained dominant until *ca.* 8900 cal yr BP (Bezrukova *et al.*, 2005a; 2005b). Vegetational changes

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

accompanying the reduction in spruce forests included the expansion of pine and fir between *ca.* 8900–5700 cal yr BP under continued warming and still relatively humid conditions (Bezrukova *et al.*, 2005a). Maximum thermal conditions and decreased humidity after *ca.* 5500 cal yr BP led to the establishment of modern forest communities along the northeast coast (Bezrukova *et al.*, 2005a).

Kataoka *et al.* (2003) conducted similar studies at Chivyrkui bog and report that shrub tundra with mixed spruce and birch forests and steppe communities were present in the area during the late Glacial period, with maximum spruce expansions between *ca.* 10,300–9400 cal yr BP, in contrast to the study by Bezrukova *et al.* (2005a). Kataoka *et al.* (2003) also indicate that taiga retreated along the northeast coast between *ca.* 9400–6800 cal yr BP in favor of birch and willow shrubs prior to the widespread expansion of pine forests after *ca.* 6800 cal yr BP.

Results from a palynological study of a sediment core from Lake Kotokel, located *ca.* 100 km south of Chivyrkui bog along the eastern Baikal coast, indicate steppe expansion over forest between *ca.* 11,350–10,200 cal yr BP due to increases in both temperature and aridity, followed by the rapid spread of forests from *ca.* 10,200–6800 cal yr BP under apparently more humid and milder climatic conditions (Tarasov *et al.*, 2002). These data also indicate that fir was most abundant near Lake Kotokel between *ca.* 6800–3200 cal yr BP, suggesting warm and humid conditions during this interval, with the widespread expansion of pine and larch forests after *ca.* 3200 cal yr BP in response to a more arid and continental climate (Tarasov *et al.*, 2002). Of interest to note, Lake Kotokel was re-cored in summer 2005 with scheduled analytical techniques emphasizing both high resolution core sub-sampling for multi-proxy paleolimnological data and a more detailed reconstruction of the chronological sequence via AMS dating (A. Mackay, personal communication, 2005).

Along the southeast coast of Baikal, palynological data indicate the spread of spruce dominated forests into the area by *ca.* 13,000 cal yr BP (Takahara *et al.*, 2000; Bezrukova *et al.*, 2005b). At Dulikha bog, cold and humid conditions associated with forest-tundra environments are indicated between *ca.* 13,000–12,200 cal yr BP, followed by a brief arid phase with increases in both larch and willow at *ca.* 12,200 cal yr BP, with greater humidity and renewed expansion of spruce forests between *ca.* 11,400–10,700 cal

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

yr BP (Bezrukova *et al.* 2005a). Increases in larch, willow, and steppe assemblages between *ca.* 10,700–10,500 cal yr BP are again interpreted as a brief interval of aridity, followed by the initial spread of fir and pine forests under increasing humidity from *ca.* 9900–9300 cal yr BP (Bezrukova *et al.*, 2005a). Between *ca.* 6900–5600 cal yr BP a shift towards reduced precipitation led to the retreat of fir forests and the expansion of pine. Vegetation assemblages are reported to have remained relatively stable along the southeast coast over the last *ca.* 5600 cal yr BP (Bezrukova *et al.*, 2005a), although minor spruce increases are noted between *ca.* 6300–4500 cal yr BP and again between *ca.* 3200–2550 cal yr BP (Bezrukova *et al.*, 2005b). This latter increase corresponds to a late Holocene peak in spruce abundance at Kuchelga bog along the west-central coast of Lake Baikal (Bezrukova *et al.*, 2005c). At Lake Chernoe, located in the Khamar-Daban region which forms the mountainous border of Lake Baikal on the southeast, pollen data indicate that the expansion of pine forests was underway by *ca.* 7800 cal yr BP and reached its maximum extent after *ca.* 6300 cal yr BP, which is consistent with data obtained from Lake Bol'shoe Eravnoe in the Vitim Upland and Lake Tanga in the Chita area further to the east (Tarasov *et al.*, 2002).

Across Siberia

North of the Baikal region, Holocene climate change studies in Yakutia and the Central Siberian Plateau are far fewer in number. Investigations here have focused primarily on the late Glacial/Holocene transition, with sites often lacking secure chronological controls (Andreev *et al.*, 1997; Andreev and Klimanov, 1999; Velichko *et al.*, 1997, 2002). Despite these limitations however, it is still useful to briefly summarize preliminary Holocene reconstructions for the region. Andreev *et al.* (1997) report palynological data from central Yakutia which indicate forest expansion over steppe by *ca.* 11,500 cal yr BP, however this vegetational succession appears to have been time transgressive in the region with some sites showing evidence of steppe communities persisting as late as *ca.* 8400 cal yr BP. Larch and birch forests with an admixture of shrubby areas remained dominant throughout the region until *ca.* 6800 cal yr BP, when pine and spruce forests become more common under increasing temperatures, reaching a maximum at *ca.* 6300 cal yr BP (Andreev and Klimanov, 1999). By *ca.* 5000 cal yr BP

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

cooler conditions led to a slight decline in forest vegetation, particularly spruce and pine, and an increase in alder and birch shrubs (Andreev and Klimanov, 1999). During the late Holocene, the composition of forest species in central Yakutia appear to have fluctuated, though were generally dominated by birch, pine, and larch (Andreev and Klimanov, 1999). In southern Yakutia vegetation changes during the early Holocene indicate the widespread expansion of shrub alder into existing open larch-birch woodlands (Andreev *et al.*, 1997), along with pine and spruce forests (Velichko *et al.*, 1997). Larch woodlands succeeded to pine and spruce forests by *ca.* 6800 cal yr BP under a warmer and wetter climate, with drier conditions during the latter half of the Holocene supporting larch and pine dominated forests (Velichko *et al.*, 1997).

Further north, in the Siberian arctic, macrobotanical assemblages have been studied to trace forest development and the movement of the northern tree line across Eurasia in response to Holocene climatic changes. MacDonald *et al.* (2000), integrating new data with that published previously by Kremenetski *et al.* (1998), report that warming and widespread northern forest development was initiated between *ca.* 11,350–10,200 cal yr BP, with forests expanding to the present arctic coastline by *ca.* 9000 cal yr BP. The period of maximum postglacial northern forest expansion continued from *ca.* 9000–4500 cal yr BP under increasingly warm conditions, estimated to have been between *ca.* 4–5°C higher than today (MacDonald *et al.*, 2000). A cooling trend by *ca.* 4500–3200 cal yr BP is interpreted from a reduction of forests and the southern migration of the tree line to present positions. Other studies from the far north have utilized a variety of proxy archives which generally support the trends outlined above from macrobotanical evidence, however some regional differences are observed from west to east as well as more minor climatic oscillations captured in a few records with greater temporal resolution (Anderson *et al.*, 2002; Andreev *et al.*, 2003, 2004; Clayden *et al.*, 1997; Jasinski *et al.*, 1998; Kienel *et al.*, 1999; Laing *et al.*, 1999; Peteet *et al.*, 1998; Pisaric *et al.*, 2001).

In west Siberia, the most numerous and detailed paleoecological investigations are from peatland sites in the Western Siberian Lowland (WSL) region, the majority of which show similar temperature trends as those indicated by northern tree line macrofossil data published by Kremenetski *et al.* (1998) and MacDonald *et al.* (2000).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Kremenetski *et al.* (2003) report widespread boreal peatland development in the WSL between *ca.* 11,000–8000 cal yr BP under a relatively warm and moist climate, with reduced development from *ca.* 8000–4000 cal yr BP associated with increasingly warm and dry conditions, and finally a cooling trend after *ca.* 4000 cal yr BP. Blyakharchuk's (2003) investigation of both lacustrine and peatland pollen records from the southern WSL shows an opposite humidity trend during the early–middle Holocene, with generally warm and dry conditions between *ca.* 10,700–7800 cal yr BP, followed by continued warming and increasing wetness from *ca.* 7800–4500 cal yr BP, with cooler and moist conditions after *ca.* 4500 cal yr BP.

In a study from northwest Siberia, Peteet *et al.* (1998) report Holocene vegetation dynamics based on macrofossil and pollen records which suggest both forest and peatland development prior to *ca.* 10,500 cal yr BP under generally warm conditions followed by continued warming along with increased moisture until *ca.* 7800 cal yr BP. Subsequent drying between *ca.* 7700–6000 cal yr BP and again after *ca.* 4900 cal yr BP is also indicated, punctuated by a wetter interval between *ca.* 6000–4900 cal yr BP (Peteet *et al.*, 1998). Blyakharchuk and Sulerzhitsky's (1999) pollen study of Bugristoye bog in western Siberia shows cool and dry steppe-tundra conditions prior to *ca.* 11,350 cal yr BP, followed by forest expansion between *ca.* 11,350–10,050 cal yr BP associated with increased warming and consequent melting of permafrost resulting in greater moisture availability. Precipitation levels during this interval are indicated to have been relatively low given the predominance of dry-ground pollen types in areas unaffected by deteriorating permafrost (Blyakharchuk and Sulerzhitsky, 1999). Between *ca.* 10,000–9400 cal yr BP increasing precipitation and continued forest expansion is evident at the site and the period from *ca.* 7500–6300 cal yr BP is interpreted to have been the warmest and wettest of the entire Holocene, followed by cooling after *ca.* 6300 cal yr BP (Blyakharchuk and Sulerzhitsky, 1999). Thus, Holocene environmental reconstructions derived from western and northern Siberian proxy records are generally consistent with respect to temperature trends, but interpretations of moisture patterns show greater variability. This discrepancy may be related more to local site factors such as topography and the fluctuating hydrological conditions on the landscape following the degradation of

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

permafrost rather than the direct influence of changing atmospheric precipitation regimes (Borren *et al.*, 2004; Peteet *et al.*, 1998).

Additionally, in the Altai Mountains of southern Siberia, palynological investigations of three lacustrine sequences have been reported by Blyakharchuk *et al.* (2004). These records date back as far as *ca.* 16,000 cal yr BP and indicate that vegetational sequences developed from postglacial pioneering communities into steppe and tundra complexes by *ca.* 12,000 cal yr BP. The late Glacial data lack evidence for climatic oscillations and instead suggest a rather consistent warming trend in the region (Blyakharchuk *et al.*, 2004). These sequences also show forest development between *ca.* 12,000–9500 cal yr BP under continued warming and increasingly moist conditions, with maximum forest expansion from *ca.* 9500–7500 cal yr BP during a more pronounced humid phase (Blyakharchuk *et al.*, 2004). After *ca.* 7500 cal yr BP, cooler and more continental conditions prevailed and vegetation complexes appear to have remained relatively stable in the area over the last *ca.* 5000 cal yr BP (Blyakharchuk *et al.*, 2004).

In neighboring northeast Kazakhstan, palynological investigations of a sediment core from Ozerki swamp provide a record of vegetation changes at the site spanning the last *ca.* 15,600 cal yr BP (Tarasov *et al.*, 1997; Kremenetski *et al.*, 1997). These data suggest that cool and wet conditions between *ca.* 15,600–11,650 cal yr BP supported montane steppe-taiga, followed by a reduction in arboreal vegetation between *ca.* 11,650–8600 cal yr BP. This successional trend is attributed to decreased winter temperatures during the early Holocene by as much as *ca.* 8°C compared to the present (Tarasov *et al.*, 1997). Between *ca.* 8600–8000 cal yr BP a humid phase led to the expansion of birch forests into the region which then retracted between *ca.* 8000–6650 cal yr BP (Tarasov *et al.*, 1997). The expansion of pine after *ca.* 6650 cal yr BP resulted in the establishment of modern vegetation complexes (steppe-pine/birch woodland) in the area (Tarasov *et al.*, 1997).

Mongolia and South

A number of investigations to the south of Lake Baikal provide additional insights into the spatial and temporal dimensions of Holocene climate change across continental east Asia and are thus included in this review. Paleoecological investigations in

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Mongolia and adjacent areas have increased substantially over the last decade given the growing scientific interest in modeling the variability of the Pacific (east Asian) summer paleomonsoon system. Monsoonal trends across the broader region reveal an asynchronous pattern during much of the Holocene and these shifts in intensification led to significant ecological changes on the landscape involving hydrological fluctuations and the associated reorganization of biotic communities. While several recent studies are providing important new details related to the timing and magnitude of climatic changes at the northern limits of the paleomonsoon trajectory, others have yet to yield reliable age models to compliment their respective paleoecological records. Despite these limitations however, data are emerging to begin development of a preliminary reconstruction of general climatic trends across the region during the Holocene.

In far western Mongolia, lithological, pollen, and diatom studies from a radiocarbon dated sediment core from Lake Hoton provide an important record of Holocene climate and environmental change for the remote Mongolian Altai (Tarasov *et al.*, 2000). Data from the base of the core indicate that steppe conditions existed at the site prior to *ca.* 10,200 cal yr BP, interpreted as the result of low winter temperatures possibly combined with dry summers, followed by increased humidity and the expansion of montane coniferous forests between *ca.* 10,200–4500 cal yr BP (Tarasov *et al.*, 2000). At nearby Lake Achit, located in the northeastern sector of the Mongolian Altai, pollen records also indicate forest expansion over steppe from *ca.* 10,600–7500 cal yr BP (Tarasov *et al.*, 2000). Precipitation diminished after *ca.* 4400 cal yr BP however, resulting in a decline in forest communities which were replaced by steppe environments which continue to occupy the region today (Tarasov *et al.*, 2000). Thus, the Lake Hoton and Lake Achit records indicate that generally wetter than present conditions resulting from the northwestern expansion of the Pacific summer monsoon system existed during much of the early and middle Holocene periods in western Mongolia (Tarasov *et al.*, 2000). However, given that the bulk sediment samples used for radiocarbon dating each represent *ca.* 25 cm of core length, the Lake Hoton chronology is consequently rather generalized.

In the Uvs Basin of northwestern Mongolia, Grunert *et al.* (2000) report paleoecological sequences based on various geomorphic data, as well as a sediment core

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

pollen record from Lake Bayan. These data indicate that late Glacial lake level transgressions were initially accompanied by increased forestation by *ca.* 13,200 cal yr BP, which then succeeded to mixed forest-steppe environments followed by a slight lake regression between *ca.* 10,150–8100 cal yr BP (Grunert *et al.*, 2000). This regression interval coincided initially with renewed forest development, with subsequent expansion of steppe conditions during the latter portion of this apparently more arid phase. A renewed transgression at Lake Bayan along with the re-establishment of forest and forest-steppe environments occurred between *ca.* 8000–5000 cal yr BP (Grunert *et al.*, 2000). This interval of increasing regional humidity also corresponds with local peat formation. After *ca.* 5000 cal yr BP steppe conditions expanded along with local dune mobilization, followed by renewed forest and peat development accompanied by a minor lake transgression phase prior to *ca.* 2000 cal yr BP (Grunert *et al.*, 2000). Evidence for very recent transgressions in the Uvs Basin is also indicated.

In the Khangay Mountain region of north-central Mongolia, paleoecological data derived from a sediment core from Lake Telmen provide another important record of middle–late Holocene climate change for the region. Geomorphic, lithological, and palynological data indicate greater than present aridity from *ca.* > 7000–4500 cal yr BP with greater humidity between *ca.* 4500–1600 cal yr BP (Fowell *et al.*, 2003; Peck *et al.*, 2002). Late Holocene proxies from Lake Telmen reveal slightly differing climatic interpretations, including brief aridization between *ca.* 1600–1200 cal yr BP based on pollen data (Fowell *et al.*, 2003), while sedimentological data indicate more humid than present conditions continued until *ca.* 1250 cal yr BP (Peck *et al.*, 2002). Radiocarbon dating of surficial lake sediments yielded modern ages, an indication that any introduction of older carbon into the lake system has not significantly affected the reconstructed age model for the site (Fowell *et al.*, 2003). The Lake Telmen record thus provides a fairly robust model for middle Holocene aridity in north-central Mongolia with maximum humidity occurring during the latter half of the Holocene. Unfortunately, early Holocene sequences were not recovered from the site. Paleoshoreline data from the Valley of the Lakes region south of the Khangay Mountains in central Mongolia show possible transgression phases during both the early and late Holocene periods, although

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

secure chronological controls for these sites are still unavailable (Komatsu *et al.*, 2001; Lehmkuhl and Lang, 2001).

Holocene climate reconstructions derived from other sites in northern Mongolia have also been reported, however detailed age models are again generally lacking. Sediment cores from Lake Dood, a remnant of a much larger Pleistocene lacustrine system located in the upland Darhad Basin west of Lake Hovsgol, have been studied for a number of proxies, including pollen, diatom, and lithological content. Dorofeyuk and Tarasov (1998) report that late Pleistocene forests were replaced by the expansion of steppe by *ca.* 12,650 cal yr BP, interpreted as a response to both increased temperatures and aridity. This corresponds to an interval of lake level regression dated between *ca.* 13,150–11,650 cal yr BP (Dorofeyuk and Tarasov, 1998). After *ca.* 12,650 cal yr BP, evidence suggest a relatively stable forest-steppe environment in the Darhad Basin for the duration of the Holocene up to the present. Lake level data indicate a modest transgression phase between *ca.* 11,350–6800 cal yr BP (Dorofeyuk and Tarasov, 1998), though this increase in effective moisture was apparently of a magnitude insufficient for forest expansion in the area. This was followed by another regression phase between *ca.* 6800–6000 cal yr BP and a renewed transgression between *ca.* 6000–3900 cal yr BP (Dorofeyuk and Tarasov, 1998). Fowell *et al.* (2002) studied the pollen content of a separate core from Lake Dood which indicates maximum humidity at the yet undated base of this core, and at both *ca.* 4200 cal yr BP and *ca.* 3000 cal yr BP. Peck *et al.* (2001), citing a *ca.* 3570 ^{14}C yr BP date for surficial lake sediment and a *ca.* 3450 ^{14}C yr BP age differential between paired bulk sediment and wood samples from the core column, caution that a large correction factor may need to be applied to all existing age models for Lake Dood. Thus the chronology currently available for the site is still quite tentative.

Immediately east of the Darhad Basin is Lake Hovsgol, the largest and deepest (maximum depth 262 m) lake in Mongolia. While Hovsgol has received considerable scientific study over the years, detailed paleoecological and chronological investigations have only recently been published. Earlier work by Dorofeyuk and Tarasov (1998) focused on middle to late Holocene climate changes derived from lithological, diatom, and pollen analyses of a core extracted from a shallow bay near the southern end of the

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

lake. Despite limited chronological controls, interpretation of these data indicate generally high humidity and lake levels at *ca.* 6800 cal yr BP with forest dominated landscapes (Dorofeyuk and Tarasov, 1998). A subsequent lake level regression allowed peat formation at the core site by *ca.* 6650 cal yr BP before inundation between *ca.* 6250–5650 cal yr BP (Dorofeyuk and Tarasov, 1998). Another regression phase is indicated between *ca.* 5650–4500 cal yr BP, which coincides with a greater component of steppe vegetation at *ca.* 4850 cal yr BP, followed by renewed peat development by *ca.* 4350 cal yr BP (Dorofeyuk and Tarasov, 1998). A transgression phase is reported between *ca.* 4000–2750 cal yr BP with subsequent shallowing between *ca.* 1750–450 cal yr BP (Dorofeyuk and Tarasov, 1998).

More recent studies at Lake Hovsgol show that lithological and biogenic silica data obtained from numerous gravity cores span the last *ca.* 24,000 cal yr BP, recording basin-wide phases of regional climate change (Prokopenko *et al.*, 2005). These data indicate that during the Last Glacial Maximum (LGM) lake levels were depressed by *ca.* 100 m compared to the present, followed by a dramatic transgression phase after *ca.* 16,000 cal yr BP attributed to significantly increased precipitation in the region (Chebykin *et al.*, 2002; Fedotov *et al.*, 2004; Prokopenko *et al.*, 2005). The diatomaceous Holocene layer suggests that lake productivity and biogenic silica content reached maximum levels prior to *ca.* 7250 cal yr BP before declining possibly due to lower nutrient input from decreased precipitation and runoff (Fedotov *et al.*, 2004; Nara *et al.*, 2005; Prokopenko *et al.*, 2005).

Another important paleoecological site from northern Mongolia is Gun Lake, located *ca.* 100 km to the east of the Orkhon-Selenga confluence near the Russian border. Dorofeyuk and Tarasov (1998) report palynological data indicating the dominance of forest-steppe vegetation at the site prior to *ca.* 10,900 cal yr BP followed by the expansion of steppe between *ca.* 10,900–9600 cal yr BP during an interval of greater aridity. Between *ca.* 9600–9000 cal yr BP arboreal pollen begins to increase and a relatively stable forest-steppe environment is indicated for the remainder of the Holocene up to the present (Dorofeyuk and Tarasov, 1998). Lithological and diatom evidence generally indicate a transgression phase between *ca.* 9000–3550 cal yr BP, followed by

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

lake retraction from *ca.* 3550–2050 cal yr BP, and a renewed expansion between *ca.* 2050–1250 cal yr BP (Dorofeyuk and Tarasov, 1998).

Other paleolimnological investigations have also been conducted at Gun Lake in recent years. Based on diatom and various sedimentological analyses, Feng *et al.* (2005) report evidence for shallow conditions between *ca.* 10,700–7650 cal yr BP, followed by generally high lake levels from *ca.* 7650–2150 cal yr BP and a regression phase between *ca.* 2150–1400 cal yr BP. Wang *et al.* (2004a, 2004b), analyzing both mineral magnetic and organic carbon proxies from the same sediment core, report cold and dry conditions prior to *ca.* 10,500 cal yr BP, relatively warm and wet conditions with forest expansion from *ca.* 10,500–8700 cal yr BP, followed by continued warming and drying between *ca.* 8700–6500 cal yr BP. These data also indicate generally cool and wet conditions at the site over most of the last *ca.* 6500 cal yr BP, except during comparatively warmer and drier intervals between *ca.* 5000–4000 cal yr BP, *ca.* 3500–3200 cal yr BP, and *ca.* 2500–1900 cal yr BP (Wang *et al.*, 2004a, 2004b). Thus climatic trends interpreted from various paleolimnological proxies from Gun Lake by different investigators are at times inconsistent, and correction factors are indicated though yet to be applied to the reconstructed site age models based on the *ca.* 1090 ^{14}C yr BP date obtained at the top (surface) of the core (Feng *et al.*, 2005). Additional investigation of these records is needed to resolve past climatic variability at this northern Mongolian site.

Further south, Holocene climate change studies in China are quite numerous and typically reveal a time transgressive pattern in the regional influence of the east Asian summer paleomonsoon system (An *et al.*, 2000; He *et al.*, 2004). It is beyond the scope of the present work to review the various paleoclimate records from this region however. Rather, a brief summary of results from a site in far northwestern China is given which illustrates the general Holocene climatic trends in the area bordering western Mongolia. Rhodes *et al.* (1996) report multi-proxy analyses of a sediment core from Lake Manas which indicate relatively warm and wet conditions at the site between *ca.* 11,350–6800 cal yr BP (thermal and humidity maximum between *ca.* 8350–6800 cal yr BP) as steppe vegetation advanced into the formerly desert-dominated landscape during this relatively long interval of lake transgression (Rhodes *et al.*, 1996). Between *ca.* 6800–5200 cal yr BP there is evidence of fluvial sedimentation, lake regression, and renewed

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

desertification, all characteristic of greater aridity at the site, with subsequent minor transgressions between *ca.* 5200–2550 cal yr BP, though briefly punctuated by increased aridity from *ca.* 4200–3750 cal yr BP, followed by relatively low amplitude climatic instability over the last *ca.* 2550 cal yr BP (Rhodes *et al.*, 1996). These reconstructions appear to be in relatively good agreement with those from other sites in northwestern China, most notably indicating the expansion of summer monsoon circulation across the region in the early Holocene before its displacement further south by the middle Holocene (An *et al.*, 2000; He *et al.*, 2004; Rhodes *et al.*, 1996).

Summary

The above review of north Asian paleoenvironmental proxy data illustrates the growing record of Holocene climate change and variability across the region. While these studies add significant new details to the climatic history of the area, insufficient spatial and temporal resolution (*i.e.*, relatively few sites, often poor dating controls, and large sampling intervals) in many of the available datasets remain a primary limiting factor in both continental and sub-regional syntheses. In addition, inconsistencies in both the quality and resolution of field data, combined with the multitude of different types of proxy archives used for environmental reconstructions, present fundamental challenges in establishing both accurate site age models and sound climatic interpretations. At a continental scale, these problems are compounded in that data also indicate asynchronous or time-transgressive climatic trends across the broader region during the Holocene. Discordance among these records is not surprising given the noted problems inherent in interpreting complex field data, the vast size of the area, the differing influences of prevailing atmospheric circulation patterns, and the great diversity in topography and associated vegetation complexes. With relatively few high resolution site records available from the region, additional investigations of local-scale environmental sequences are still widely needed before more meaningful sub-regional and pan-regional models can be adequately developed. Further, greater emphasis on finer temporal and spatial resolution in Holocene climatic reconstructions is also necessary for examining specific environmental-cultural interactions. With these issues in mind, the focus now turns to the results of new paleoecological data from the Basovo and Burdukovo sites.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

These records add additional details to both the Holocene environmental history of the Lake Baikal region and the ecological context surrounding the observed biocultural discontinuity during the region's middle Neolithic period.

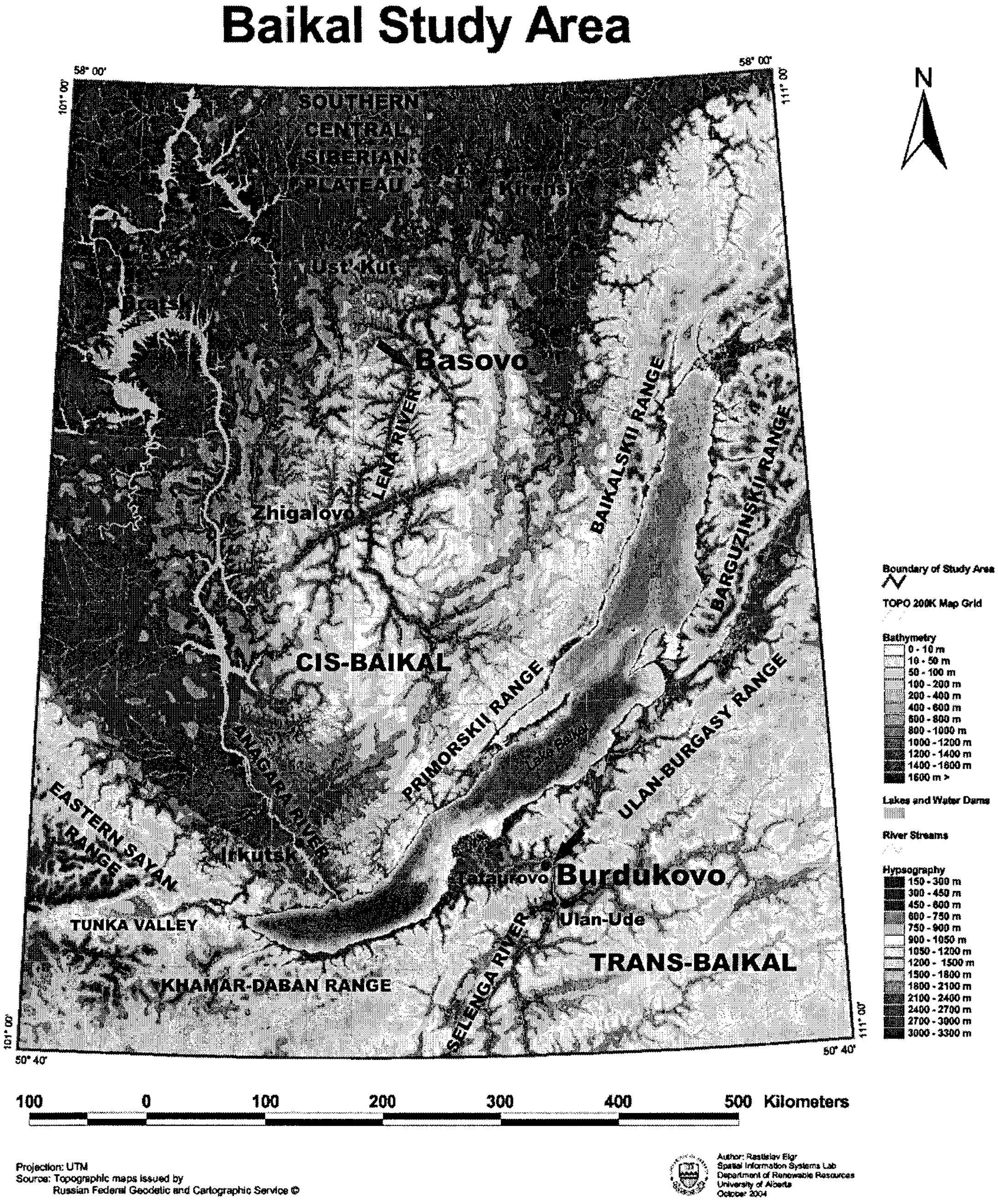
Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Site/Region	N (°)	E (°)	Elev. (asl)	Time (cal ka yr BP)	Methods	Reference
Northern Siberia, Russia	~75–67	~50–160	<100m	10.0 – 0	Mb	MacDonald *et al.*, 2000; Kremenetski *et al.*, 1997
Western Siberia, Russia	~72–50	~60–90	<200m	12.0 – 0	S, P	Kremenetski *et al.*, 2003; Blyakharchuk, 2003; Peteet *et al.*, 1998; Blyakharchuk and Sulerzhitsky, 1999
Yakutia, Russia	~64–61	~120–130	~150m	12.0 – 0	P	Andreev *et al.*, 1997; Andreev and Klimanov, 1999; Velichko *et al.* 1997, 2002
Lake Baikal, Russia	56–52	104–110	456 m	>100.0 – 0	P, D	Demske *et al.*, 2005; Karabanov *et al.*, 2000
Basovo, Russia	55.52	105.47	345 m	>11.0 – 0	S, Mf, Mb	Present study
Chivyrkui bog, Russia	53.40	109.12	460 m	12.0 – 0	P	Bezrukova *et al.*, 2005a, 2005b; Kataoka *et al.*, 2003; Krivonogov *et al.*, 2004; Takahara *et al.*, 2000
Lake Kotokel, Russia	52.46	108.06	458 m	12.0 – 0	P	Tarasov *et al.*, 2002
Burdukovo, Russia	52.07	107.29	490 m	>11.0 – 0	S, Mf	Present study
Lake Dood Nur, Mongolia	51.33	99.38	1538 m	14.6 – 0	S, P, D	Tarasov and Dorofeyuk, 1998; Fowell *et al.*, 2002, Peck *et al.*, 2001
Dulikha bog, Russia	51.31	105.00	~460 m	>13.0 – 0	P	Bezrukova *et al.*, 2005a, 2005b; Takahara *et al.*, 2000
Lake Hovsgol, Mongolia	50.53	101.16	1645 m	23.0 – 0	S, L, P, D	Tarasov and Dorofeyuk, 1998; Prokopenko *et al.*, 2005
Ozerki Swamp, Kazakhstan	50.42	80.47	210 m	15.6 – 0	P	Kremenetski *et al.*, 1997; Tarasov *et al.*, 1997
Lake Uvs, Mongolia	50.37	92.90	759 m	16.7 – 0	S, L	Grunert *et al.*, 2000
Siberian Altai, Russia	~50.30	~87.20	~2000 m	12.0 – 0	P	Blyakharchuk *et al.*, 2004
Lake Gun, Mongolia	50.25	106.60	600 m	11.5 – 0	S, L, P, D	Tarasov and Dorofeyuk, 1998; Feng *et al.*, 2005; Wang *et al.*, 2004a, 2004b
Lake Bayan, Mongolia	50.00	94.02	932 m	15.4 – 0	S, P	Grunert *et al.*, 2000
Lake Achit, Mongolia	49.50	90.60	1435 m	14.6 – 0	P	Tarasov *et al.*, 2000
Lake Telmen, Mongolia	48.83	97.33	1789 m	7.0 – 0	S, P	Fowell *et al.*, 2003, Peck *et al.*, 2002
Lake Hoton, Mongolia	48.67	88.30	2083 m	11.5 – 0	S, P, D	Tarasov *et al.*, 2000
Lake Manas, China	45.75	86.00	251 m	13.8 – 0	S, L, P	Rhodes *et al.*, 1996
China	–	–	–	>10.0 – 0	S, L, P, D	An *et al.*, 2000; He *et al.*, 2004

Methods: S – sedimentology; L – lake level; P – pollen; D – diatom; Mb – macro-botanical remains; Mf – macro-faunal remains.

Table 2.1. Holocene climate proxy records mentioned in text (listed from north to south).



Baikal Study Area

Projection: UTM
Source: Topographic maps issued by
Russian Federal Geodetic and Cartographic Service ©

Author: Rastislav Elgr
Spatial Information Systems Lab
Department of Renewable Resources
University of Alberta
October 2004

Figure 2.1. Geographic setting of the Lake Baikal region and location of study sites.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

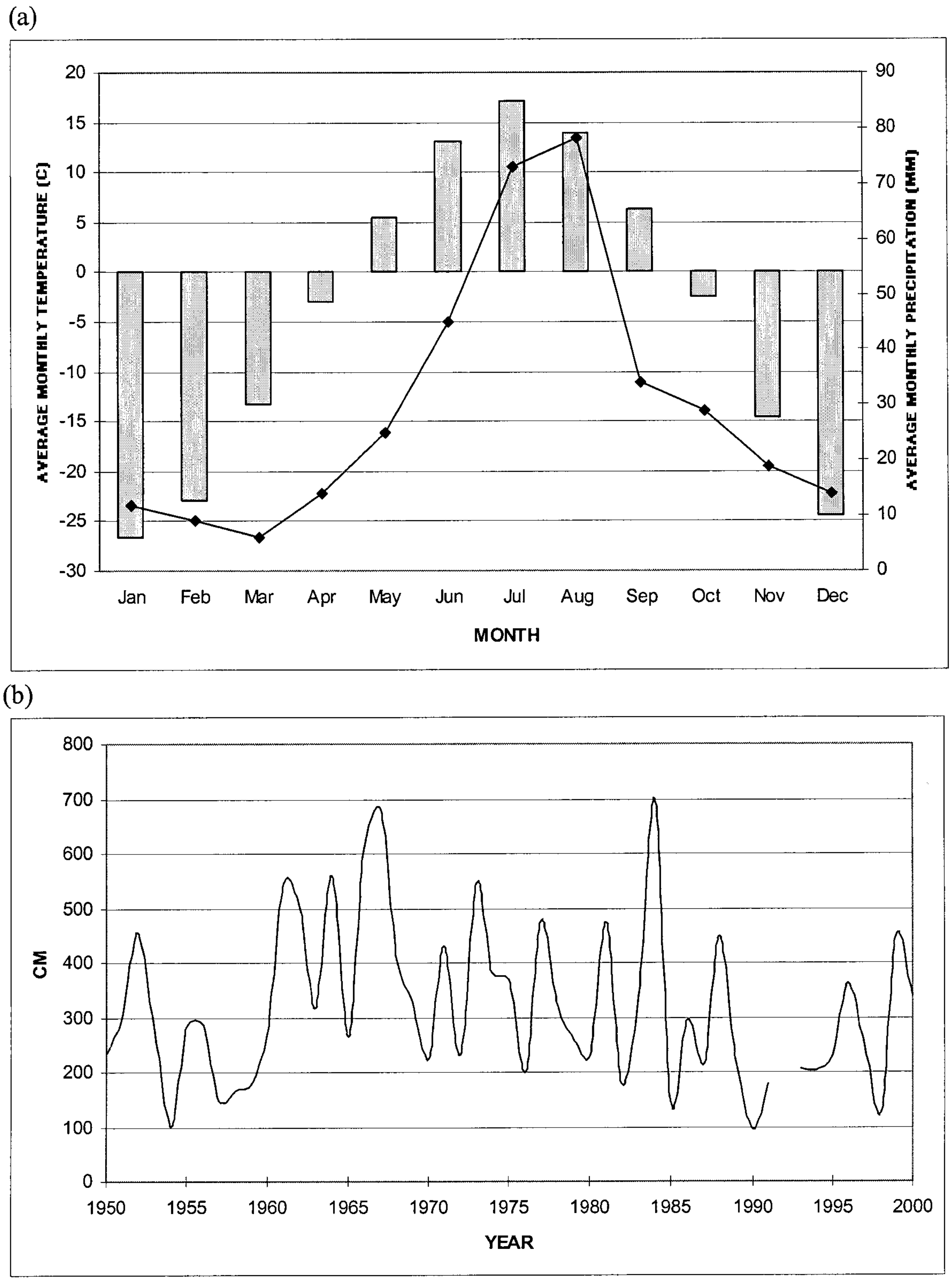


Figure 2.2. Climate data for the upper Lena River valley, Orlinga hydrometeorological station: (a) 1916–1947 monthly average temperature (*bar graph*) and precipitation (*line graph*) (Reference book for climatology of the USSR, 1949); (b) 1950–2000 record of high water level during spring breakup (Irkutsk Meteorological Agency, 2002).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

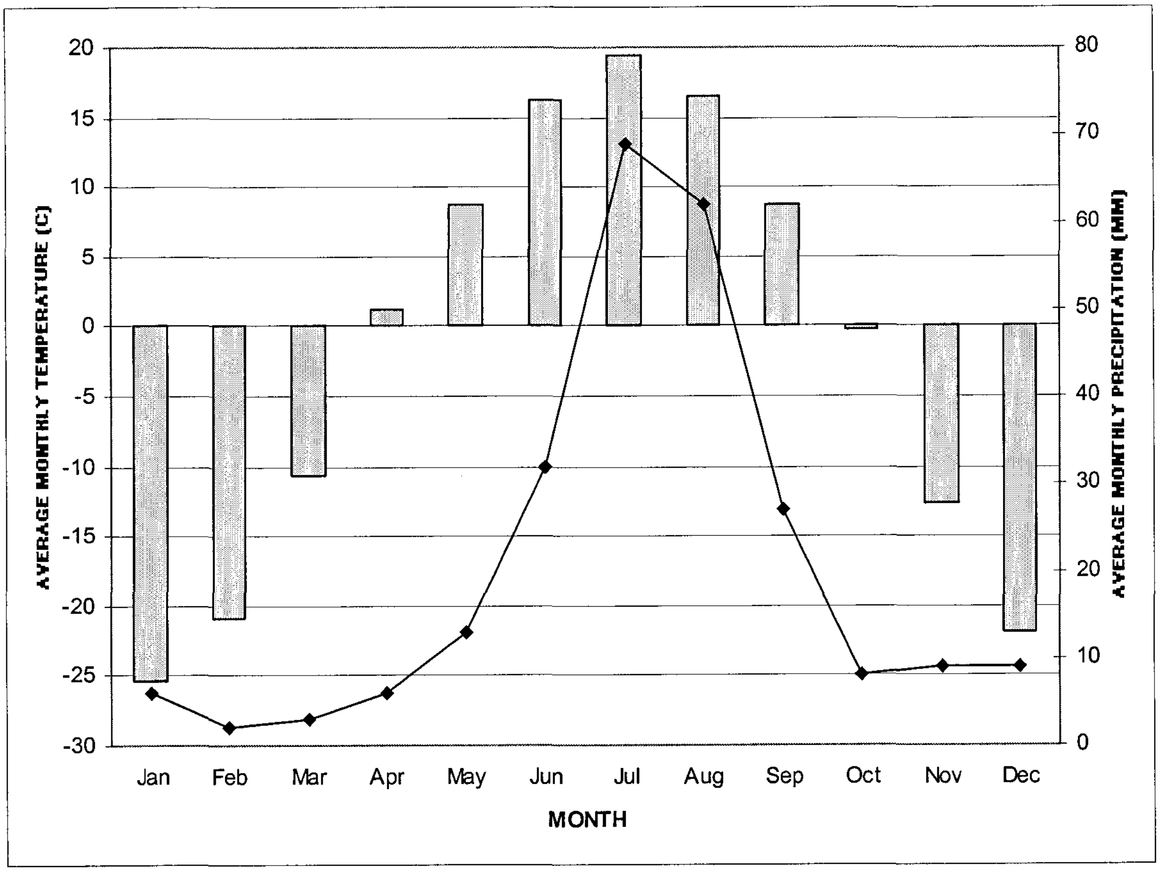


Figure 2.3. Climate data for the lower Selenga River valley, Ulan-Ude climate station (Snitsarenkov, 1983; *bar graphs* represent monthly average temperature and *line graphs* represent monthly average precipitation).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

CHAPTER 3

Materials and Methods

Fieldwork

Fieldwork for this research commenced during summer 1999 as part of a 5-week geoarchaeological survey of the upper Lena River valley from the settlements of Zhigalovo (54°48' N, 105°10' E) to Ust'Kut (56°48' N, 105°48' E), a stretch of river *ca.* 340 kilometers in length (Figure 2.1). During this reconnaissance several archaeological sites were excavated by members of the Department of Archaeology and Ethnography, Irkutsk State University, and a stratified floodplain sequence near the settlement of Basovo was identified as a unique study site for documenting both local malacological successions and Holocene environmental changes in the upper Lena River valley. Time limitations during the 1999 field season required additional short visits to Basovo during the summers of 2000 and 2002 to adequately study and sample the locality.

Fieldwork in the lower Selenga River valley of western Trans-Baikal began in 2001 during a 3-day reconnaissance of the area near the settlements of Tataurovo and Burdukovo (Figure 2.1). During this survey stratified alluvial sediments rich in malacofauna and an overlying sequence of aeolian deposits and buried pedogenic horizons were identified along the cutbank of the Selenga River first terrace, *ca.* 2 km downstream from the village of Burdukovo. A second brief trip to the site in 2002 was necessary to complete the preliminary investigation. Fieldwork for a more detailed sedimentological and paleomagnetic study of the aeolian stratigraphic sequence at Burdukovo was completed in July 2004, however data from this latter field season is not included in this dissertation and is the subject of a graduate student thesis project in the Department of Physics, University of Alberta, Edmonton, Canada.

The Basovo and Burdukovo study sites were initially selected for investigation based on the following criteria: (1) stratigraphic sections were located in areas where

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

permission had been granted to conduct original field research (*i.e.*, no prior work had been conducted at these sites); (2) study sections appeared to record greater time resolution for the Holocene than was observed during reconnaissance trips to other sites in the area (*i.e.*, exhibited by comparatively thick sequences with generally high sedimentation rates and multiple buried soils); and (3) the potential for sections to yield multi-proxy datasets, including abundant and diverse malacofaunal assemblages. Stratigraphic descriptions, field sampling, and subsequent laboratory analyses were undertaken to reconstruct the developmental history of each site and the contexts of associated paleoecological datasets. The delineation of site stratigraphic units is based on the principles of lithostratigraphy and pedostratigraphy outlined in the North American Commission on Stratigraphic Nomenclature (1983) and Morrison (1998). Textural classes and soil classifications are based on the Canadian System of Soil Classification (Soil Classification Working Group, 1998), with the WRB international classification equivalents provided in brackets (International Society of Soil Science, 1998). Explanations of pedologic and lithofacies codes are given in Appendix A.1 (Eyles *et al.*, 1983) and field descriptions and laboratory results are presented in Appendices A.2–A.8.

Laboratory Analyses

Sedimentology

At the Basovo site, bulk samples for various sedimentological analyses were described and collected from "cleaned" sections at 5-centimeter consecutive intervals following natural stratigraphic levels from depths reaching 2.60 m up to the modern surface. At Burdukovo, collection followed similar procedures, however a 10-centimeter sample interval was used from depths reaching over 4.0 m up to the modern surface. At both sites, smaller sampling intervals were also used in some cases (e.g., thin units or near stratigraphic boundaries) and occasionally a greater interval was used for more homogeneous deposits. Bulk samples varied between *ca.* 150–250 grams dry sediment weight. For granulometric analyses, dried sediment was first passed through a 2000 μm-diameter sieve to separate the fine-earth fraction from larger particles (*i.e.*, coarse fragments), followed by hydrometer measurements of the sand (2000–50 μm), silt (50–2 μm), and clay (< 2 μm) fractions (Sheldrick and Wang, 1993). Subsequent analyses

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

included ultrasonic sieving of the sand fraction into very coarse (2000–1000 μm), coarse (1000–500 μm), medium (500–250 μm), fine (250–100 μm), and very fine (100–50 μm) components (Gee and Bauder, 1986). Due to the very limited occurrence of coarse textured sediments, the 2000–500 μm sand fractions are combined for graphical presentation of the data. Grain-size determinations were conducted with the assistance of technicians at the Natural Resources Analytical Laboratory, Department of Renewable Resources, University of Alberta.

Samples collected from the Burdukovo first terrace cutbank were also measured for mass specific high frequency magnetic susceptibility (4.65 kHz) and low frequency magnetic susceptibility (0.465 kHz) using a Bartington MS2 meter and a Bartington MS2B dual-frequency sensor on disaggregated bulk sub-samples placed into 1 cm^3 plastic containers (K. Dlussky, personal communication, 2004). Frequency dependency of magnetic susceptibility (FD) was calculated to determine possible production of ultrafine superparamagnetic minerals by pedogenic processes (Evans and Heller, 2003). Magnetic susceptibility analyses were performed at the Laboratory of Paleomagnetism and Petromagnetism, Department of Physics, University of Alberta. Additionally, carbon content was measured by the wet-oxidation digestion method using a Carlo-Erba NA 1500 CNS Elemental Analyzer to determine total and total organic carbon, with the inorganic component derived by the difference (Ellert and Jansen, 1996). Soil pH was determined in a 1:1 water-sediment solution using a Fisher Accumet model 360 pH meter following standard laboratory procedures. Both carbon and pH analyses were conducted at the Natural Resources Analytical Laboratory, Department of Renewable Resources, University of Alberta.

Sediment micromorphology samples were collected at Basovo from the High Floodplain Section 2 (HFS2) in 10 cm x 6 cm x 4 cm reinforced aluminum frames at selected contact points across stratigraphic boundaries and in vertical sequence along the lower half of the profile. Thin sections (*ca.* 30 μm thick) for 14 undisturbed oriented samples were prepared by technicians at the Thin Section Laboratory in the Department of Earth and Atmospheric Sciences, University of Alberta, and described by Dr. Konstantin Dlussky, Laboratory of Paleomagnetism and Petromagnetism, Department of Physics, University of Alberta, for mineralogical composition, microstructure, and

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

pedogenic features using a petrographic microscope at magnifications up to x720. While micromorphological pedofeatures are generally quite distinct and informative in mature soil profiles, relatively young alluvial soils often lack well developed pedogenic properties. Nevertheless, micromorphological samples exhibit several lithological and pedological characteristics of the alluvium and complement the results from other field and laboratory analyses. Preparation techniques for micromorphology samples followed Murphy (1986) and terminology used to describe micromorphological features followed Bullock *et al.* (1985).

Macrofossils

At the Basovo site, macrofossils (*i.e.*, molluscs, vertebrates, ostracods, beetles, and charcoal) were processed from 50 bulk sediment samples each volumetrically measured to 2.5 liters of moist sediment collected from the High Floodplain Section 2b (HFS2b) at 5-centimeter consecutive intervals from a depth of 2.50 m up to the modern surface. At Burdukovo, 25 macrofossil samples each volumetrically measured to 4.0 liters of moist sediment were collected from Section T1.100 at 10-centimeter consecutive intervals from depths between 4.10–1.70 m below the modern surface. To ensure a systematic recovery of macrofossil datasets, all samples were first wet-screened through a 500 μm sieve at laboratories of the Russian Academy of Sciences in Irkutsk, Russia (Basovo samples were processed at the Institute of Geochemistry and the Burdukovo samples were processed at the Institute of the Earth's Crust). Screened samples were then air-dried and transported back to Canada where they were examined under a binocular-microscope at variable magnifications (x6–x50) to extract all identifiable macrofossils using fine forceps and brushes (Ložek, 1986).

Land and freshwater molluscs occur in great abundance and species diversity throughout much of the stratified floodplain sedimentary sequence at Basovo. At Burdukovo, terrestrial mollusc abundance is high in the alluvium, however few macrofossils are preserved in the overlying aeolian sediments. Following extraction of fossil molluscs from screened-matrices, specimens were sorted by species (see *Taxonomic Remarks* section) and quantified by shell apices for all adult, juvenile, and fragmented individuals. In samples where diagnostic base fragments outnumbered apices

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

for a given taxa (*e.g.*, *Pupilla* and *Vertigo*), then base criteria were used for quantification of the minimum number of individuals. Bivalve counts were rounded up to the nearest even number and halved, giving the minimum number of individuals for each species. Scanning Electron Microscopy (SEM) imaging of many of the molluscan species from the Basovo and Burdukovo assemblages was conducted at facilities at the University of Cambridge, UK, and these images are presented in Plates A–X.

Quantified results of molluscan data are presented as frequency histograms and plots of number of species, number of individuals, and terrestrial/aquatic ratios. For the frequency histograms, all samples with more than 200 terrestrial specimens are plotted as a percentage of the total terrestrial sum. In those samples containing fewer than 200 individuals, percentage calculations were not deemed statistically significant and thus are indicated by absolute values of individuals for each species represented (+ indicates single shells and •(#) indicates total number of shells). For aquatic taxa from the Basovo site, both the relatively high abundance and species diversity warranted a separate frequency histogram, however in this case all samples containing greater than 50 aquatic specimens were calculated as a percentage of the total terrestrial sum in order to illustrate the dominant aquatic trends at the site, despite the lower level of statistical certainty. Additionally, ordination of the molluscan data by principal components analysis (PCA) was carried out using the software package CANOCO v. 4.5 (ter Braak and Šmilauer, 1998; A. Mackay, personal communication, 2005), and zonation of the molluscan assemblages were performed by Two-Way Indicator Species Analysis (TWINSPAN; Hill, 1979; A. Mackay, personal communication, 2005). Prior to ordination, identified species were calculated as a percentage of the total identified taxa; however given the high abundance of juvenile *Vallonia* spp. and *Vertigo* spp. from the assemblages, which can not be identified to species level, these values were calculated as a percentage of the sum of juveniles plus total identified taxa (A. Mackay, personal communication, 2005). Only species present in one or more samples at greater or equal to 1 % were included in PCA.

Vertebrate fossils from the Basovo site (*i.e.*, small mammals, amphibians, and fish) were also recovered in sufficient numbers to warrant their detailed study. Micro-faunal bone and teeth were present in 40 of the 50 bulk macrofossil samples and this

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

material was identified by Mr. Simon Parfitt, Department of Palaeontology, Natural History Museum, London, UK (Parfitt, 2004). Vertebrate remains were recovered in very limited numbers from the Burdukovo site and as a result these data were excluded from this study. Several Coleoptera specimens were collected from the uppermost samples in the stratigraphic sequence at Basovo, and these specimens were identified by Dr. Russell Coope, Royal Holloway, University of London, UK. Ostracods were not expected to be included in this study given the finer sieving measurements necessary for their adequate recovery. Nonetheless, a small number of ostracod shells were recovered at Basovo and these samples are currently being examined by Dr. John Whittaker, Department of Paleontology, Natural History Museum, London, UK. Results from ostracod analyses are expected in 2006.

Macrobotanical remains were also present in some abundance at the Basovo site, consisting primarily of wood charcoal. A total of 48 stratified charcoal samples, each containing multiple fragments of variable size and states of preservation, were collected either *in situ* or in bulk samples and sent to Dr. Rowena Gale, Royal Botanic Gardens, Kew, UK, for identification. All macrobotanical remains measuring *ca.* > 0.5 mm were microscopically examined at magnifications up to x400 and matched to reference material of modern wood samples (Gale, 2004). When possible, transverse, tangential, and radial surfaces were prepared and analyzed using standard techniques (Gale and Cutler, 2000). Very few non-charcoal macrobotanical remains were recovered from the samples collected. All taxonomic classifications follow *Flora Europaea* (Tutin *et al.* 1964–80).

Microfossils

At the Basovo site, samples for potential microbotanical analyses were collected from the High Floodplain Section 2 (HFS2) in 50 ml polypropylene containers at 3-centimeter consecutive intervals from a depth of 2.50 m up to the modern surface. Preliminary analytical tests, conducted by Dr. Steve Boreham, Department of Geography, University of Cambridge, UK, revealed that fossil pollen is generally poorly preserved in the highly oxidized and calcareous alluvial sediments and soils along this section of the upper Lena River valley, and as a result palynological investigations were suspended.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Limited experiments assessing phytolith preservation revealed encouraging results, however systematic extractions have yet to be performed and these samples await future analyses.

Radiocarbon Dating

Charcoal preserved in stratified contexts at Basovo was used to construct a detailed age model for the site based on a series of radiocarbon analyses. Given the research focus on reconstructing the Holocene environmental history of the site, the High Floodplain Section 2 (HFS2) was selected for establishing site chronological controls. Twelve AMS radiocarbon determinations provide the temporal framework for the site. Charcoal specimens were either hand-picked *in situ* or extracted from screened bulk macrofossil samples collected at 5-centimeter consecutive intervals. At Burdukovo, seven AMS radiocarbon determinations from either charcoal or humic acids derived from bulk soil samples establish the temporal context for the site. Charcoal specimens were either hand-picked *in situ* or extracted from screened bulk macrofossil samples collected at 10-centimeter consecutive intervals. Bulk soil samples represent a 10-centimeter composite of a single pedogenic horizon. All materials for radiocarbon determinations were pre-treated and analyzed by ISOTRACE laboratories in Toronto, Canada, and calibrated following INTCAL98 (Stuvier *et al.*, 1998). Dates presented in Chapters 4 and 5 are listed in radiocarbon (^{14}C) years BP, and in Chapter 6 these data are converted to calibrated (cal) years BP to facilitate comparisons with results from other regional paleoenvironmental proxy records (Tables 4.1 and 5.1).

Molluscan Taxonomic Remarks

The molluscan assemblages reported in this research are the most detailed Holocene successional records of terrestrial and freshwater molluscs in all of Siberia, or indeed the eastern Palaearctic. Given the rarity, abundance, species diversity, and scientific interest in the recovered assemblages, consultation with Quaternary malacologist Dr. Richard C. Preece, University Museum of Zoology Cambridge, occurred during trips to England in September of 2002, 2003, and 2004. Identifications were made on specimens ranging from complete adults to apical fragments of juveniles,

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

and all but three of the terrestrial and four of the aquatic genera were assigned species level classifications. Future consultations with Russian malacological specialists will be necessary to identify all remaining undetermined specimens.

Many of the fossil molluscan taxa recovered from Basovo and Burdukovo represent rare and/or zoogeographically interesting species in that their occurrence in the Lake Baikal region was largely inferred or previously unsuspected. The presence of some taxa at these sites represents great expansions in their known geographical range in Eurasia. The ecology of a few of these species is still poorly known but their association with more familiar taxa provides indirect evidence of their general habitat preferences (Table 4.2). Some of the most significant species found at the study sites are illustrated in Plates A–X and discussed in more detail below. All taxonomic identifications were made in consultation with internationally recognized malacologists and by following Likhachev and Rammel'meier (1962), Schileyko (1984), and Zhadin (1965).

The terrestrial genus *Vallonia* (Plates A–D) constitutes the most abundant group of molluscs found at each of the study sites, comprising *ca.* 72.5 % and *ca.* 60 % of the entire shell assemblages at Basovo and Burdukovo, respectively. Adult shell morphology exhibited considerable variation and required consultation with *Vallonia* specialist Dr. Jochen Gerber (The Field Museum of Natural History, Chicago, USA) in January 2003 to accurately determine species-level identifications. Five different species of *Vallonia* were identified from stratified Holocene deposits at Basovo and Burdukovo, including the more well-known and geographically widespread *V. costata, V. pulchella,* and *V. tenuilabris*, along with the regional forms *V. kamtschatica* and *V.* cf. *chinensis*. The geographical distribution of these latter two species within Asia is still poorly documented and little is known about their specific habitat associations.

Vallonia costata is a Holarctic species distinguished by a flattened spire, thickened apertural lip, distinct shouldering of whorl periphery, and relatively wide and evenly spaced ribbed sculpture. This species is generally thought to occupy moderately dry, open prairie and meadow landscapes and occurs both rarely and in low abundance in wet environments (Gerber, 1996). Schileyko (1984) has also found this species living in deciduous and mixed forests in Siberia. Ecologically, *V. costata* is used as an indicator

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

species to define periods of moderate floodplain surface drying at the Basovo and Burdukovo study sites.

Vallonia pulchella is another Holarctic species, identified by its thickened apertural lip, well-rounded whorl profile, and distinctly smooth shell surface (*i.e.*, lacks strong ribbing). This species is usually found in wetter habitats than *V. costata*, such as moist meadows, marshes, and damp floodplains (Gerber, 1996). Schileyko (1984) also describes *V. pulchella* as inhabiting forest and bushland environments in Siberia, which is consistent with my own observations. While present in very low abundance, *V. pulchella* was found living in the lower Selenga River valley of southern Siberia near a perennial spring in a moist, semi-closed canopy mixed coniferous-deciduous forest with a rich undergrowth of shrubs, ferns, and mosses. *V. pulchella* is one of several species used to identify periods of increased wetness at the study sites.

Vallonia tenuilabris is a distinctly larger species than other members of *Vallonia* found at Basovo and Burdukovo. Other morphological features of this species include a raised spire, non-shouldered whorl profile, thin apertural lip, and a shell surface with dense, finely ribbed sculpture. This species became extinct in Europe at the end of the Pleistocene when it was typically associated with cool, dry, and open habitats *(i.e.*, 'cold-steppes') (Gerber, 1996). Today *V. tenuilabris* is presumed to occur widely throughout northern Asia, in both open and shaded environments. This species was found in relatively high abundance living in a semi-closed canopy forest in the lower Selenga River valley, as described above for *V. pulchella.*

Vallonia kamtschatica is a strictly Asian form whose recent distribution stretches from the Yenisei River in the west through central and eastern Siberia to the Pacific Coast, including Kamchatka, the Kuril Islands, and Hokkaido, as well as Mongolia and northern China (Gerber, 1996). *V. kamtschatica* is distinguished by its medium size, relatively flattened spire and non-shouldered whorl periphery, with moderate to dense, finely ribbed sculpture. The apertural lip of this species is often more variable in form than other members of *Vallonia* found at the study sites, however it is generally thin. Very little is known about the ecology of *V. kamtschatica*, having only been described as associated with sparse birch and poplar forests, as well as with grassy vegetation in rocky

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

environments (Gerber, 1996). Near the western shore of Lake Baikal, this species has been found among moss covered stones (L. Prozorova, personal communication, 2004).

A form tentatively assigned to *Vallonia chinensis*, an extremely rare Asian species, was found in great abundance in stratified sequences at both the Basovo and Burdukovo sites. This species is identified by its relatively large shell, which exhibits a raised spire, non-shouldered whorl profile, thickened apertural lip, and moderately dense, ribbed sculpture. According to Gerber (personal communication, 2003), *V. chinensis* was first described by Suzuki in 1944 from middle Pleistocene sediments near Harbin, China. However, these 'type' specimens were subsequently destroyed in World War II bombings of the Japanese institute in which they were stored, and there appear to be no other specimens from the type locality in any collection in the world. Based on Suzuki's descriptions and pictures, Gerber (1996) identified 12 specimens from China (South Gansu, "near Saksagir River") and one specimen from the Amur region of the Russian Far East as *V. chinensis*, the only known specimens of this species before the recovery of those described in the present work. At Basovo, 3735 fossil adult *V.* cf. *chinensis* were recovered, making it by far the largest collection of this species in the world. An additional 2448 fossil adult *V.* cf. *chinensis* were identified from the Burdukovo assemblage. These records thus document the most abundant and westerly known distribution of this species within north Asia, and suggest that *V. chinensis* is much more widespread than previously recognized. Although there is no direct ecological information known for this species, its occurrence and successional trends in relation to other species with better known environmental affinities provides for the first time indirect evidence of the types of habitats *V. chinensis* is found within continental Asia.

The sub-division of *Vallonia* into the five species listed above was based on shell morphology of complete adult individuals. All juvenile and fragmented specimens from this group were recorded as *Vallonia* spp., as species level identifications of immature individuals are often impossible, and the identification of incomplete specimens can lead to inaccuracies. However, for quantification purposes and the construction of site frequency histograms, all *Vallonia* spp. individuals were proportioned for each sample according to the total number of complete adults present for each of the identified species of *Vallonia*. Raw counts for *Vallonia* spp. and all other taxa are presented in Appendix

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

B.1 (Basovo assemblage raw counts) and Appendix B.2 (Burdukovo assemblage raw counts).

Specimens of the terrestrial genus *Vertigo* (Plates E–F) also exhibited significant morphological variation at Basovo. Selected adult individuals representing the assemblage diversity were analyzed by Vertigininae specialist Dr. Beata Pokryszko, Museum of Natural History, Wroclaw University, Poland. Eight species of *Vertigo*, including *V. alpestris, V. antivertigo, V. extima, V. genesii, V. geyeri, V. microsphaera, V. parcedentata,* and *V. pygmaea*, were identified in the Basovo assemblage (B. Pokryszko, personal communication, 2003b), distinguished primarily by size, denticular arrangement, and shell microsculpture. Of these species, only *V. antivertigo, V. extima,* and *V. microsphaera* were found as fossils at Burdukovo.

The *Vertigo* assemblage from Basovo represents a major contribution to our understanding of the zoogeographical distribution of these species in northern latitudes. The Basovo *V. parcedentata*, *V. genesii*, and *V. geyeri* are the first known occurrences of these species in Asia, greatly expanding their previously known ranges on a continental-scale (see Pokryszko, 2003a). Also of notable interest is *V. microsphaera*, first described by Schileyko (1984) on the basis of only two specimens from the North Pacific, one from a rock crevice on Bering Island and the other from bamboo thickets on a hill slope on Shikotan Island (B. Pokryszko, personal communication, 2003b). Prozorova (2002) also found this species living among forest leaf litter and bamboo (*Sasa kurilensis*) covered slopes in the southern Kuril Islands. *V. microsphaera* occurs as fossils at both Basovo (356 specimens) and Burdukovo (2 specimens), which represent both the first known records of this species in continental Asia and the largest existing collection of this taxa. Additionally, *V. extima*, a species previously known only from sites in northern Scandinavia and coastal areas of Chukotka and Alaska, as well as from one site in the northern Yenisei region (Waldén, 1986; Pokryszko, 2003a), is also found at Basovo and Burdukovo, representing the only other known occurrences of this species in continental Eurasia and its southernmost known distribution.

Regarding the gross ecology of *Vertigo* species found at the Basovo and Burdukovo study sites, only *V. alpestris* prefers macrohabitats other than wetlands (Pokryszko, 1993, 2003a). *V. alpestris* is most widely associated with woodland habitats

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

or open rocky surfaces. Our knowledge of habitat preferences of *V. microsphaera* is still limited by insufficient data, but its association with more well-known species again provides indirect information regarding its autecology in continental Asia. For quantification purposes and construction of the terrestrial frequency histogram, all juvenile and fragmented specimens assigned to *Vertigo* spp., excluding *V. microsphaera*, whose distinct pattern of finely-ribbed microsculpture allowed its separation even among juvenile apical fragments, were proportioned for each sample according to the total number of complete adults for each of the identified species of *Vertigo*.

The identification of specimens belonging to the terrestrial genus *Discus* (Plates M–P) is still unresolved to species level. In eastern Siberia and the Russian Far East, *D. ruderatus ruderatus*, *D. ruderatus pauper*, and *D. ruderatus depressus* are all known to occur (L. Prozorova, personal communication, 2004), and adequate reference material was unavailable to distinguish the Basovo and Burdukovo material to sub-species. Variability in both the strength of apical microsculpture and the degree of angularity or 'keeling' of the whorl periphery are observed in specimens of *Discus* from Basovo, suggesting the possible co-occurrence of multiple forms. Specimens of *Discus* from Burdukovo are typically larger and more homogenous in regard to morphology than those observed from Basovo, and may represent a single species, most likely *Discus ruderatus pauper*, though this is still unconfirmed. Uminski (1962) illustrates a non-overlapping spatial distribution for *D. ruderatus ruderatus* and *D. ruderatus pauper* in north Asia. However, until adequate reference material can be consulted, specimens of *Discus* from the Basovo and Burdukovo sites are presented only as *Discus* spp., recognizing that this preliminary grouping may include more than one sub-species. Future assessment of this material with Russian malacological specialists may clarify the spatial distribution of these taxa both within the Lake Baikal region and continental east Asia.

Members of the terrestrial group Succineidae are presented only as *Oxyloma/Succinea* spp. Future analyses of this fossil material may result in more precise identifications if attributes other than anatomical parts can be used as the primary diagnostic features (*i.e.*, shell morphology). At least two taxa, and probably more, are included within this initial grouping of *Oxyloma/Succinea* spp. Despite the lack of species level identifications for these taxa, this group is widely associated with very moist

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

conditions and as a result is used to identify periods of increased wetness at the study sites. *Punctum pygmaeum* (Plate K), a terrestrial species regarded as 'catholic', though generally not abundant in dry habitats, is present at both Basovo and Burdukovo and may also be an indicator of increased wetness at the study sites. The identification of adult specimens of *Carychium pessimum* (Plate I) were verified by Dr. Beata Pokryszko, as were those of *Gastrocopta theeli* (Plates G–H), a species known to occur in Holocene deposits in the Lake Baikal region and lives in the Yenisei River valley today (Filippov *et al.*, 2000).

Selected adult *Nesovitrea* specimens were examined by Dr. A. Riedel (Museum of Natural History, Wroclaw University, Poland), who identified them as *N. hammonis*, differentiating this form from *N. petronella* based on criteria outlined in Waldén (1966). Additionally, Starobogatov (1996) indicates that there are many forms of *Cochlicopa* present in Russia, thus those found at the Basovo and Burdukovo study sites are provisionally assigned to the most widespread of these species, *C.* cf. *lubrica*. The separation of *Euconulus fulvus* from *E. alderi* is difficult with fossil material, and as a result these species have not been distinguished from one another and are referred to only as *E. fulvus* aggregate (Plate L). Fossil slug plates are also difficult to distinguish by species and thus provisionally assigned to the generic class of *Deroceras/Limax* spp. (Plate R). *Bradybaena*, tentatively identified as *B.* cf. *schrencki* (Plate Q), is found as fossils at Burdukovo and in both fossil and living form at Basovo.

For the aquatic taxa, specimens from the *Gyraulus* group (Plates S–U) exhibited greater variability in form and microsculpture than can be represented by a single species alone. While these specimens were initially identified as *G. acronicus* (Meier-Brook, 1983; C. Meier-Brook, personal communication, 2003), the matter appears to be much more complicated (R.C. Preece, personal communication, 2004; T. Sitnikova, personal communication, 2004). In addition to the presence of a relatively large, bulky form with a large body whorl and weak spiral microsculpture, identified as *Gyraulus* A sp., an even larger and more distinctly and finely-ribbed form with a wide umbilicus is recognized as *Gyraulus* B sp. A small, more depressed and lightly-ribbed form characteristic of *G. albus* is also present in the assemblage. Prozorova (2003) reports 32 different species of *Gyraulus* in Russia. Future analyses of the *Gyraulus* material with the assistance of

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

regional specialists will be necessary for more confident identification. Within the Lymnaeidae, species identifications could only be reliably made to the generic level, and require future consultation with Russian Lymnaeidae specialists for more accurate separations at species level. At least six taxa are represented, including *Lymnaea* cf. *fragilis*, *Stagnicola (atra)* sp., *Galba truncatula* ex. gr. *sibirica*, and possibly one other *Galba* form, and at least two *Radix* species, tentatively identified as *Radix* A sp. and *Radix* B sp. All bivalve specimens were identified by *Pisidium* specialist Dr. J.G.J. Kuiper (Garches, France).

Preliminary sampling of modern malacofauna living near the Burdukovo locality took place near a small perennial spring along Sukhaia Ravine, a biotope characterized as a moist, semi-closed canopy riparian zone with mixed trees of pine, willow, and poplar along with a rich undergrowth of shrubs, ferns, and mosses. Associated molluscan taxa included *Cochlicopa* cf. *lubrica*, *Columella columella*, *Punctum pygmaeum*, *Pupilla muscorum*, *Succinea/Oxyloma* spp., *Succinella oblonga*, *Vallonia pulchella*, *Vallonia tenuilabris*, *Bathyomphalus contortus*, *Galba truncatula* ex. gr. *sibirica*, *Gyraulus* spp., *Musculium lacustre*, *Polypylus sibirica*, and *Valvata macrostoma*. Detailed sampling of modern molluscan fauna near the Basovo site awaits future field studies. The molluscan assemblages resulting from this study will be sub-sampled and donated to selected museum collections in North America and Russia, with the primary Basovo and Burdukovo site assemblages donated to the University Museum of Zoology Cambridge, UK (UMZC).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

CHAPTER 4

The Basovo Site, Upper Lena River Valley: Results and Interpretations

Introduction

Near the settlement of Basovo, stratified floodplain sediments of the Lena River were the focus of detailed study and collection for paleoecological analyses (Figures 2.1 and 4.1). Stratigraphic sequences are exposed along an actively eroding cutbank composed of generally fine-grained alluvial sediments and buried soils. From this cutbank upstream (south) to the outlet of Domashnii Creek, the valley landscape consists of an older high terrace (T-2) and a high (T-1) and low (T-0) floodplain (Figure 4.1). The high terrace rises *ca.* 7–10 m above the Lena River, and while discontinuous in occurrence, can be found in many areas between the settlements of Zhigalovo and Ust'-Kut. Previous studies in the upper Lena River valley have reported a late Pleistocene age (Q_{III}) for this terrace based on the recovery of *Coelodonta antiquitatis* Fich., *Mammuthus primigenius* Blum., and *Cervus* sp. (Obruchev, 1892; Pavlovskii, 1929). Near Basovo, the high terrace parallels the Lena River to the north of Domashnii Creek for a distance of *ca.* 750 m where it intersects the floodplain with gently sloping topography.

At its widest point, the floodplain extends up to *ca.* 800 m from the east edge of the present river channel to the base of the adjacent valley slopes, and continues downstream from the studied cutbank for a distance of *ca.* 2.5 km. This landform can be sub-divided into at least two components, an older high floodplain and a younger low floodplain (Figure 4.1). Given the research focus on reconstructing the Holocene environmental history at the site, the high floodplain section was selected for detailed description and systematic sampling for sedimentological, geochronological, and macro- and micro-fossil analyses.

The cutbank of the high floodplain is *ca.* 220 m in length and *ca.* 3–5 m in height and composed of loamy alluvial sediments with buried soils which formed during periods

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

of greater floodplain stability. Sections were described and sampled at selected stratigraphic exposures designated as High Floodplain Sections 1, 2, and 3, hereafter referred to as HFS1, HFS2 and HFS3, respectively (Figures 4.1 and 4.2). HFS2 is further sub-divided into two components when referring to specific sampling profiles, HFS2a (sedimentological samples) and HFS2b (macrofossil samples). Along the cutbank exposing the sediments underlying the high floodplain, a subtle south to north elevation gradient is observed both along the modern surface as well as in underlying stratified deposits. This differential in elevation has significantly influenced sedimentation patterns, drainage conditions, cryoturbation processes, and soil genesis during the course of floodplain development. HFS1 is located along the slightly elevated southern end of the high floodplain where stratigraphic sequences, particularly in the lower portion of the section, exhibit both fewer laminations and other microstratigraphic detail that characterize HFS2 and HFS3, located *ca.* 45 m and *ca.* 53 m to the north, respectively, and at slightly lower elevations. Generally, pedogenic sequences on the floodplain consist of Gleyed Cumulic and Gleyed Cumulic Humic Regosols (Gleyic Fluvisols) (Figures 4.2, 4.3, and 4.4; Appendices A.2 and A.3). Results from AMS radiocarbon analyses of charcoal samples from the Basovo high floodplain section are presented in Table 4.1. Site stratigraphy is described in detail below.

Stratigraphy

Unit 1

Lithology: Unit 1 consists of a bedded, clast-supported gravel composed of well-rounded pebbles, cobbles, and boulders of mixed lithology.

Interpretation: These sediments were deposited under high-energy fluvial conditions and represent a gravel bar of the upper Lena River.

Unit 2

Lithology: Unit 2 is a weakly stratified sequence of fine loamy sediments with very low organic carbon (*ca.* < 0.5 %) content. These deposits occur as the basal fine-textured unit along the entire high floodplain section overlying Unit 1. Sediments are highly calcareous, yellowish red (5YR 4/6) loams with generally poorly defined parallel

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

horizontal bedding. Occasionally the bedding is slightly undulating and exhibits small changes in granulometric composition due to alluvial sorting. Micromorphological features (Figure 4.4a) indicate coarse/fine particle-size ratios (c/f boundary at 10 μm) that vary between 30:70 and 40:60 with open porphyric related distribution. Occasional to abundant, loose, discontinuous silty infillings occur in sub-horizontal planar voids. Few (*ca.* 5–10 % in area) iron nodules of variable size (50–1000 μm) occur with rare, distinct iron depletion zones, indicating periods of reducing and oxidizing conditions associated with water table fluctuations. Within the upper *ca.* 0.25 m of this unit sediments begin to show very weak alteration caused by the overlying pedogenic profile of Unit 3. These pedofeatures include ultrafine to very-fine subangular blocky microstructure and a stipple speckled birefringence fabric (b-fabric) of the groundmass. Downward an ultrafine platy microstructure prevails with crystallitic and mosaic speckled b-fabrics. Pedogenic alteration in Unit 2 is very minimal and can only be recognized in micromorphological cross-section. Molluscs become increasingly abundant near the top of this unit. The base of Unit 2 and nature of contact with underlying coarse alluvial material were not directly observed during excavations of the study sections along the high floodplain cutbank, exceeding depths of 3.35 m, 2.70 m, and 2.50 m below the modern surface at HFS1, HFS2, and HFS3, respectively.

Interpretation: Unit 2 represents the accumulation of fine alluvium along the bank of the upper Lena River, broadly estimated to date to the late Pleistocene. These data suggest accelerated landscape erosion in the upper watershed and subsequent deposition and landform aggradation downstream and mark the continuation of postglacial floodplain development at Basovo.

Unit 3

Lithology: Unit 3 ranges between 0.15–0.30 m in thickness and is composed of very-fine loamy sediments overprinted by a weakly developed cumulic soil profile (buried soil E). Due to slight elevation differences and their associated affects on landform development, this unit varies in composition along the high floodplain cutbank. At Section HFS1, Unit 3 is *ca.* 0.15 m thick and occurs *ca.* 1.60 m below the modern surface and consists of dark reddish brown (5YR 2.5/2) silty clay loam. Cryogenic

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

features are absent at HFS1 and the lower boundary of this unit is clear and wavy. Northward along the cutbank (*i.e.*, with decreasing elevation) at HFS2 and HFS3, stratigraphic features of Unit 3 become distinctly more complex due to increased sedimentation during pedologic development, more frequent water table fluctuations, and pronounced cryogenic deformation. At these latter sections, Unit 3 ranges between *ca.* 0.25–0.30 m thick and occurs *ca.* 1.75 m and *ca.* 2.05 m below the modern surface, respectively, consisting predominantly of dark reddish brown (5YR 2.5/2 to 5YR 3/2) silty clay loam. Micromorphological features (Figures 4.4b and 4.4c) indicate coarse/fine particle-size ratios varying from 30:70 to 20:80 with open porphyric related distribution. In general, stipple-speckled and mosaic-speckled b-fabrics are characteristic for this unit on the whole, however fine materials consisting of mixed clay and calcite particles also reveal the more limited occurrence of a crystallitic b-fabric. This unit also contains few (*ca.* 5–10 % of area) iron nodules of variable size (50–1000 μm) and rare (*ca.* < 2 %) iron hypo- and quasi-coatings occurring with rare, distinct iron depletion zones along voids, indicating alternating reducing and oxidizing conditions. Few well-rounded to rounded pebbles, gravels, and cobbles occur near the base of this unit at HFS2. This coarse layer is both limited and irregular in its occurrence along the high floodplain. Molluscs become both increasingly abundant and species-rich in this unit. At HFS2, wood charcoal recovered from the lower pedogenic horizon from this cumulic unit returned ages of 8770 ± 80 ^{14}C yr BP (1.95 m below surface) and 9490 ± 80 ^{14}C yr BP (1.95 m below surface), and an age of 9880 ± 100 ^{14}C yr BP (1.97 below surface) from charred bone. Near the upper boundary of Unit 3 wood charcoal was dated to 8260 ± 130 ^{14}C yr BP (170–175 m below surface).

Buried soil E: At HFS1, Unit 3 includes a moderately developed calcareous buried soil with subangular blocky macrostructure that grades downward to minimally altered silty clay loam and loamy parent materials. At HFS2 and HFS3, multiple incipient soils are evident as very thin (*ca.* < 5 cm), dark, and discontinuous layers with relatively high organic carbon content (*ca.* 1.15–1.45 %). The upper part of Unit 3 has medium prismatic microstructure parting downward to very-fine subangular blocky. Soil horizon boundaries for this cumulic and cryoturbated unit are irregular and broken. At HFS2, a small (diameter *ca.* 6 cm), circular-shaped krotovina was observed in this unit.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Interpretation: Unit 3 is interpreted as silty clay loam floodplain alluvium overprinted by a cryogenically altered immature cumulic soil profile (Gleyed Cumulic Regosol [Gleyic Fluvisol]). Sedimentation of this unit generally occurred under a comparatively low-energy alluvial environment relative to other deposits represented along the high floodplain, evident by its generally very-fine textural composition. Weak soil genesis occurred in an accretionary matrix with intervening overbank sedimentation of fine silts. Pedogenic features are indicated by darker colors, increased organic carbon content, and development of soil structure. At HFS2, the base of this unit contains discontinuous and poorly sorted coarse materials including sand, pebbles, and cobbles, the origin attributed to the melt-out of ice rafted debris washed onto the paleo-floodplain surface. AMS radiocarbon dates provide bracketing ages for this cumulic unit, with a mean pooled average, based on three dates, of *ca.* 9450 ^{14}C yr BP (Stuiver and Reimer, 2005) for the lower pedogenic horizon, and *ca.* 8260 ^{14}C yr BP for the uppermost pedogenic interval. In general, the pedogenic sequence indicates relative floodplain surface stability at Basovo for the first time during the Holocene.

Unit 4

Lithology: Unit 4 ranges between 0.70–0.90 m in thickness and consists predominantly of clayey and silty loams with weakly developed soils (buried soils D_1 and D_2) in its upper part. At HFS1, this unit extends from *ca.* 0.90–1.60 m below the surface and is composed of a black (10YR 2/1) calcareous silt loam fining downward to a dark grey (10YR 4/1) clay loam, with a relatively homogenous reddish brown (5YR 4/3) clay loam in its lower half. At HFS2, Unit 4 extends from *ca.* 1.00–1.80 m below the surface and is represented in the lower portion by cryoturbated and non-uniform alluvium, differentiated primarily by textural composition, with an overlying pedogenic sequence. The basal sediments of this unit at HFS2 and HFS3 consist of a thin (*ca.* < 0.10 m), reddish brown (5YR 4/4) loam underlying a thicker (*ca.* 0.35 m) reddish brown (5YR 4/3) clay loam. Total organic carbon content for these sediments is relatively low, ranging between *ca.* 0.40–0.75 %, while the total inorganic carbon fraction reaches a maximum for the entire sequence (up to *ca.* 3.87 %). Micromorphologically, sedimentary particles vary between 40:60 to 30:70 in coarse/fine ratios with open

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

porphyric related distribution, along with intervening 60:40 coarse/fine elements with close porphyric laminations (Figures 4.4d). Occasional to abundant (*ca.* 2–20 %), loose, discontinuous silty infillings occur in sub-horizontal planar voids, and channel voids are also present, occupying *ca.* 5–20 % of void space. Very few (*ca.* 2–5 %) iron pedofeatures (mostly nodules of variable morphology with evidence of mottling and hypo-coatings) occur along with very few (*ca.* 2–5 %) calcite pedofeatures (mostly nodules up to 400 μm). Within the clay loam matrix, very weakly developed ultrafine to very-fine subangular blocky microstructure is observed, with a combination of subangular blocky and platy microstructures downward, as well as mosaic-speckled and crystalline b-fabrics. At a depth of *ca.* 1.45–1.55 m, a crystalline b-fabric dominates due to the very high proportion of ultrafine calcite particles (*i.e.*, enrichment with secondary carbonates). Malacofauna are both species-rich and abundant (reaching a sequence maximum) in Unit 4.

The upper portion of Unit 4 is composed of organic-rich, calcareous black (10YR 2/1) silt loam and dark grey (10YR 4/1) clay loam pedogenic horizons. At HFS2 and HFS3, this sequence is approximately twice as thick as that observed at HFS1. Micromorphological features (Figure 4.4e) in the upper portion of Unit 4 exhibit a 50:50 ratio in coarse/fine elements with close porphyric related distribution. Iron pedofeatures (mostly mottles up to 2000 μm) increase upwards throughout this unit from about *ca.* 1 % near the lower boundary to *ca.* 10–15 % near the upper boundary, and rare to occasional silty infillings occur in void spaces. Cryogenic features are prominent throughout this unit. AMS radiocarbon dating of charcoal from Unit 4 produced ages of 6350 ± 60 ^{14}C yr BP (1.30–1.35 m below surface) near the middle of the unit, 3380 ± 80 ^{14}C yr BP (1.05 m below surface) near the top of the unit, and 2790 ± 60 ^{14}C yr BP (1.00–1.05 m below surface) at the unit's upper boundary.

Buried soil D_2: A complex pedogenic sequence overprints the alluvial sediments comprising Unit 4. Buried soil D_2 consists of a gleyed, weakly developed, dark grey clay loam with relatively high total organic carbon content (*ca.* 1.15–1.60 %) and platy macrostructure. At HFS1, this soil horizon is *ca.* 0.10–0.15 m thick with a clear and wavy lower boundary. At HFS2, this soil horizon is *ca.* 0.20 m thick with an abrupt and irregular lower boundary. Post-pedogenic modification of soil structure (*i.e.*, repeated

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

wetting and drying cycles or ice lensing) may account for its moderately developed platy character. Micromorphology samples from HFS2 reveal weak to moderate, ultrafine to very-fine subangular blocky microstructure with a mosaic-speckled b-fabric and few to frequent (*ca.* 10–25 %) calcite pedofeatures (mostly nodules up to 3000 μm). Few (*ca.* < 15 %) iron mottles are also present in this soil horizon.

Buried soil D_1: The upper portion of this pedogenic sequence consists of a moderately developed and weakly gleyed black silt loam with very high total organic carbon content (*ca.* 1.90–3.40 %). At HFS1, this soil horizon is *ca.* 0.25 m thick with a clear and wavy lower boundary, and at HFS2 the horizon is *ca.* 0.15–0.20 m thick with a clear and irregular lower boundary. Structural properties are similar to those described above for buried soil D_2; however a significant proportion of fissure microstructure prevails in the uppermost portion of this soil horizon, showing weak cementation of sand particles with either carbonates or clay. Numerous carbonate and iron pedofeatures indicate pedogenic translocation of calcite and iron. Additionally, channel voids occupy *ca.* 5 % of total void space, except in the uppermost *ca.* 3–4 cm of this unit where they occur frequently (*ca.* 15–30 %), ranging between 400–600 μm in diameter. These voids (*i.e.*, worm casts) are infilled with material mixed from overlying sediments, which penetrate the stratigraphic boundary between Units 4 and 5.

A distinct stratigraphic marker within the high floodplain is a thin (*ca.* 1–3 cm), charcoal-rich layer separating Units 4 and 5. Only faint traces of charcoal could be identified at the slightly elevated HFS1, whereas a more continuous, though still irregular, lens was observable at both HFS2 and HFS3. A wood charcoal sample collected from this charcoal layer at HFS2 returned an age of *ca.* 2790 ^{14}C yr BP.

Interpretation: Unit 4 is interpreted as fine loamy alluvium weakly to moderately altered by pedogenic processes (Gleyed Cumulic Humic Regosol [Gleyic Fluvisol]) in its upper portion. The loamy alluvium comprising this unit is texturally non-uniform and suggests periods of floodplain instability during initial sedimentation. By the beginning of the mid-Holocene however, increasing floodplain stability is indicated by pedogenic development. At HFS2 and HFS3, cryogenic features are prominent in much of this unit, evidence of a still active permafrost layer at the site.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

The origin of the thin lens of charcoal separating Units 4 and 5 is interpreted as the accumulation of organic debris washed onto the former floodplain surface following a forest fire further upstream. It is conjectured that an increase in slope instability associated with de-vegetated surfaces in the burned areas generated higher erosional rates and accelerated run-off, and this material was subsequently deposited downstream during post-fire flooding. This burn event may also account for the initial increase in sedimentation rates and instability evident in the overlying stratigraphic record. At present, there is no archaeological evidence to suggest that this charcoal layer is associated with anthropogenic activities, though this also remains a possibility. Wood charcoal from this lens returned an age of *ca.* 2790 ^{14}C yr BP, and some of this charred material appears to have been reworked into the overlying sedimentary sequence of the high floodplain.

Unit 5

Lithology: Unit 5 is composed of dark brown (7.5YR 3/4) loamy sediments with a very weakly developed buried soil (buried soil C) in its upper portion. Only traces (*ca.* 1–3 cm thick) of this unit occur at the slightly elevated HFS1, but it is generally thicker, though still discontinuous at HFS2 and HFS3, reaching a maximum thickness of *ca.* 0.15 m in some places. A heterogeneous sediment composition, irregular unit boundaries, and evidence of bioturbation all indicate the disturbed nature of Unit 5. Micromorphological features (Figure 4.4f) exhibit a 30:70 particle-size ratio of coarse/fine elements with open porphyric related distribution, along with abundant and scattered charcoal fragments. Rare to occasional sand/silt/clay infillings occur in frequent (*ca.* 10–20 %) channel voids (400–600 μm in diameter). This material is mixed from Units 4, 5, and 6, and these pedofeatures penetrate the stratigraphic boundaries between these units. The presence of very few (*ca.* 2 %) iron pedofeatures (mostly nodules up to 100 μm) indicates limited iron segregation. Very few mollusc shells are present in this unit. Radiocarbon dated wood charcoal samples from Unit 5 returned ages of 2620 ± 90 ^{14}C yr BP (0.97 m below surface) and 2910 ± 60 ^{14}C yr BP (0.95–1.00 m below surface) at HFS2, generally consistent with the age obtained from the charcoal lens separating Units 4 and 5.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Buried soil C: The very weakly developed buried soil of this unit ranges between *ca.* 3–5 cm thick. The high total organic carbon content measurement (4.03 %) for this unit may be partly influenced by detrital (*i.e.*, non-pedogenic) carbon present in the sample submitted for analysis. A platy macrostructure and an ultrafine to very-fine subangular blocky microstructure dominate, with a minor proportion of fissure microstructure, along with mosaic-speckled and grano-striated b-fabrics. Calcite pedofeatures are entirely absent from this unit. A large (*ca.* 0.20–0.30 m diameter), irregularly-shaped krotovina was observed in this unit at HFS2, which extended into underlying Unit 4.

Interpretation: Unit 5 is interpreted as loamy alluvium very weakly altered by a thin, incipient soil (Orthic Regosol [Haplic Fluvisol]). Sedimentation of this unit may have occurred immediately following the burn event mentioned previously, and marks a trend towards valley erosion and active aggradation on the floodplain during the late Holocene. This unit is non-uniform in thickness across the high floodplain, represented by sediments up to *ca.* 0.15 m thick along the northern section of the cutbank (*i.e.*, HFS2 and HFS3) and becoming increasingly thin to entirely absent near the slightly elevated HFS1, with frequently broken horizon boundaries with adjacent sediments. AMS radiocarbon analyses of two wood charcoal samples from this unit returned ages of *ca.* 2620 ^{14}C yr BP and *ca.* 2910 ^{14}C yr BP, which, when averaged together, is consistent with the date obtained from the thin charcoal layer at the boundary of Units 4 and 5. The uniformity of these radiocarbon dates indicates that the abundant charcoal scattered throughout Units 5 and 6 is associated with this same burning event and thus samples submitted for radiocarbon determinations from these units are likely in a redeposited context. Taken together, the mean pooled average of four AMS radiocarbon dates on material attributed to this forest fire is *ca.* 2800 ^{14}C yr BP (Stuiver and Reimer, 2005) which is used as the approximate age both for the burn event and the Unit 4/5 stratigraphic boundary.

Unit 6

Lithology: Unit 6 is variable in composition along the cutbank of the high floodplain. At HFS1, this unit is *ca.* 0.30 m thick and consists of a dark brown loamy

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

accretionary pedogenic sequence that directly overlies the thin (*ca.* 1–3 cm) and discontinuous Unit 5. Further north, at HFS2 and HFS3, Unit 6 is also *ca.* 0.30 m thick but is composed of poorly defined parallel horizontally stratified reddish brown (5YR 4/4), calcareous loamy sands in its lower part, with an overlying calcareous cumulic soil profile (buried soil B). The basal alluvial sediments of this unit at HFS2 and HFS3 have very low organic carbon contents (*ca.* 0.50 %) and sedimentary particles consist of a 50:50 ratio of coarse/fine elements with close porphyric related distribution, with rare clay coatings occurring on sandy grain surfaces. Occasional channel voids (400–600 μm) are infilled with materials mixed from Units 4, 5, and 6, and very few (*ca.* 2 %) carbonate nodules, as well as few (*ca.* 2–5 %) iron mottles and nodules (up to 300 μm), occur in the lowermost portion of this unit. Malacofauna are moderately abundant in Unit 6. A wood charcoal sample collected from the center of Unit 6 at HFS2 returned an age of 2780 ± 360 ^{14}C yr BP (0.82 m below surface).

Buried soil B: Overprinting of this parent material by pedogenic processes is indicated by dark colors, high organic carbon contents (*ca.* 1.92–3.07 %), and subangular blocky macrostructure. Soil development in this unit is represented by a moderately developed, dark brown (7.5YR 3/2) loamy horizon *ca.* 0.15–0.20 m thick with overlying sandy laminations acting to modify pedogenic processes, and thus creating a thin (*ca.* < 10 cm), dark brown (7.5YR 3/4) sandy loam transitional horizon at the unit's upper boundary.

Interpretation: Unit 6 is interpreted as loamy alluvium weakly altered by pedogenesis (Cumulic Regosol [Haplic Fluvisol]). This sequence represents a renewed period of floodplain instability at the site evidenced by the deposition of sandy loam alluvium followed by a period of relative surface stability which fostered pedogenic development on the floodplain. Soil genesis, however, was at times interrupted by the deposition of fine sandy lenses from either periodic flood events or from wind-blown sediments transported from exposed local sandbars. Wood charcoal collected from the moderately-well developed soil horizon in the center of Unit 6 returned an age of *ca.* 2780 ^{14}C yr BP, consistent with the interpretation that material from the underlying sequence has been reworked into overlying sediments and is thus in a secondary context.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Unit 7

Lithology: Unit 7 ranges between 0.60–0.65 m in thickness and exhibits a consistent stratigraphic expression across the entire high floodplain section, characterized by calcareous, yellowish red (5YR 4/6), fine sandy loam sediments (*ca.* 0.10 m thick) in the lower part of the unit (directly above Unit 6) with an overlying pedogenic sequence (buried soil A and the modern surface soil). The basal sediments from this unit have very low organic carbon contents (*ca.* 0.40–0.55 %) and contain the highest percentage of sand in the entire high floodplain sedimentary record. Upward fining of particles coincides with increased organic carbon contents. These organic-rich horizons are very dark greyish brown (10YR 3/2 to 10YR 3/3) in color. Mollusc shells are generally limited in number in this upper unit. Wood charcoal samples from the buried soil horizon of Unit 7 at HFS2 returned inverted ages of 1630 ± 90 ^{14}C yr BP and 1410 ± 60 ^{14}C yr BP from depths of 0.30–0.35 m and 0.40–0.45 m below the modern surface, respectively.

Buried soil A and *modern surface soil*: The buried sandy loam soil horizon associated with Unit 7 is *ca.* 0.25 m thick with subangular blocky macrostructure and high total organic carbon contents (*ca.* 2.60–3.20 %). The thin (*ca.* < 0.10 m), weakly developed modern surface soil formed in the upper part of the unit is also distinguished by a sandy loam textural composition, subangular blocky to granular macrostructure, and high total organic carbon contents (*ca.* 1.65–3.35 %). The modern surface horizon appears to have been left relatively unaltered by local anthropogenic activities, apart from the seasonal grazing of domestic livestock. Several small krotovina were also observed in this unit.

Interpretation: Unit 7 is interpreted as loamy floodplain alluvium weakly altered by two separate pedogenic profiles (Cumulic Regosol [Haplic Fluvisol]), indicating a continuation of alternating cycles of floodplain stability and instability at the site. The uppermost horizon from this unit is the modern surface soil. Two wood charcoal samples from the top of the buried soil horizon of this unit average *ca.* 1520 ^{14}C yr BP.

Low floodplain

The low floodplain (Figure 4.1) is *ca.* 2.0–2.5 m in height and composed primarily of stratified sandy loam and loamy alluvium directly overlying a gravel of

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

mixed lithology. Modern nesting of sparrows along the low floodplain cutbank has altered the natural stratigraphy in many places. Pedogenic horizons are all very weakly developed, reflecting their immaturity and limited formation time necessary for acquiring pedogenic features. Sedimentological descriptions and results from laboratory analyses from a representative section from the low floodplain are summarized in Figure 4.5 and Appendix A.4.

Molluscs

The stratified molluscan assemblage recovered from Basovo exhibits remarkable shell abundance and species richness spanning the entire Holocene Epoch (Figure 4.6). Of the 50 bulk (2.5 l) sediment samples collected and processed, over *ca.* 72,500 individuals comprising at least 30 terrestrial and 23 aquatic taxa are represented in the assemblage (Table 4.2; Figures 4.7 and 4.8; Plates A–X; Appendix B.1). All of the samples were fossiliferous, 17 of which contained < 200 shells, 15 contained between 200–1000 shells, and 18 samples comprised > 1000 shells, with the richest sample composed of *ca.* 7500 individuals. The genus *Vallonia* dominates the record, represented by over *ca.* 51,000 individuals or *ca.* 72.5 % of the entire assemblage. The extraordinarily high shell counts allow greater confidence in data assessment and also facilitated the recovery of rarer species.

Successional trends are typically well defined and allow classification into six local mollusc zones (Bsv1–Bsv6). This zonation scheme was initially developed based solely on the interpretation of sequential patterns depicted in the frequency histograms. Subsequent statistical assessment of the data by Two-Way Indicator Species Analysis (TWINSPAN; Hill 1979) generally supports these delineations. The principal difference observed between these so-called 'subjective' and 'objective' zonation techniques is found in Zone Bvs6, where several samples from this zone were grouped within other zones delineated by TWINSPAN. Low shell abundance in some of the samples from Zone Bvs6 may account for this discrepancy. Otherwise, correspondence between all other zones generally supports the proposed local molluscan zonation scheme developed for Basovo. The assemblage is interpreted to reflect mostly autochthonous contexts and

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

enable successional trends to be regarded as reliable indicators of local floodplain ecology.

Statistical quantification of the molluscan data by principal components analysis (PCA) is presented in Figures 4.9 and 4.10. The mollusc sample biplot shown in Figure 4.9 illustrates both the intra- and inter-group variability of identified mollusc zones. Figure 4.10 depicts the association between different mollusc species represented in the assemblage. These data are particularly informative for those species whose ecological contexts are still poorly documented. The associations of these lesser known species with those whose habitat affinities are better documented give insights into the ecological significance of these taxa. Basovo molluscan zonal descriptions and interpretations are outlined in detail below.

Zone Bsv1: 200–250 cm (*ca.* > 10,000 ^{14}C yr BP)

Mollusc Zone Bsv1 includes the earliest assemblages recovered from Basovo. This basal sequence exhibits comparatively low mollusc abundance, particularly in the lower component, with increasing species richness, represented by up to 25 taxa near the upper boundary. Dominant terrestrial species in this zone include *Vallonia tenuilabris* (*ca.* 25 %), *Vallonia* cf. *chinensis* (up to *ca.* 40 %), *Vallonia kamtschatica* (*ca.* 15–50 %), *Punctum pygmaeum* (up to *ca.* 20 %), and *Vertigo extima* (*ca.* 8 %). Less abundant terrestrial taxa (*ca.* < 5 %) include *Oxyloma/Succinea* spp., *Pupilla muscorum*, *Succinella oblonga*, and *Vertigo alpestris*, along with catholic species such as *Cochlicopa* cf. *lubrica*, *Nesovitrea hammonis*, *Euconulus fulvus* agg., and *Deroceras/Limax* spp. Aquatic taxa are mostly limited in abundance though increase in relative frequency in the upper 0.10 m of this zone, represented by *Galba truncatula* ex. gr. *sibirica*, *Radix* A sp. *(ovata?)*, *Gyraulus* A sp. and *G. crista*, *Musculium lacustre*, *Pisidium henslowanum*, *P. subtruncatum*, *P. nitidum*, *Sphaerium* sp., and *Valvata aliena* and *V. macrostoma*. Higher frequencies of aquatic species may be indicative of frequent flooding and pooling on this relatively unstable and aggrading landform. The molluscan assemblage on the whole is characteristic of cool and moist conditions, with open-ground, marsh, and forest habitats. This unit is considered to be late Pleistocene in age (*ca.* > 10,000 ^{14}C yr BP), though this age estimate has yet to be verified through absolute dating methods.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Zone Bsv2: 170–200 cm (*ca.* 9450 to *ca.* 8260 ^{14}C yr BP)

Malacofaunal changes in Zone Bsv2 include a significant increase in total abundance and the highest degree of species richness found in the assemblage (up to 38 taxa in the uppermost sample). This zone is dominated by terrestrial species (*ca.* > 95 %) with aquatic taxa present in negligible numbers. The genus *Vallonia* is represented by a series of changes, initially with a sharp increase in *V. kamtschatica* (up to *ca.* 60 %), followed by the first appearance of *V. costata* (up to *ca.* 30 %), a species indicative of moderately dry, open landscapes. Both of these species however begin a decline near the upper boundary of this zone. Absolute values of *V.* cf. *chinensis* are initially low, but this species steadily increases in prominence and reaches an assemblage maximum (up to *ca.* 65 %) at the top of Zone Bsv2. Values of *V. tenuilabris* gradually decline and the first appearance of *V. pulchella* (*ca.* 5 %) is also noted at the top of this zone. Additionally, *Punctum pygmaeum* and *Vertigo extima* decrease in abundance and the general absence of aquatic species are all further indications of relatively drier conditions at the site. Reduced numbers of *Deroceras/Limax* spp., *Pupilla muscorum*, *Succinella oblonga*, and *Vertigo alpestris* occur in the upper portion of this zone.

A number of other terrestrial taxa also make first appearances in the record, including the open-ground species *Vertigo parcedentata* and *Columella columella,* marsh species *Vertigo geyeri*, *V. antivertigo*, and *Gastrocopta theeli*, and potential shade-demanding species such as *Vertigo alpestris*, *Bradybaena* cf. *schrencki*, and *Discus* spp. Of these species, *V. parcedentata* and *V. geyeri* are particularly noteworthy in that they are not only new to the Basovo assemblage, but this is apparently the first documented record of these species in Asia, extending their previously known geographical ranges on a continental-scale (Pokryszko, 2003a, personal communication, 2003b). Of additional interest to note for this zone is the presence and peak of the extremely rare species *Vertigo microsphaera*, which may point towards a preference for open and drier habitats in continental Asia for this still poorly documented species. Previously, *V. microsphaera* had only been found in the Kuril Islands off the Pacific coast (Pokryszko, 2003a; Prozorova, 2002; Schileyko, 1984). AMS radiocarbon dates provide bracketing ages for this moderately dry adapted malacological zone, with a mean pooled average of *ca.* 9450

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

^{14}C yr BP (based of three dates) near the lower boundary and *ca.* 8260 ^{14}C yr BP at the upper boundary.

Zone Bsv3: 135–170 cm (*ca.* < 8260 to *ca.* > 6350 ^{14}C yr BP)

Mollusc abundances reach a maximum in Zone Bsv3 with a continuation of high though decreasing species richness. Compositional changes within the genus *Vallonia* are again prominent features defining zonal boundaries. *V.* cf. *chinensis* continues to dominate the assemblage, particularly in the lower portion (between *ca.* 30–50 %), however more ecologically informative (*i.e.*, until more is known about spcific habitat preferences of *V. chinensis*) is the increase of *V. pulchella* (up to *ca.* 40 %), a species characteristic of wet habitats such as moist meadows. *V. tenuilabris* undergoes a modest rise (up to *ca.* 15 %) while *V. kamtschatica* and the moderately dry adapted *V. costata* decrease sharply. The transient occurrence of *Zonitoides nitidus* at the lower zonal boundary seems to coincide with the onset of these generally wetter conditions indicated by this assemblage. Also near the lower boundary, marsh species *Carychium pessimum* and *Vertigo genesii* make first appearances at the site, the latter of which also marks the first documented record of this species in Asia.

Among the other terrestrial fauna from Zone Bsv3, catholic species remain relatively stable, while the marsh adapted taxa *Oxyloma/Succinea* spp. (up to *ca.* 20 %) and *Vertigo extima* (up to *ca.* 15 %) steadily increase in abundance and reach a maximum peak in the upper 10 cm of this zone, further evidence of increasingly wetter conditions at the site. *Vertigo antivertigo* and *Discus* spp. continue to occur in limited frequency throughout this zone, however a number of other terrestrial taxa found in the underlying sequence are either no longer present (*Succinella oblonga, Vertigo alpestris, V. geyeri, V. parcedentata*, and *Columella columella*) or occur only in negligible numbers within the lower portion of this zone (*Vertigo microsphaera, Bradybaena* cf. *schrencki*, and *Gastrocopta theeli*). Aquatic taxa are relatively abundant and comprise *ca.* 30 % of the total assemblage near the upper zonal boundary, represented most prominently by members of the slum-group *Anisus leucostoma, Aplexa hypnorum*, and *Pisidium casertanum*. These slum-taxa, which are typically known to inhabit small water bodies subject to stagnation and considerable temperature variations (Sparks, 1961), suggest

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

ephemeral pooling on the floodplain surface and lend further evidence of relatively wet conditions reflected by this malacofaunal zone. Other aquatic taxa from this sequence include the catholic *Stagnicola* (*atra*) sp. and *Radix* B sp., as well as the large, finely ribbed form preliminarily designated as *Gyraulus* B sp. AMS radiocarbon dates bracket Zone Bsv3, providing a maximum age of *ca.* < 8260 ^{14}C yr BP at the lower boundary and a minimum age of *ca.* > 6350 ^{14}C yr BP at the upper boundary.

Zone Bsv4: 100–135 cm (*ca.* 6350 to *ca.* 3380 ^{14}C yr BP)

Compositional changes within the assemblage continue in this zone, generally showing high species richness but comparatively only moderate abundance. Again, *Vallonia* is the dominant malacofaunal component, represented by the sustained presence of *V. pulchella* (up to *ca.* 20 %) along with increases in both *V. kamtschatica* (up to *ca.* 40 %) and *V. costata* (up to *ca.* 20 %). *V.* cf. *chinensis*, while present in significantly reduced numbers relative to its peak in underlying Zone Bsv3, continues to occur at moderate levels (up to *ca.* 25 %), but *V. tenuilabris* declines abruptly. Of particular interest is the recurrence of *V. costata*, which may indicate a renewed period of increasingly drier conditions at the site. *V. pulchella*, however, continues to exist in relatively high numbers, suggesting the presence of moister habitats on the floodplain as well. These changes in *Vallonia* coincide with marked decreases in *Oxyloma/Succinea* spp. and *Vertigo extima*, taxa associated with wet and moist conditions, and to a lesser degree *Pupilla muscorum*. The wet adapted *Zonitoides nitidus* again makes a transient appearance at the base of this zone, just prior to the *V. costata* rise. Catholic species generally show minor increases in proportion, and greater species richness is accounted for by the reoccurrence of *Discus* spp., *Bradybaena* cf. *schrencki*, *Gastrocopta theeli*, *Vertigo microsphaera*, *V. antivertigo*, and *V. pygmaea*, as well as the first sustained presence of *Carychium pessimum*. Aquatic taxa from this zone indicate a significant reduction in the dominance of slum species (*e.g.*, those tolerant of ephemeral and stagnant water conditions) and slight increases in the marsh adapted *Galba truncatula* ex. gr. *sibirica*, as well as *Gyraulus* A sp. The malacofauna record from Zone Bsv4 generally indicates moderately dry conditions, though still moist enough for wet-ground adapted species like *Vallonia pulchella* to exist. Bracketing AMS radiocarbon dates

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

provide an age of *ca.* 6350 ^{14}C yr BP for the lower boundary and an upper age of *ca.* 3380 ^{14}C yr BP for Zone Bsv4.

At the upper boundary, this zone is punctuated by a biostratigraphic unconformity where faunal abundance, richness, and diversity reach the lowest levels in the entire sequence. Geochemical alteration (*i.e.*, acidification) of the soil matrix by the overlying thin charcoal layer separating stratigraphic Units 3 and 4 may account in part for the poor preservation of mollusc shell in this portion of the sequence. The charcoal lens is dated to *ca.* 2800 ^{14}C yr BP, however given the near absence of fossil molluscs at the top of this zone, preference is given to the date of *ca.* 3380 ^{14}C yr BP as the upper age boundary for Zone Bsv4.

Zone Bsv5: 65–100 cm (*ca.* < 2800 to *ca.* > 1520 ^{14}C yr BP)

This zone represents a period of increased instability in the stratigraphic sequence and marks a trend towards reduced shell abundance and species richness. In the terrestrial component, *Vallonia kamtschatica* (*ca.* 30–40 %) and *V. pulchella* (*ca.* 20 %) are found in relatively high numbers, while *V.* cf. *chinensis* and *V. costata* become increasingly rare. *Vallonia tenuilabris* percentages increase throughout this zone (up to *ca.* 35 %). Other terrestrial species, such as *Oxyloma/Succinea* spp. (*ca.* 10–18 %), *Vertigo extima* (*ca.* 10–17 %), *Nesovitrea hammonis* (up to *ca.* 10 %), *Euconulus fulvus* agg. (*ca.* 5–10 %), and *Discus* spp., also show increases in this zone, while *Bradybaena* cf. *schrencki*, *Succinella oblonga*, *Carychium pessimum, Vertigo microsphaera, V. pygmaea*, and *V. geyeri* occur in limited or isolated samples only. Aquatic fauna from this zone are dominated by *Gyraulus* B sp., *Aplexa hypnorum*, *Galba truncatula* ex. gr. *sibirica*, and *Stagnicola (atra)* sp. Aquatic species richness is greatest in the lower portion of this unit, which also includes *Gyraulus* A sp. and *G. crista*, *Valvata macrostoma*, *Anisus leucostoma*, *Radix* B sp., *Musculium lacustre*, and *Pisidium* spp. The dominance of wet-ground taxa in this unit indicates the presence of moist, open meadows and marsh habitats on the floodplain. Bracketing AMS radiocarbon dates provide a maximum age of *ca.* < 2800 ^{14}C yr BP (mean pooled average of 4 dates) for the lower boundary and an age of *ca.* > 1520 ^{14}C yr BP (average of 2 dates) for the upper boundary of this zone.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Zone Bsv6, Sub-zones A and B: 0–65 cm (*ca.* 1520 ^{14}C yr BP to the present)

Zone Bsv6 is divided into two sub-zones given the limited abundance in the upper (A) portion. The lower (B) component is represented by comparatively low mollusc abundance and fluctuating species richness. Terrestrial fauna are again dominated by the genus *Vallonia*, including *V. kamtschatica* (up to *ca.* 70 %) and *V. costata* (up to *ca.* 30 %), and to a much lesser extent *V. tenuilabris* (up to *ca.* 7 %). *V. pulchella* and *V.* cf. *chinensis* become increasingly rare or altogether absent from the assemblage, further evidence of increasingly drier habitats on the floodplain. Catholic species such as *Deroceras/Limax* spp., *Punctum pygmaeum, Cochlicopa* cf. *lubrica, Nesovitrea hammonis,* and *Euconulus fulvus* agg., as well as *Oxyloma/Succinea* spp., V*ertigo extima*, and *Pupilla muscorum*, also occur in this sub-zone. Aquatic fauna are represented in negligible numbers and primarily in the lower portion of sub-zone B, and include *Gyraulus* spp., *Aplexa hypnorum, Anisus leucostoma, Galba truncatula* ex. gr. *sibirica*, *Musculium lacustre*, and *Pisidium* spp. *Valvata macrostoma* occurs at the top of this sub-zone. The few terrestrial species from sub-zone A primarily include *Vallonia kamtschatica*, *V. costata*, *V. tenuilabris* and *V. pulchella*, *Deroceras/Limax* spp., *Punctum pygmaeum*, *Vertigo* sp., and *Carychium pessimum*. A seemingly high aquatic percentage for sub-zone A is accounted for by very low mollusc totals in some samples. Aquatic taxa from sub-zone A include *Galba truncatula* ex. gr. *sibirica*, *Gyraulus* spp., *Valvata macrostoma*, *Anisus leucostoma, Radix* B sp., *Musculium lacustre*, and *Pisidium* spp. Despite the decline in mollusc abundance, species present in this zone continue to impart an ecological signature, perhaps indicating a return to increasingly drier conditions at the site from *ca.* 1520 ^{14}C yr BP up until the present. Alternatively, greater anthropogenic activity on the floodplain in historic times could have altered the natural composition of the molluscan population and overprinted any climatic significance for Zone Bsv6.

Vertebrates

Descriptive results from the identification of small vertebrate fossils found at Basovo are summarized in Parfitt (2004). Extracts from this report and integration of data are presented below.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

> Although not common, small vertebrate remains were recovered from much of the stratigraphic sequence at Basovo. Preservation of the bone material was generally good, with some physical breakage, but little sign of soil corrosion, rounding or weathering. Several bones were leached by root action and manganese concretions, which form a coating on surfaces..... implying burial under damp conditions. Good preservation of some particularly fragile specimens indicates lack of transport or post-mortem depositional breakage, suggesting that the bones were buried rapidly in a low-energy depositional environment. A number of the microtine molars show evidence of corrosion by gastric juices, showing that some small mammal material was deposited at the site by predators, probably in the form of regurgitated pellets of birds of prey or in the faeces of mammalian carnivores. Digested bones are dispersed vertically through the section..... with no evidence for concentration of predator-altered bone at any particular level. This suggests that although predators brought some of the bones to the site, not all of the remains were necessarily introduced in this way..... The most abundant bones from the site are of small mammals. Remains of at least 7 species were identified, with stratigraphic distribution as summarised in [Figure 4.11 and Appendix A.5].

The earliest identifiable vertebrate records are from Unit 3, dated between *ca.* 9450 and *ca.* 8260 ^{14}C yr BP, and include the flat-skulled shrew *Sorex roboratus* and the Ungar vole *Microtus maximowiczii*. *Sorex roboratus* is found throughout Siberia, extending from the Pacific Coast west as far as the Ob River and south to Vladivostok, Lake Baikal, and Mongolia, though its associated habitats are still poorly documented (Parfitt, 2004). Hoffman (1985) describes the holotype as having been captured near the Kolyma River mouth in northeast Siberia among dense pine forest. The recovery of the Ungar vole *Microtus maximowiczii* from this unit is exceptionally noteworthy considering that the modern range for this species is apparently restricted to an area extending from the east shore of Lake Baikal to the upper Amur Basin (Corbet, 1978, Gromov and Polyakov, 1992). According to Parfitt (2004):

> *Microtus maximowiczii* is known from only a few localities in that region..... the closest of which is over 200 km [east] of Basovo. It has hitherto never been found west of Lake Baikal...... The identification of the Basovo specimen to species is somewhat tentative because the dentition of *Microtus maximowiczii* is indistinguishable morphologically from its sibling species the Manchurian vole *Microtus fortis* (Orlov *et al.*, 1974). Adults of the two vole species do however differ in size (*Microtus fortis* is larger than *Microtus maximowiczii*) and this disparity in body size is also reflected in dimensions of the teeth (Gromov and Polyakov, 1992). The Basovo first lower molar can be distinguished from that of the *Microtus fortis*, on the basis of its small size; the Basovo M_1 measures 3.02 mm, smaller than that of *Microtus fortis* (length M_1: range 3.3–4.0 mm, mean 3.5 mm), but within the range of *Microtus maximowiczii* (length M_1: range 2.6–3.2 mm, mean 2.9 mm)..... Ecologically, the Manchurian reed vole and Ungar vole inhabit similar environments with a preference for marshes and riparian areas bordering streams and rivers. *Microtus fortis* is strongly associated with marsh-meadow and floodplain meadow along the banks of streams, lakes, and marshes. It prefers bushy banks; especially those rich in fallen logs and moist

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

> meadows overgrown with trees and bushes. According to Ognev (1966) it was found in all locations examined except stone-strewn steppe, bare mountains and typical taiga. *Microtus maximowiczii* lives in birch woodland and in tussock- covered marshes and bush thickets along riverbanks, but it avoids steppe (Ognev 1966).

Vertebrate fossils recovered from the lower portion of Unit 4 (*ca.* < 8260 to *ca.* > 6350 ^{14}C yr BP) include those of the Korean field mouse *Apodemus peninsulae*, a species typically associated with woodland or scrub, as well as numerous amphibian remains. Those from the upper portion of this unit (*ca.* < 6350 to *ca.* > 2800 ^{14}C yr BP) include the grey-sided vole *Clethrionomys rufocanus*, a species that commonly inhabits wet coniferous forests (Kaneko *et al.*, 1998). Remains of northern birch mouse *Sicista betulina* and Eurasian pygmy shrew *Sorex minutus* cluster around the small mammal "peak" near the lithological boundary of Units 6 and 7 (*ca.* < 2800 to *ca.* > 1520 ^{14}C yr BP). The bones of *S. minutus* appear to be from the same individual, and this species is known to occur in a wide variety of habitats including woodland, grassland, dunes and heath, and is also tolerant of damper conditions (Parfitt, 2004). *Sicista betulina* is typically found in woodland or scrub habitats. Approximately 10 cm above this vertebrate "peak", remains of the water vole *Arvicola terrestris* were found. This species indicates more-open vegetation and favors wet meadow, marsh, and banks of rivers and lakes with sedges and reeds (Parfitt, 2004). In summarizing the Basovo vertebrate data, Parfitt (2004) concludes:

> The small mammal fauna therefore provides evidence of woodland and riparian grassland or marsh at the edge of the river..... The presence of *Microtus maximowiczii* at Basovo indicates a westwards extension of its range in the early Holocene..... [The] small-scale concentrations of small mammal specimens centered on 65–70 cm and 185–190 cm do not coincide with peaks in the number of digested bones. These can probably be taken to reflect the accumulation of animals that died of causes other than predation.

Sparse remains of fishes and amphibians are also present throughout the stratigraphic sequence at Basovo, though the identification of these specimens is still unresolved.

Coleoptera

Beetle remains were found in very limited numbers at the Basovo site. All of the recovered specimens were collected from the uppermost 10 cm of the high floodplain section and thus represent essentially modern fauna present at the site. Nonetheless, for

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

completeness of macrofossil analyses and better characterization of the modern environment, these data are included in this discussion. Coleoptera remains are primarily represented by three families: Staphylinidae (*Silpha* sp.?), Scarabaeidae (*Aegialia* sp., *Aphodius* sp., *Heptaulacus* sp., *Homaloplia* sp.) and Curculionidae (*Apion* sp., *Phyllobius* sp. or *Polydrusus* sp., *Trachyphloeus* sp., *Sitona* sp., and *Notaris* sp.) (R. Coope, personal communication, 2004). *Silpha* is a predatory species which feeds on carcass maggots, *Aphodius* and *Heptaulacus* are dung beetles, *Aegialia* lives among grass roots in sandy places, *Notaris* feeds on reedy vegetation, and *Sitona* feeds on the larvae that live on the roots of Papilionacea (R. Coope, personal communication, 2004). While these data are of limited use for the present study, they may be of interest to future scholars of Coleoptera of the Lake Baikal region.

Charcoal

Stratified wood charcoal fragments recovered from screened macrofossil samples from the high floodplain section were examined to identify the range of fossil taxa present at the site. Results from these identifications are reported in Gale (2004) and Appendix A.6, and summarized below.

> With [one] exception..... the samples were small and consisted of tiny fragments of charcoal. Even the larger fragments rarely measured > 1.0mm in radial cross-section and it was unusual to find pieces including more than a single growth ring. The charcoal-rich sample..... from a burn layer [Unit 5], contained fragments measuring up to 10mm in length, with up to 3 growth rings in cross-section..... The charcoal was often poorly preserved and friable and most fragments were either degraded or had been infiltrated with extraneous substances which coated the cell walls. Consequently, it was difficult to examine diagnostic features on the tangential and radial surfaces..... The taxa identified include: Betulaceae [*Betula* sp. (birch)], Salicaceae [*Salix* sp. (willow) and *Populus* sp. (poplar)] and Pinaceae [*Pinus* sp. (pine); *Picea* sp. (spruce); and *Larix* sp. (larch)]. Although the identified charcoal was predominantly coniferous, owing to the degraded wood structure and small fragment size, it was not possible to secure positive identification of this material to genus level..... [and thus] were named as *Pinus/ Picea/ Larix*, based on the presence of axial and horizontal resin canals. Anatomical differences, such as the wall thickness of the epithelial cells lining the resin canals, can be used to distinguish pines (with thin-walls) from spruce and larch (with thick-walls) (Phillips, 1948). In this instance, however, resin canals, although present, were sparse and too degraded to provide a reliable guide. The poor condition of the charcoal also prevented the examination of diagnostic features on the radial surface. It may be worth noting that none of the charcoal appeared to contain the large tracheid to ray pits that occur in Scots pine (*Pinus sylvestris*)..... Willow (*Salix* sp.) and poplar (*Populus* sp.) are also anatomically similar although, in mature wood, it is sometimes possible to distinguish one from the other by the ray type (i.e., heterocellular in willow; homocellular in poplar) (Gale and Cutler, 2000). In the charcoal available [from Basovo], these uniseriate rays were extremely difficult to examine.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Identified wood charcoal samples generally cluster within each of the stratigraphic units representing pedogenic cycles. Unit 3 (*ca.* 9450 to *ca.* 8260 ^{14}C yr BP) is dominated by *Pinus/Picea/Larix*; however *Betula* and *Salix/Populus* also make a presence in the assemblage during soil formation associated with Unit 4 (*ca.* < 6350 to *ca.* > 2800 ^{14}C yr BP). Overlying Unit 5 (*ca.* 2800 ^{14}C yr) contains an abundance of wood charcoal, dominated by *Pinus/Picea/Larix*, but also includes *Betula.* This material is likely reworked and is thought to be associated with the biostratigraphic feature (i.e., burn event) present at the boundary between Units 4 and 5. Above this stratigraphic marker, only coniferous charcoal (*Pinus/Picea/Larix*) is found in each of the overlying stratigraphic units. While the degraded cellular structure of fossil charcoal recovered from Basovo limits its usefulness for ecological interpretations, these data do demonstrate the local presence of coniferous forests throughout the Holocene, as well as increased macrobotanical diversity in the upper portion of Unit 4.

Pollen

Pollen and spores are generally poorly preserved in the highly oxidized and calcareous sediments at Basovo. Of the 8 samples processed to assess the degree of pollen preservation at the site, only one yielded concentrations sufficient to evaluate a palynological signal (S. Boreham, personal communication, 2003). This sample came from the buried pedogenic horizon at the top of Unit 4, just below the charcoal layer dated to *ca.* 2790 ^{14}C yr BP. Pollen yields are represented primarily by pine (*ca.* 70 %) and grass (*ca.* 23 %), along with sedge, Rosaceae, and spores. The soil matrix of this sample may have undergone geochemical alteration induced by the overlying charcoal-rich layer separating Units 4 and 5, which might account for both the greater preservation of fossil pollen and the absence of fossil mollusc shell in this part of the high floodplain stratigraphic sequence. Given the otherwise barren assessment of pollen preservation at the site, processing of the remainder of samples was given a low priority status and ultimately these analyses were suspended altogether. Systematic phytolith studies have yet to be undertaken on these samples but remain a viable paleoenvironmental proxy record for the Basovo site.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Summary

Holocene Reconstruction of the Basovo Site

The data presented above provide a multi-proxy record of Holocene floodplain development at Basovo and allow for the first time a relatively high temporal resolution reconstruction of postglacial environmental change in the upper Lena River valley (Figure 4.12). At the end of the late Pleistocene, gravel (Unit 1) and fine sandy alluvium (Unit 2) began to accumulate along the Lena River bank near what is today the settlement of Basovo, which provided the basal parent materials for the initiation of floodplain aggradation. The upper portion of these sediments contain a malacofaunal assemblage (Zone Bsv1) dominated by *Vallonia tenuilabris*, *Vallonia* cf. *chinensis*, *Punctum pygmaeum*, and *Vertigo extima*, species characteristic of generally cool and moist conditions with associated open-ground, marsh, and forest habitats.

Sedimentation of overlying Unit 3 occurred under a comparatively low energy depositional environment, evident by a fine silty clay loam matrix, with intervening periods of floodplain stability which allowed incipient pedogenic horizons (buried soil E) to form. This cumulic pedogenic sequence was initiated by *ca.* 9450 ^{14}C yr BP and though episodically interrupted by the deposition of very fine alluvium during low energy flood events, soil formation processes and hence relative floodplain surface stability continued until *ca.* 8260 ^{14}C yr BP. Malacofauna from this unit (Zone Bsv2) are both abundant and species-rich, dominated primarily by three terrestrial taxa of the genus *Vallonia*, *V. kamtschatica*, *V.* cf. *chinensis*, and *V. costata*. While the autecology of the former two species remains poorly documented, the latter species is typically known to inhabit open and moderately dry environments. Low abundances of *Vallonia pulchella*, *Succinea/Oxyloma* spp., and *Vertigo extima*, species associated with more moist conditions, as well as the general absence of aquatic taxa, also signify relatively dry habitats on the floodplain. Of further interest is the recovery of *Vertigo microsphaera*, a species previously known only from the Kuril Islands, as well as *V. geyeri* and *V. parcedentata*, which represent the first documented occurrences of these taxa in Asia (Pokryszko, 2003a, personal communication, 2003b). Additionally, the recovery of the Ungar vole *Microtus maximowiczii* in this unit, whose present range is restricted to the drier Trans-Baikal region and had never previously been found west of Lake Baikal, may

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

indicate the local presence of forest-steppe landscapes during the early Holocene in what is today dense taiga. Identified wood charcoal from Unit 3 suggests coniferous forests were also present in the area. The collective early Holocene data indicate that the Basovo floodplain was relatively stable, though episodically under the influence of low energy overbank deposition, which allowed pedogenesis to occur under at least moderately dry and open conditions with nearby forested environments.

Increased landscape instability following this period of early Holocene floodplain pedogenic development is indicated by the deposition of comparatively coarse textured, non-uniform loamy alluvium comprising the lower portion of Unit 4. Malacofauna from this sequence (Zone Bvs3) are both species-rich and the most abundant in the entire assemblage. Associated terrestrial taxa are again dominated by *Vallonia* cf. *chinensis*, as well as *Vallonia pulchella*, *Oxyloma/Succinea* spp., and *Vertigo extima*, the latter three species all known to inhabit wet meadow and marsh habitats. The decline of *V. costata* to negligible levels in this unit supports this ecological interpretation of increasingly wetter conditions at the site. The proliferation of aquatic species such as *Anisus leucostoma* and *Aplexa hypnorum* near the top of this sequence indicates a period of ephemeral pooling on the floodplain surface. Amphibian remains dominate the vertebrate record from this zone. This interval of floodplain aggradation is bracketed by radiocarbon dates of *ca.* < 8260 and *ca.* > 6350 ^{14}C yr BP. These site data indicate that the end of the early Holocene was a period of non-pedogenic floodplain development under conditions increasingly wetter than those which immediately preceeded it.

The uppermost portion of Unit 4 consists of a pedogenic sequence (buried soils D_1 and D_2) representing a renewed period of low deposition and relative floodplain stability at Basovo. Associated malacofauna (Zone Bsv4) show a substantial decrease in abundance but still relatively high species richness, except near the upper boundary of this sequence where they fall to an assemblage minimum. Terrestrial taxa are again dominated by open-ground, marsh, and catholic species, most prominently by members of *Vallonia*. Of particular interest is the recurrence of *V. costata*, whose prevalence indicates a return to drier habitats on the floodplain. The rapid decline in wet-ground taxa such as *Oxyloma/Succinea* spp. and *Vertigo extima*, as well as aquatic species, also indicates a trend towards increasingly drier conditions at the site. *V. pulchella*, however,

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

continues to exist in relatively high numbers, suggesting moister and more diverse habitats on the floodplain. Remains of *Clethrionomys rufocanus* may indicate the presence of moist coniferous forests in close proximity to the floodplain as well. Wood charcoal from this sequence also suggests greater botanical diversity near the site, including mixed coniferous (*Pinus/Larix/Picea*)-deciduous (*Betula* and *Salicaceae*) forests. Sediments from the upper part of this unit yielded palynological data indicative of a pine forest with grassland. Radiocarbon dated wood charcoal again provides bracketing ages for the above sequence (upper component of Unit 4 and Zone Bsv4). The lower boundary is dated at *ca.* 6350 ^{14}C yr BP and the upper boundary to *ca.* 2800 ^{14}C yr BP and 3380 ^{14}C yr BP, respectively. Thus site data spanning the middle Holocene indicate a period of relative floodplain stability which fostered pedogenesis under at least moderately dry conditions, though micro-habitats in the surrounding area were still wet enough to support relatively diverse vegetation complexes and malacofauna and small mammalian taxa accustomed to moister environments.

At the stratigraphic boundary separating Units 4 and 5, a thin lens of charcoal dated to *ca.* 2790 ^{14}C yr BP is interpreted as material redeposited onto the floodplain following a forest fire in the upper Lena River watershed. No evidence was found to suggest that this accumulation of organic debris was the result of anthropogenic activity. The post-fire landscape response was accelerated erosion and increased instability, and subsequent flooding washed this material downstream which accumulated on the floodplain surface near Basovo as loamy deposits (Unit 5) with abundant and widely scattered charcoal (*e.g.*, *Pinus/Larix/Picea* and *Betula* sp.). Weak pedogenic development (buried soil C) on the floodplain followed this period of deposition. Radiocarbon dating of wood charcoal samples from Unit 5 returned ages of *ca.* 2910 ^{14}C yr BP and *ca.* 2620 ^{14}C yr BP, generally consistent with the age obtained from the charcoal layer at the boundary of Units 4 and 5. The uniformity of these dates suggests that the abundant charcoal present in both Unit 5 and much of the overlying sedimentary sequence may be redeposited and associated with this same burning event. The mean pooled average of four AMS radiocarbon dates on charcoal thought to be attributed to this forest fire is *ca.* 2800 ^{14}C yr BP.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

The period following this burn event marks a trend towards both greater landscape instability in the upper Lena River valley and increased sedimentation rates at the Basovo site. Sediment accumulation on the floodplain during the late Holocene (*ca.* 2800 ^{14}C yr BP to the present) is twice that which occurred during the combined early and middle Holocene (*ca.* 10,000–2800 ^{14}C yr BP) periods. Immediately above Unit 5, a renewed period of landscape instability is evident by the deposition of fine sandy loam alluvium which makes up the basal sediments of Unit 6. The overlying cumulic soil profile (buried soil B) of this unit indicates intervals of greater floodplain stability, but this pedogenic sequence was interrupted by the episodic deposition of fine sandy lenses from brief flood events, particularly near the upper boundary of this unit. Malacofauna (Zone Bvs5) reappear in the sequence from an assemblage minimum to being represented by high species richness, but abundances remain comparatively low. The terrestrial taxa *Vallonia kamtschatica*, *Vallonia pulchella*, *Oxyloma/Succinea* spp., and *Vertigo extima* dominate the assemblage and indicate a return of wet, open meadow and marsh habitats on the floodplain. The absence of the moderately dry adapted *Vallonia costata* further supports this interpretation. The relatively high numbers of aquatic taxa may reflect the periodic inundation of flood waters. Wood charcoal from the pedogenic horizon in the center of this unit was dated to *ca.* 2780 ^{14}C yr BP, consistent with the interpretation that charcoal from the underlying sequence has been reworked into overlying sediments and is thus in a redistributed context. The collective data from this sequence indicate that the beginning of the late Holocene was a period of fluctuating landscape conditions, marked by periods of floodplain stability and soil formation under increasingly wet conditions, along with episodic flooding events and the deposition of fine sandy alluvium.

The overlying sedimentary sequence (Unit 7) again consists of fine sandy loam alluvium weakly altered by two distinct pedogenic profiles (buried soil A and the modern surface soil). The basal sediments from this unit contain the highest percentage of sand in the entire sequence and indicate a significant period of floodplain deposition. Vertebrate remains are extremely abundant in these sandy sediments, represented by the small mammal species *Sicista betulina*, *Sorex minutus*, and *Arvicola terrestris*. However, the association of this distinct "vertebrate peak" with relatively coarse sandy alluvium may indicate a hydrological concentration of this material. A weakly developed buried

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

pedogenic profile occurs above this unaltered alluvium and the overlying modern surface soil delineates the upper boundary of the high floodplain stratigraphic section. Associated malacofauna (Sub-zones Bsv6B and Bsv6A) show a decrease in both abundance and diversity, but they continue to yield an ecological signature despite this decline. Wet-ground taxa, such as *Vallonia pulchella*, *Oxyloma/Succinea* spp., and *Vertigo extima*, begin to disappear while *Vallonia costata* becomes a dominant component of the assemblage. These data may indicate a return to drier conditions on the floodplain, however anthropogenic activity may also be a factor influencing mollusc abundance and composition in this zone. Two wood charcoal samples from the buried soil horizon of Unit 7 average *ca.* 1520 ^{14}C yr BP. This biostratigraphic sequence indicates that the latter portion of the late Holocene up to the present can be characterized as a continuation of fluctuating landscape stability and instability on the Basovo floodplain, possibly under relatively dry conditions.

In summary, results from the Basovo site provide a detailed multi-proxy record of Holocene environmental change in the upper Lena River valley of Cis-Baikal. These data document paleohydrological regimes, pedogenic cycles, and faunal sequences at relatively high temporal resolutions and give insights into shifts in ecological conditions over the last *ca.* 10,000 years in an area where similar studies have yet to be undertaken. Furthermore, the malacological record from the site is a particularly rare and unique scientific dataset for the region. While additional site investigations are needed for establishing more definitively the paleoecological conditions of the upper Lena River valley, the Basovo record is nonetheless an important starting point for reconstructing both the environmental history of the area and the ecological context of resident Mesolithic and Neolithic hunter-gatherer populations in this part of Cis-Baikal. These issues will be discussed in more detail in Chapter 6 of this dissertation.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Unit	**Depth (cm)**	**^{14}C yr BP**	**Cal. yr BP 68 % c.i. (1σ)**	**Cal. yr BP 95 % c.i. (2σ)**	**Material**	**Lab #**
7	30–35	1630 ± 90	1415 – 1615	1330 – 1720	Charcoal	TO-10557
7	40–45	1410 ± 60	1290 – 1350	1260 – 1415	Charcoal	TO-10556
6	82	2780 ± 360	2430 – 3360	2040 – 3780	Charcoal	TO-9431
5	97	2620 ± 90	2710 – 2780	2465 – 2880	Charcoal	TO-9436
5	95–100	2910 ± 60	2950 – 3080	2915 – 3215	Charcoal	TO-10555
4	100–105	2790 ± 60	2840 – 2950	2765 – 3005	Charcoal	TO-10554
4	105	3380 ± 80	3550 – 3695	3445 – 3785	Charcoal	TO-9433
4	130–135	6350 ± 120	7200 – 7420	6985 – 7475	Charcoal	TO-10973
3	170–175	8260 ± 130	9025 – 9430	8985 – 9530	Charcoal	TO-10553
3	195	8770 ± 100	9595 – 9915	9535 – 10,185	Charcoal	TO-9434
3	195	9490 ± 80	10,665 – 10,485	10,550 – 11,120	Charcoal	TO-9432
3	197	9880 ± 80	11,195 – 11,260	11,165 – 11,440	Charred bone	TO-9435

Table 4.1. Basovo High Floodplain Section 2 (HFS2) AMS radiocarbon chronology.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Open-ground:

Columella columella (Martens 1830)
Succinella oblonga (Draparnaud, 1801)
Vallonia pulchella (Müller 1774)
Vertigo parcedentata (Al.Braun, 1847)
Pupilla muscorum (Linnaeus 1758)
Vallonia costata (Muller 1774)
Vallonia tenuilabris (Al.Braun 1843)
Vertigo pygmaea (Draparnaud, 1801)

Shade-demanding:

Vertigo alpestris Aldes, 1838
Bradybaena cf. *schrencki* (Middlendorf, 1851)
Discus spp.

Catholic:

Deroceras/Limax spp.
Euconulus fulvus agg. (Muller 1774)
Punctum pygmaeum Draparnaud, 1801
Cochlicopa cf. *lubrica* (Müller 1774)
Nesovitrea hammonis (Ström, 1765)

Marsh:

Carychium pessimum Pilsbury, 1901
Succinea/Oxyloma spp.
Vertigo genesii (Gredler, 1856)
Zonitoides nitidus (Müller 1774)
Galba truncatula ex. gr. *sibirica* (Müller 1774)
Gastrocopta theeli (Westerlund, 1877)
Vertigo antivertigo (Draparnaud, 1801)
Vertigo geyeri Lindholm, 1925
Vertigo extima (Westerlund, 1877)

Aquatic:

Aplexa hypnorum (Linnaeus, 1758)
Bathyomphalus contortus (Linnaeus, 1758)
Gyraulus cf. *albus* (Müller, 1776)
Gyraulus B sp.
Radix A *(ovata)* sp.
Stagnicola atra sp.
Valvata macrostoma Mörch, 1864
Pisidium henslowanum (Sheppard, 1823)
Pisidium nitidum Jenyns, 1832
Musculium lacustre (Müller, 1774)
Polypylus sibirica Starobogatov et Streletzkaja, 1967
Anisus leucostoma (Millet, 1813)
Gyraulus crista (Linnaeus, 1758)
Gyraulus A sp.
Hippeutis complanatus (Linnaeus, 1758)
Radix B sp.
Valvata aliena Westerlund, 1877
Pisidium casertanum (Poli, 1791)
Pisidium milium Held, 1836
Pisidium subtruncatum Malm, 1855
Sphaerium sp.

Insufficient data:

Vallonia cf. *chinensis* Suzuki 1944
Vertigo microsphaera Schileyko, 1984
Vallonia kamtschatica Likharev, 1963

Table 4.2. General ecological categories of mollusc species found at Basovo.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

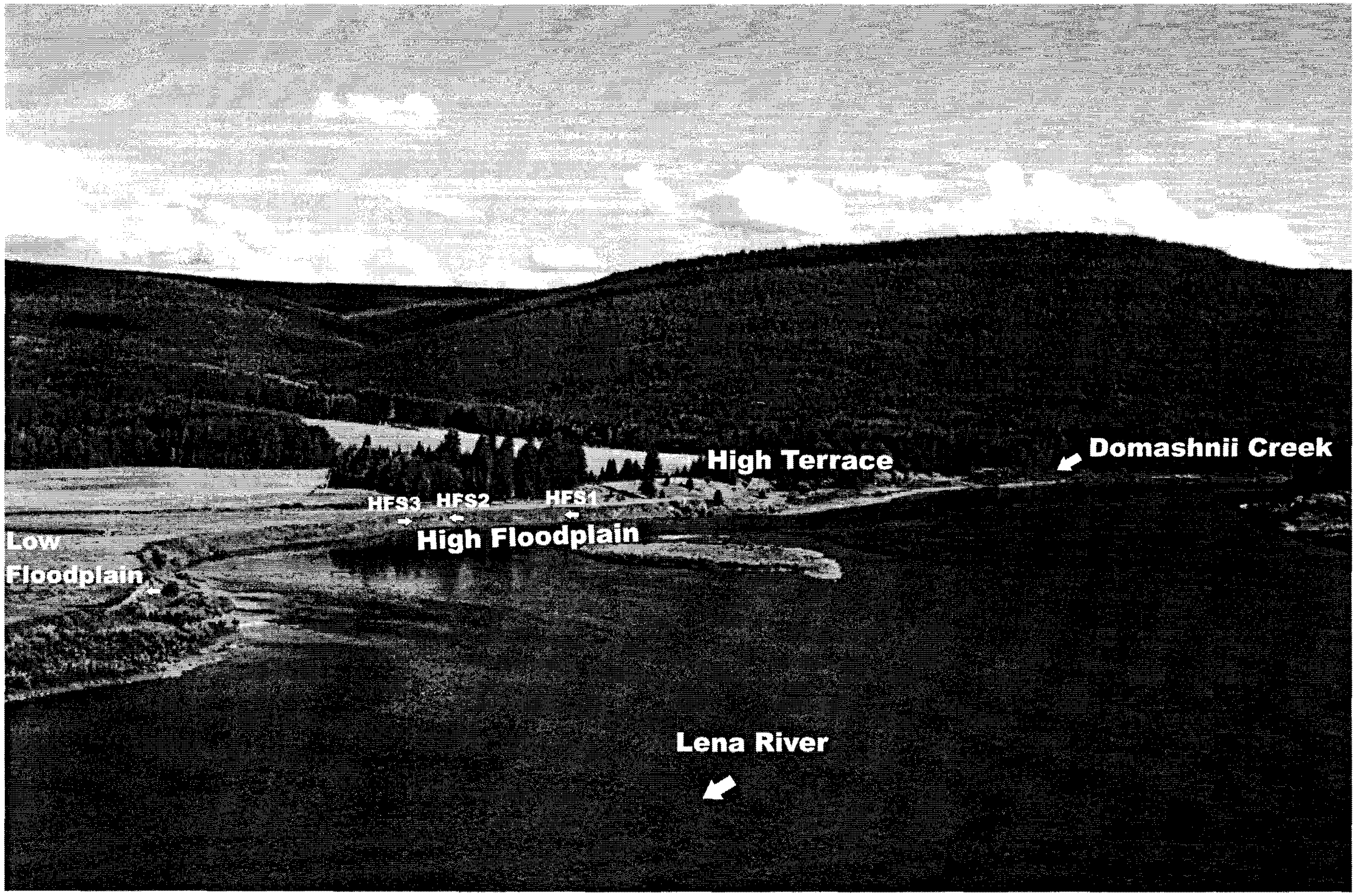


Figure 4.1. Basovo study site (location of stratigraphic sections indicated by small arrows, view looking east).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

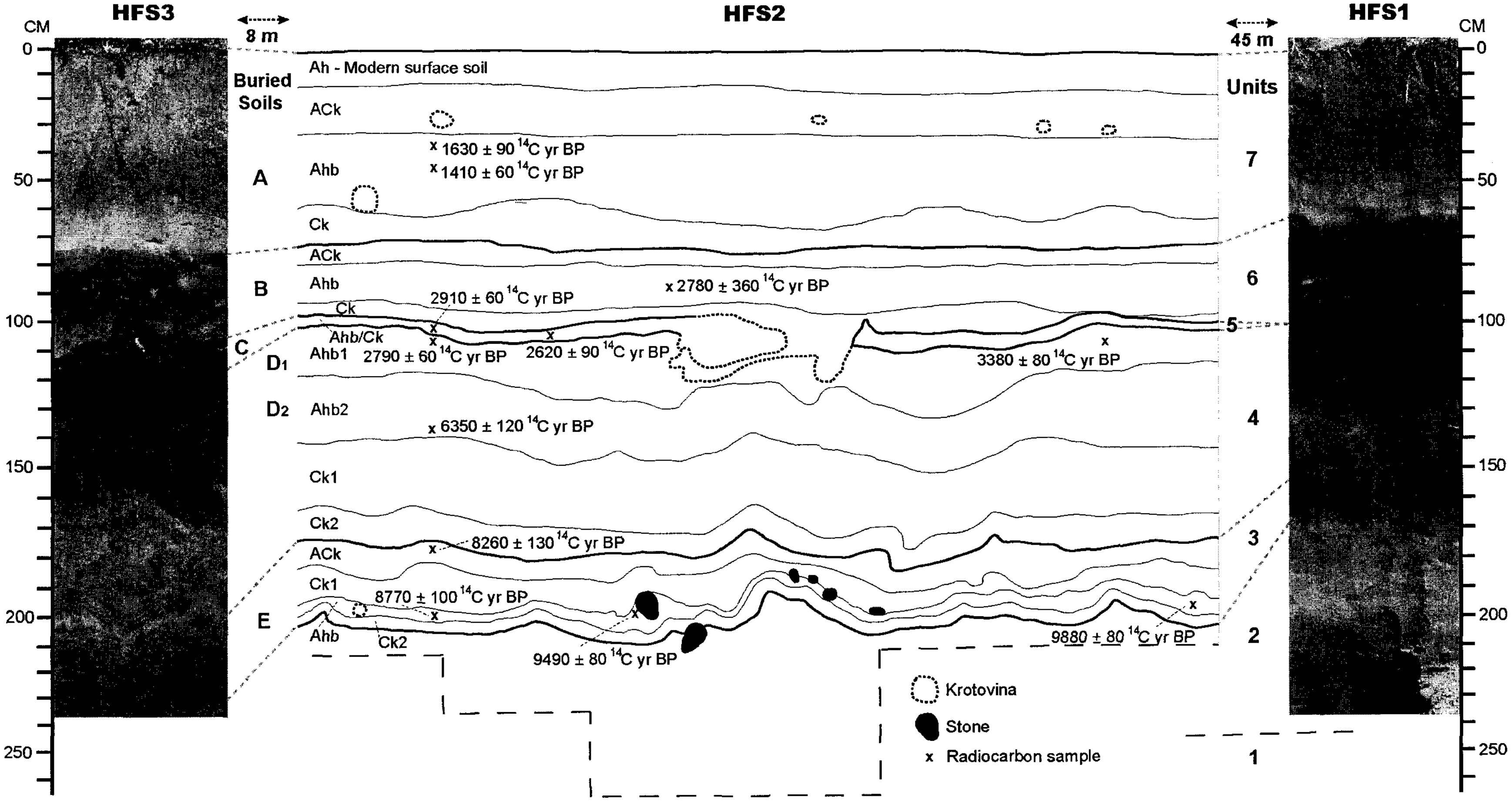


Figure 4.2. Basovo High Floodplain Sections 1, 2, and 3 (HFS1, HFS2, and HFS3) - Stratigraphic illustrations.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

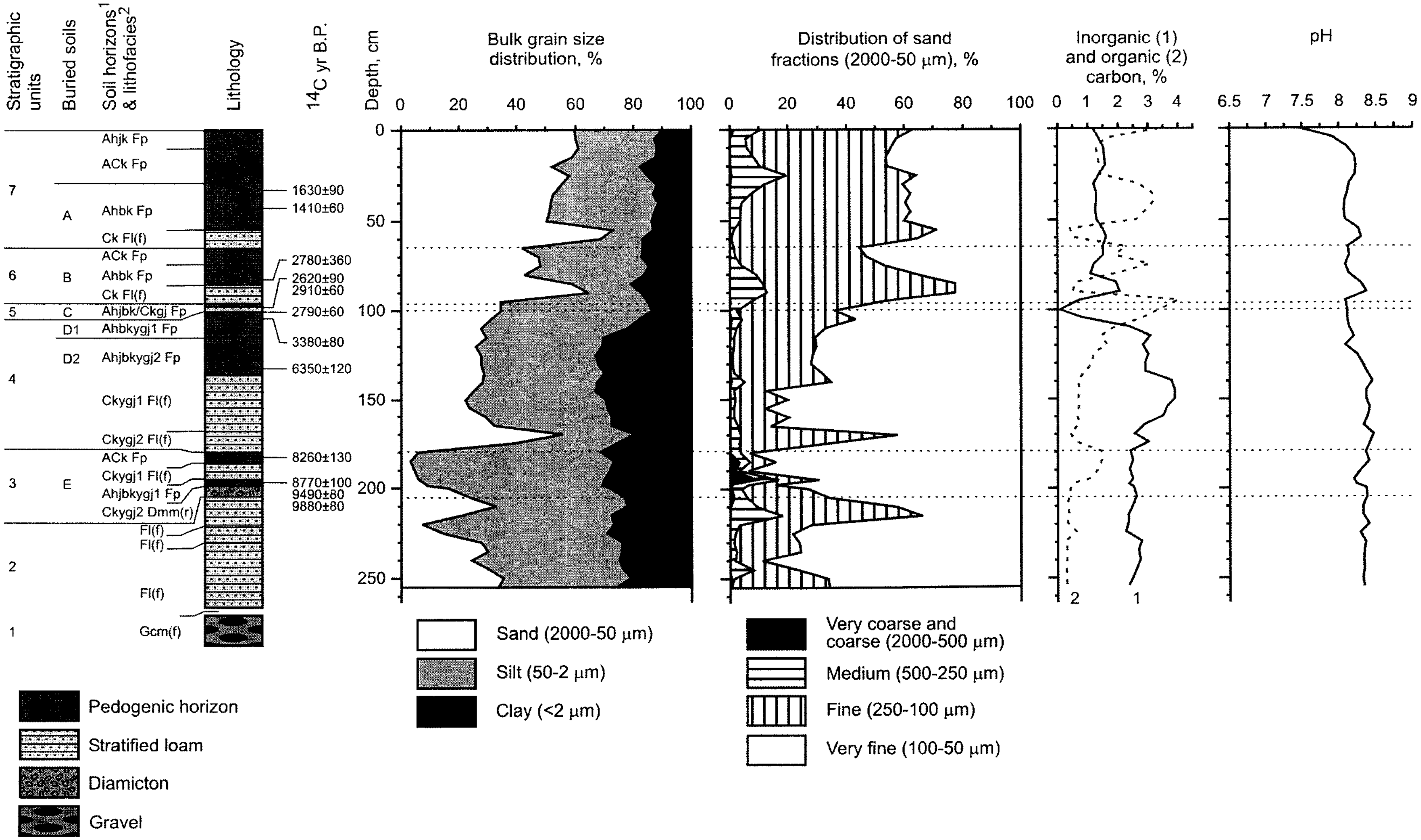


Figure 4.3. Basovo High Floodplain Section 2a (HFS2a) - Stratigraphic data summary (for pedologic¹-lithofacies² explanations see Appendix A.1).

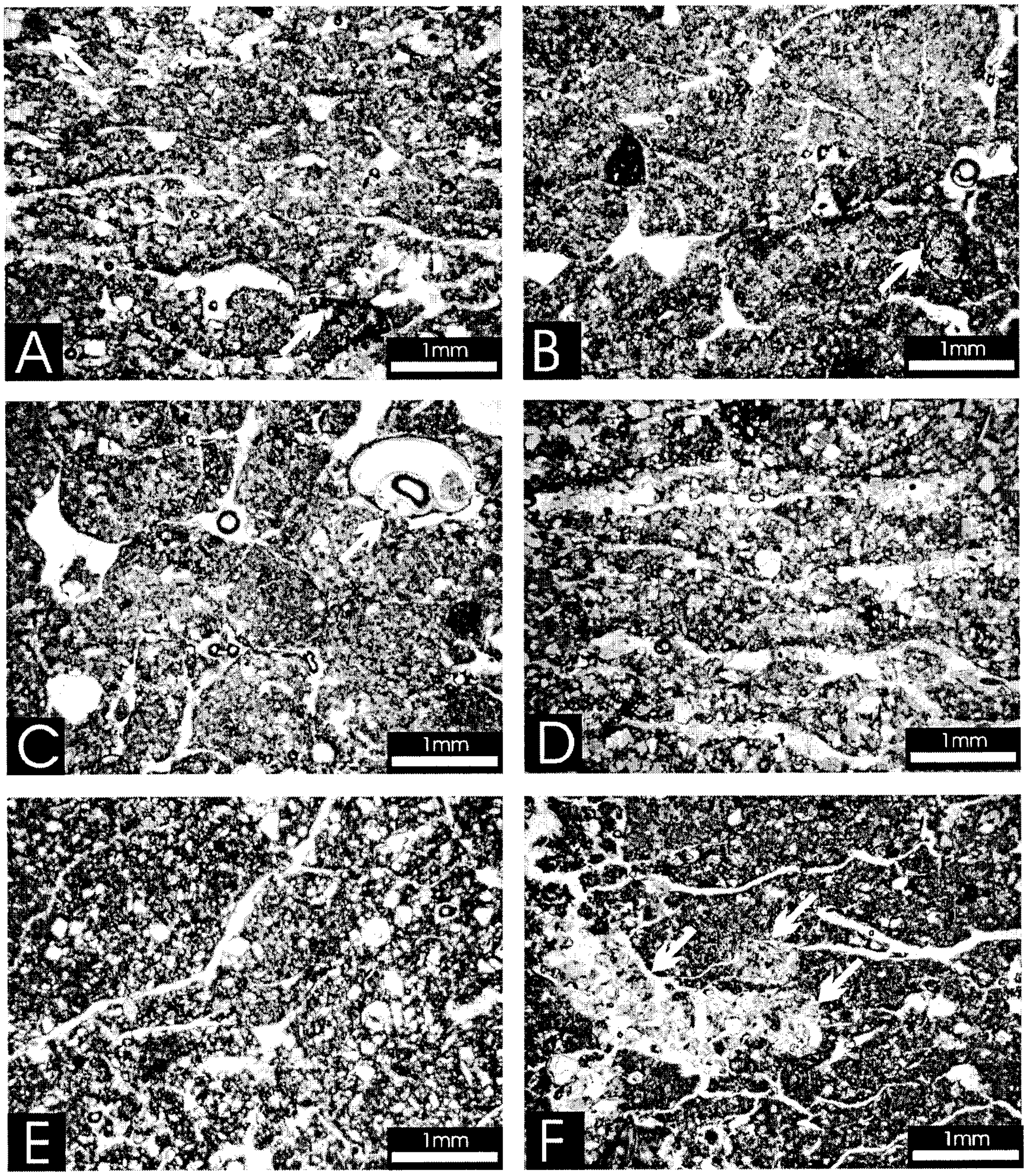


Figure 4.4. Basovo High Floodplain Section 2 (HFS2) - Micromorphological features (PPL, x20).

(A) Unit 2, 213-223 cm. Note platy structure and iron nodules (pointed with arrows);

(B) Unit 3, 172-182 cm. Note subangular blocky structure, iron nodules, and charcoal fragment (pointed with arrow);

(C) Unit 3, 172-182 cm. Note subangular blocky structure, iron nodules and mollusc shell (pointed with arrow);

(D) Unit 4, 164-174 cm. Note platy structure, sandy texture and iron mottling;

(E) Unit 4, 101-111 cm. Note fissure structure and sandy texture;

(F) Unit 5, 96 -106 cm. Note infilling of biogenic channel voids (pointed with arrows).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

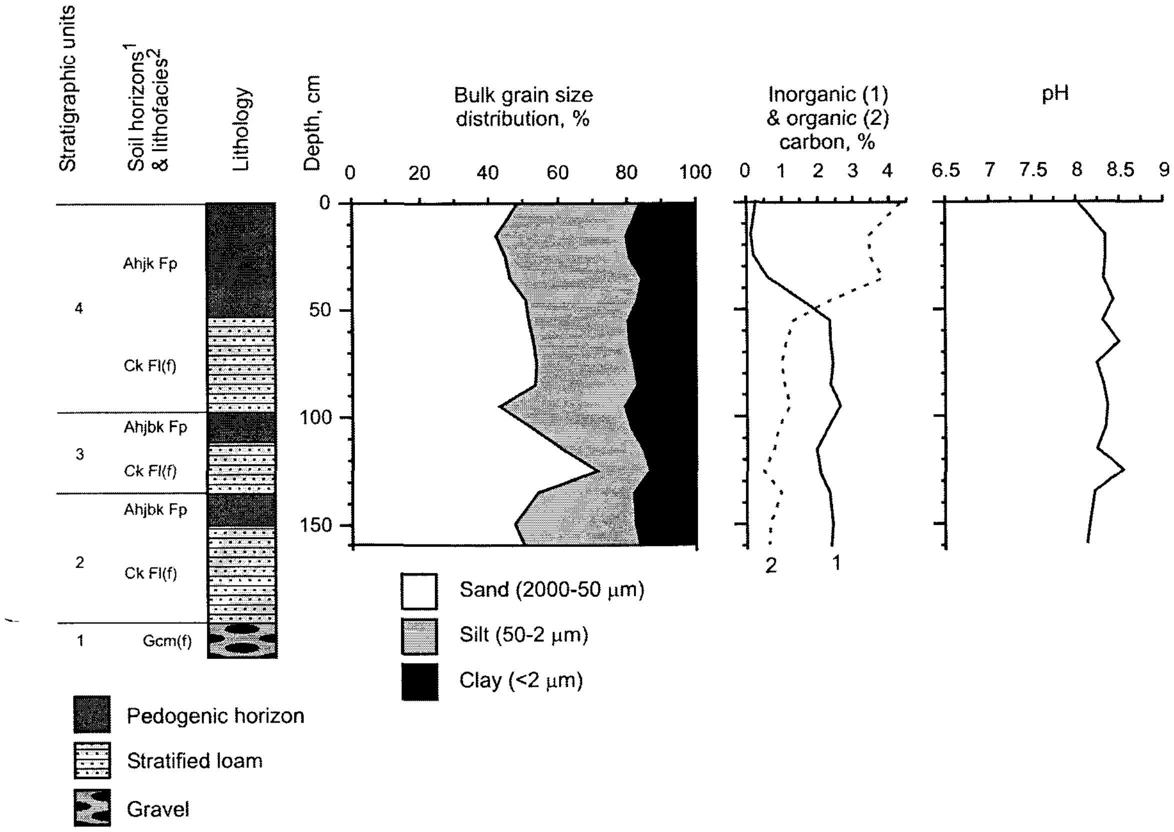


Figure 4.5. Basovo Low Floodplain Section - Stratigraphic data summary (for pedologic¹-lithofacies² explanations see Appendix A.1).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

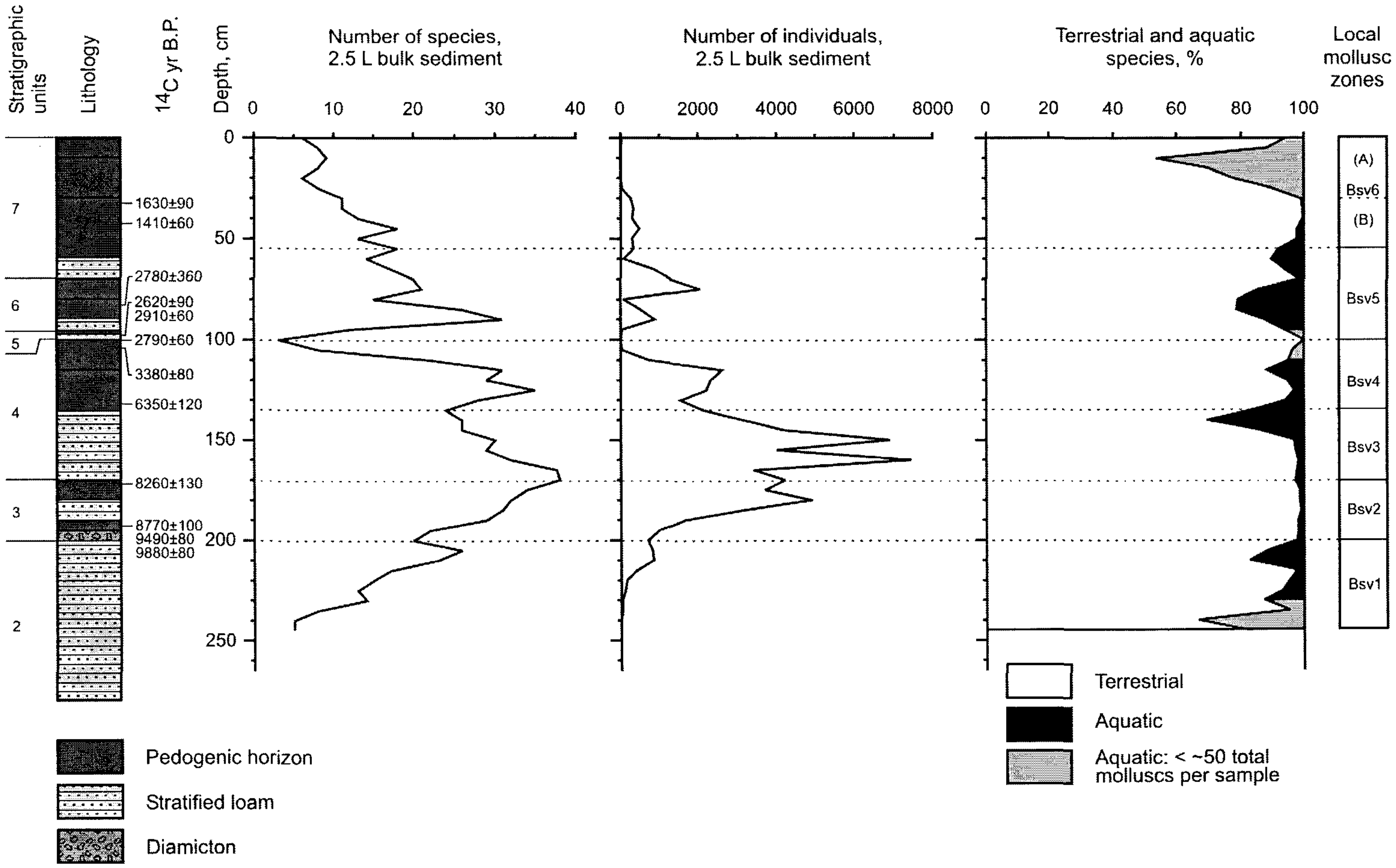


Figure 4.6. Basovo High Floodplain Section 2b (HFS2b) - Ecological profile of the fossil molluscan assemblage.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

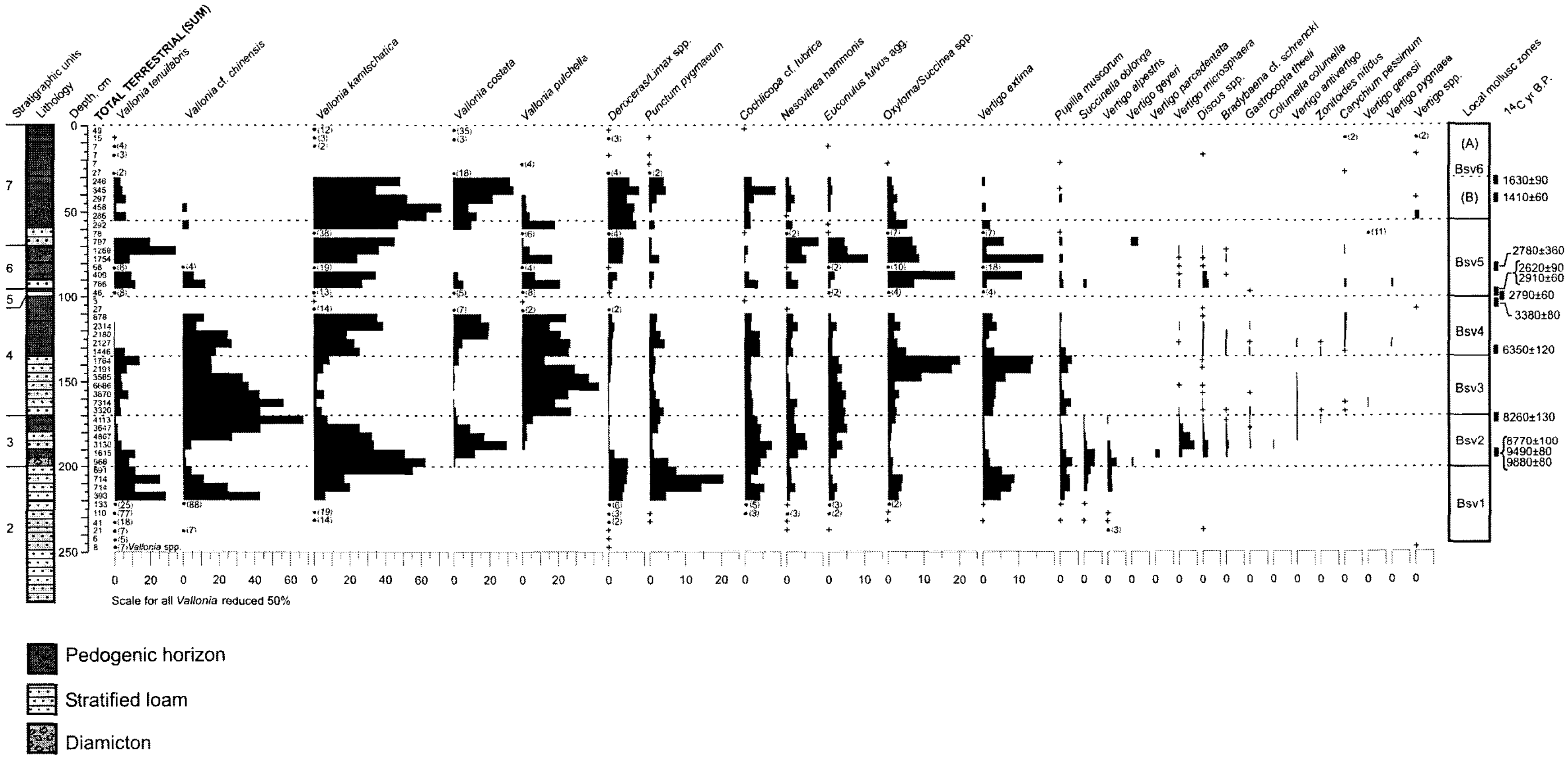


Figure 4.7. Basovo High Floodplain Section 2b (HFS2b) - Terrestrial mollusc frequency histogram. All values expressed as percentages of total land snails (+ indicates single shells; • (#) indicates number of shells in samples with less than 200 individuals).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

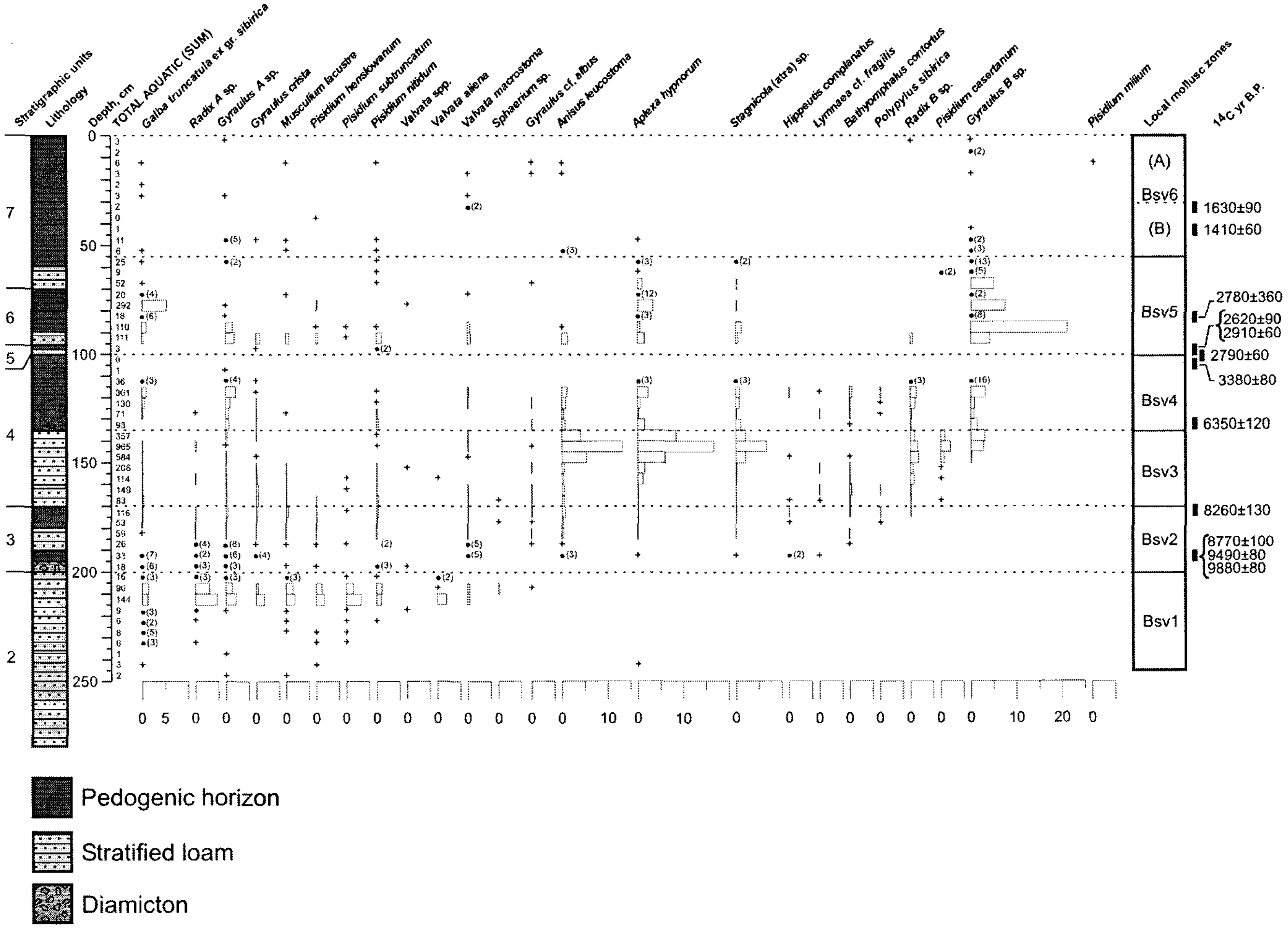


Figure 4.8. Basovo High Floodplain Section 2b (HFS2b) - Aquatic mollusc frequency histogram. All values expressed as percentages of total land snails (+ indicates single shells; • (#) indicates number of shells in samples with less than 50 individuals).

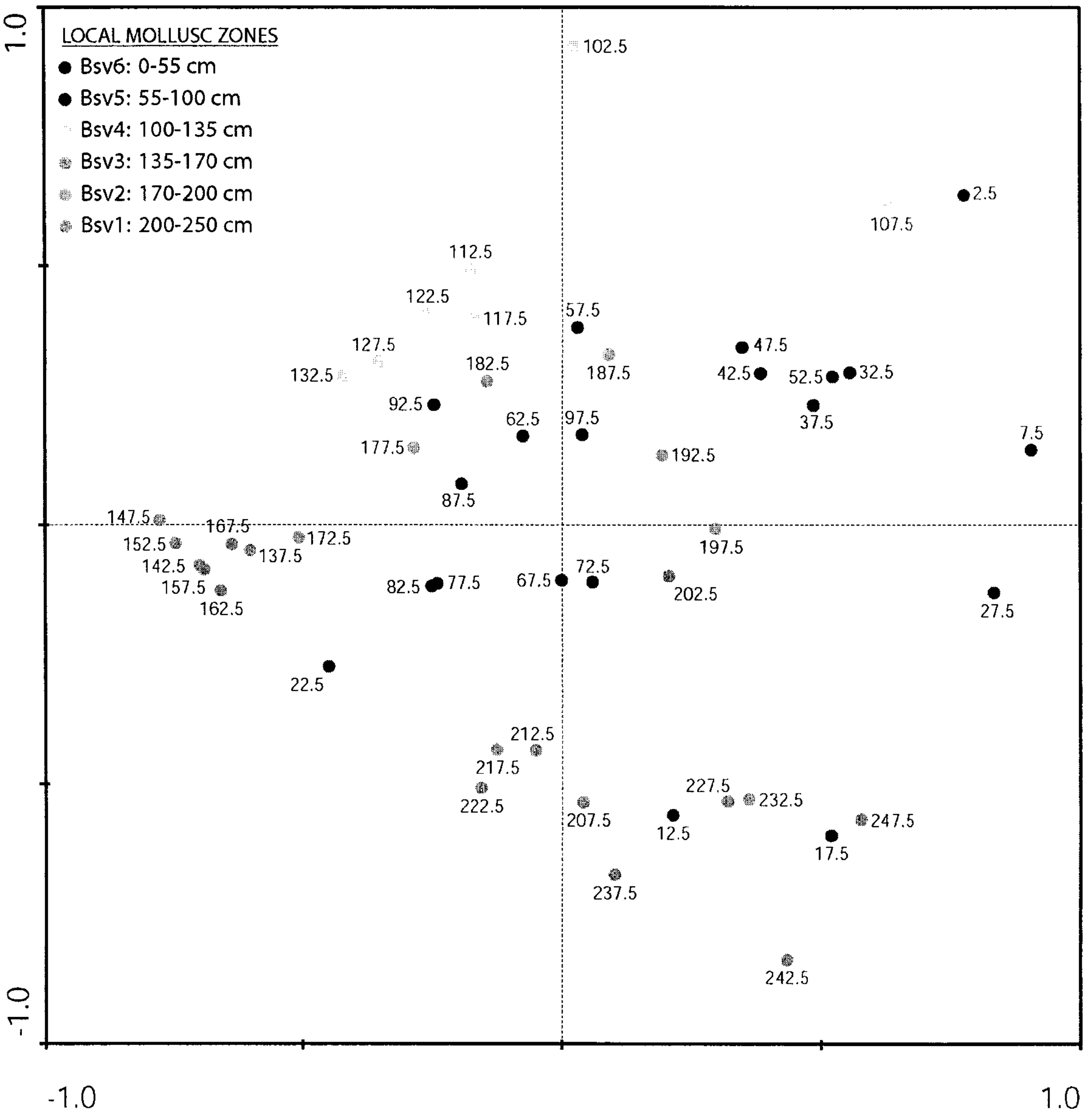


Figure 4.9. Principal components analysis (PCA) of Basovo mollusc samples, numbers correspond to sample depth (cm).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

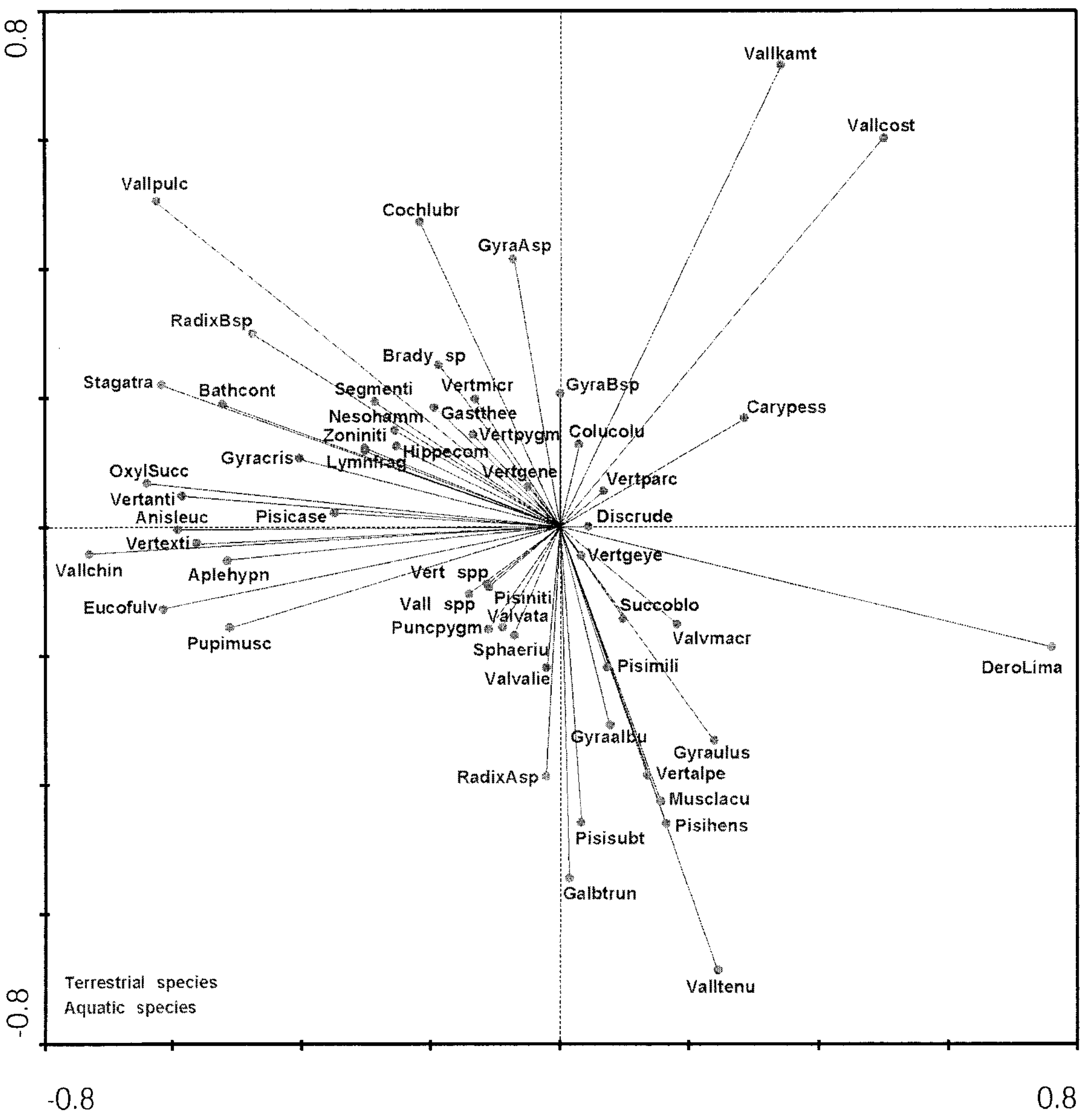


Figure 4.10. Principal components analysis (PCA) of Basovo molluscan species.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

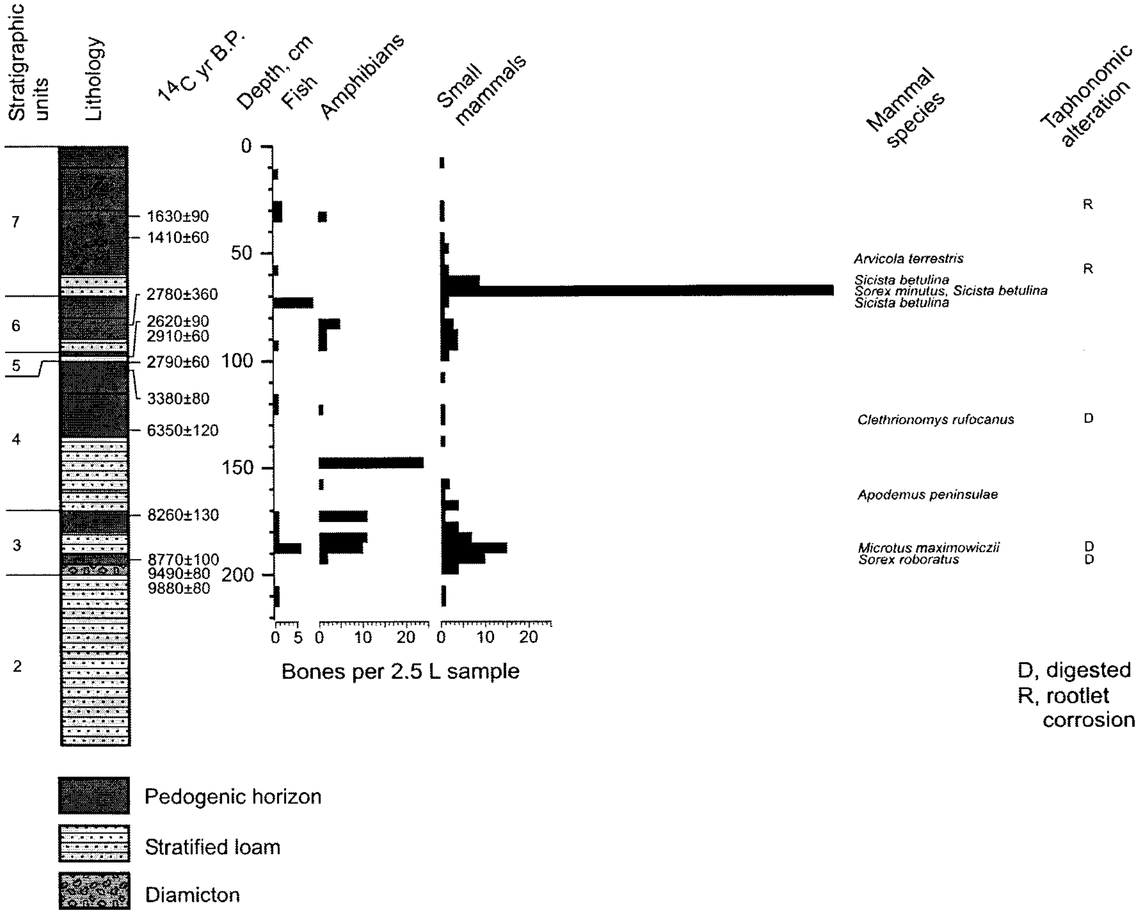


Figure 4.11. Basovo High Floodplain Section 2b (HFS2b) - Vertebrate frequency histogram.

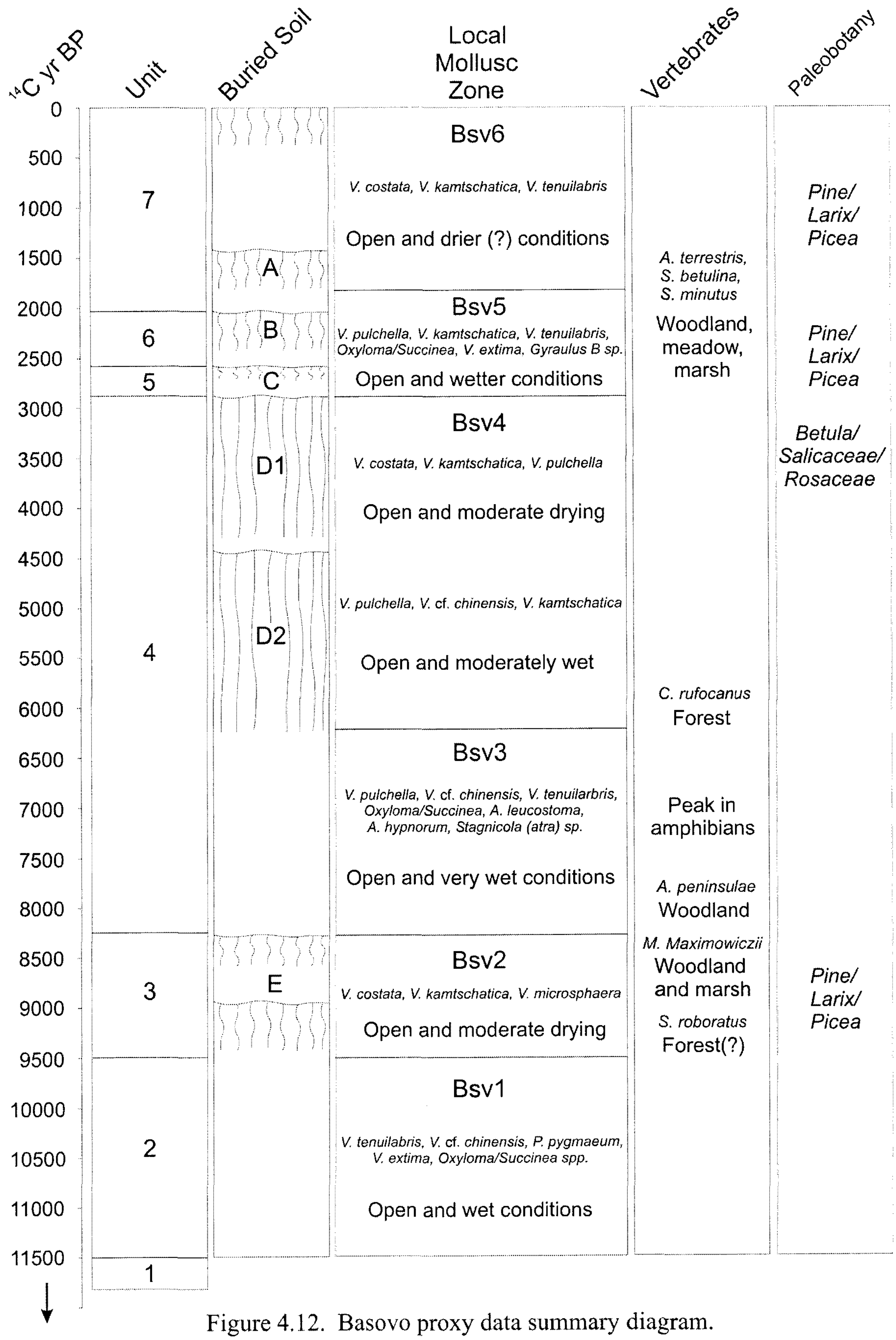


Figure 4.12. Basovo proxy data summary diagram.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

CHAPTER 5

The Burdukovo Site, Lower Selenga River Valley: Results and Interpretations

Introduction

As both a comparative study to the Basovo site record and to document better the local and regional patterns of Holocene environmental change in the broader Baikal area, stratigraphic and paleoecological sequences were also investigated along a terrace cutbank of the lower Selenga River in western Trans-Baikal (Figures 2.1 and 5.1). The study site is located *ca.* 3.5 km downstream from the settlement of Burdukovo (Figures 5.1 and 5.2). In this area, the Selenga River valley bottom is up to *ca.* 2.5 km wide and includes up to three terrace levels and a narrow (*ca.* 10 m), gravelly modern floodplain (Bazarov 1968). The *ca.* 18–22 m terrace (T-3) was not clearly visible in the immediate site area, but a remnant of the *ca.* 10–12 m terrace (T-2) is present where Sukhaia Ravine emerges from hilly terrain to join the Selenga River valley. Here sediments are exposed in a steep (up to *ca.* 30°) *ca.* 5–6 m scarp composed of fine-grained sandy loam with weakly defined parallel horizontal bedding. Modern soil cover is classified as a Eutric Brunisol (Eutric Cambisol). Buried soils and macrofossil remains were not present in exposed sections of this *ca.* 10–12 m terrace.

The first terrace (T-1) of the lower Selenga River is *ca.* 4–6 m high and extends for a distance of over *ca.* 2.5 km between the settlement of Burdukovo and the outlet of Sukhaia Ravine, reaching up to *ca.* 350–400 m at its widest point (Figures 5.1 and 5.2). Closer to Burdukovo (*i.e.*, to the south), the terrace cutbank is composed primarily of fluvial derived coarse textured sand and gravelly sediments. With increased proximity to Sukhaia Ravine (*i.e.*, downstream), the height of the terrace increases noticeably and consists of much more finely textured deposits overprinted by numerous buried, weakly developed pedogenic profiles. This sedimentary sequence is represented by three distinct depositional environments, including basal sediments composed of generally fossiliferous

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

(*i.e.*, mollusc-rich) fine-grained alluvium, a thin though distinct clay-rich lacustrine deposit, and overlying fine sandy beds of aeolian origin. Soil formation has occurred repeatedly at the site during periods of greater landform stability (Cumulic Humic Regosols and Cumulic Regosols [Mollic Fluvisols and Cumulic Arenosols]).

Stratigraphic assemblages along the first terrace cutbank were described and sampled in detail at two sections located *ca.* 72 m from each other, designated as T1.100 and T1.28 (Figure 5.3). Section T1.100 includes the underlying alluvial and lacustrine deposits (Units 1–4) at the site while section T1.28 comprises the overlying aeolian sediments (Units 5–6). These study sections are located between two buried depressions measuring *ca.* 25.0 m wide by *ca.* 2.8 m in depth and *ca.* 40.0 m wide by *ca.* 2.5 m in depth, to the north and south respectively, which represent former intermittent tributaries or abandoned channels of the lower Selenga River (Figure 5.3). Results from stratigraphic investigations at the site are described below and summarized in Table 5.1, Figures 5.4 and 5.5, and Appendices A.1, A.7, and A.8. A more detailed and high resolution sedimentological and mineral magnetic study of the overlying aeolian-pedogenic sequences (*i.e.*, samples collected during the 2004 field season) is currently in progress as part of a graduate student thesis in the Department of Physics, University of Alberta.

Stratigraphy

Unit 1

Lithology: Unit 1 is represented by non-fossiliferous, bedded sandy gravel composed of clast-supported pebbles and cobbles of variable color and mineralogy. Clasts also vary in size and morphology but generally fall within the range of *ca.* 5–10 cm in long-axis diameter and are predominately well-rounded. These basal sediments exhibit a relatively consistent stratigraphic arrangement along the first terrace cutbank under study. At section T1.100, this unit occurs at *ca.* 4.20 m below surface and has a sharp and slightly undulating boundary with overlying sandy sediments.

Interpretation: The deposition of Unit 1 occurred in a high-energy fluvial environment and represents a gravel bar of the lower Selenga River, likely dating to the late Pleistocene.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Unit 2

Lithology: Overlying Unit 2 consists of dark brown to brown (10YR 4/3–5/3) stratified loamy sediments with thin interlayers (*ca.* 1–3 cm thick) of very-fine to medium sands. This unit is *ca.* 0.90 m thick at section T1.100 and is generally coarser with more frequent lenses of sand in the non-fossiliferous lower portion where weak cross-bedding is also observed. These deposits are highly calcareous and have very low carbon contents (*ca.* < 0.8 %). Fe-Mn nodules (up to *ca.* 2.0 mm in diameter) and Fe-mottles (up to *ca.* 8.0 mm in diameter) are most abundant in the lower half of this unit, and carbonate coatings are common around matrix pore spaces. Frequency dependency of magnetic susceptibility (or FD value) is low and relatively stable. The stratigraphic boundary with underlying coarse gravel (Unit 1) is abrupt and wavy. Molluscs are abundant in the upper part of this unit. AMS dating of charred organic material collected at a depth of 3.4–3.5 m from this unit returned an age of 5655 ± 650 ^{14}C yr BP.

Interpretation: Unit 2 is interpreted as a relatively heterogeneous mix of loamy alluvial sediments, the result of differential fluvial sorting, which episodically accumulated along the bank of the Selenga River during the late Pleistocene–early Holocene and thus represents the initiation of postglacial floodplain and terrace development at the site. Given the stratigraphic association, high error margin, and age of overlying AMS radiocarbon samples from this section, material dated from this unit is considered to be in an intrusive or redeposited context. To better clarify the age of Unit 2, a sediment sample collected in a 25 cm long by 5 cm wide aluminum tube from a depth of 4.0 m below surface was submitted in April 2005 to the Archaeometry and Geochronology Laboratory at McMaster University, Hamilton, Ontario, Canada, for optically stimulated luminescence dating. Results from this sample are expected in early 2006.

Unit 3

Lithology: Unit 3 is *ca.* 1.10 m thick at section T1.100 and composed primarily of silty loam overprinted by pedogenic development in roughly the upper half of the unit. The lower component of this unit is predominantly dark greyish brown (10YR 4/2) in

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

color though darkens upward from very dark greyish brown (10YR 3/2) to very dark grey (10 YR 3/1) due to increased organic carbon content, which ranges from *ca.* 0.4 % at the base of the unit to *ca.* 1.4 % at the upper boundary. Textural composition of the lower, non-pedogenic portion of this unit is generally more homogeneous than underlying Unit 2, although occasional lenses of sandier material are evidence of limited fluvial sorting in the otherwise very weakly stratified parallel horizontal bedding. Weak Fe-mottling and common Fe-Mn nodules (up to *ca.* 2.0 mm in diameter) are also present in this bedded sequence. FD values are relatively stable before increasing sharply under the influence of soil formation processes near the top of the unit. Unit 3 also contains very poorly preserved plant tissue fragments, and malacofaunal abundance and species richness both reach a maximum in this unit.

Pedogenic development in the upper portion of Unit 3 is indicated by darker colors, high organic carbon content, weak granular to subangular blocky macrostructure, high FD values, and the presence of several krotovina and other traces of meso-fauna. This pedogenic sequence has a relatively uniform thickness along the *ca.* 100 m section of the terrace cutbank under study, occurring between 2.20–2.60 m below the modern surface at section T1.100. Limited deposition of sandier material during pedogenesis is also indicated. Soil horizon boundaries in this unit are generally clear to gradual and wavy. A charcoal sample collected at a depth of 2.58 m at section T1.100 returned an age of 8230 ± 120 ^{14}C yr BP, and humic acids from bulk soil collected from the uppermost 10-centimeters (2.20–2.30 m below surface) of this unit were dated to 7370 ± 70 ^{14}C yr BP.

Interpretation: Unit 3 is interpreted as the sedimentation of increasingly fine alluvium onto the aggrading floodplain followed by the initiation of pedogenic development and thus relative surface stability at the site for the first time during the Holocene period. This interval of soil formation lasted from *ca.* 8230 ^{14}C yr BP to *ca.* < 7370 ^{14}C yr BP, however minor inundations of floodwaters during this period are also evident. The boundary of this pedogenic sequence with overlying Unit 4 is very sharp, an indication of a relatively abrupt cessation of soil forming processes and hence rapid transformation of the floodplain surface.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Unit 4

Lithology: Deposits representing Unit 4 consist of a thin, laminated layer of dark yellowish brown (10YR 4/4) silty clay loam ranging between *ca.* 5–10 cm in thickness. At section T1.100 this unit occurs at a depth between 2.10–2.20 m below surface, although in horizontal profile along the terrace cutbank this unit is somewhat arched, sloping gently downward near each of the buried depressions which truncate the unit. Unit 4 contains *ca.* 30 % clay and is almost entirely devoid of sand-size or larger particles. Platy laminations within this unit are overprinted with subangular and angular blocky structure, a feature attributed to repeated wetting and drying (or freezeing and thawing) cycles rather than strong soil forming processes, though weak pedogenesis at the top of this unit is also indicated. FD values continue to remain high, and low values of low frequency magnetic susceptibility may reflect gleyic processes. The upper boundary of Unit 4 is not as sharp as the lower boundary, suggesting a more gradual change in the environmental conditions which followed. Mollusc shells are very limited in this unit. Charred organic remains cluster together occasionally in this unit, and material from one of these clusters was radiocarbon dated to 5720 ± 430 ^{14}C yr BP (2.19 m below surface).

Interpretation: Unit 4 is interpreted to be lacustrine in origin, having formed following high water levels and subsequent ponding on the floodplain surface. The slow deposition of suspended fines accounts for the distinct clay-rich sedimentary texture of this unit. Periodic desiccating and wetting cycles are also evident in Unit 4, and incipient pedogenic development occurred following the final drying phase and prior to the deposition of overlying fine sandy material from Unit 5. The radiocarbon date from this unit is again considered suspect given the stratigraphic context, high error margin, and age inversion with other dated material in the stratigraphic sequence. Further, these charred remains from Unit 4 are consistent in age with organic material dated from Unit 2, which may point to a similar intrusive origin. Taking into account the bracketing ages from adjacent units, Unit 4 is estimated to be *ca.* 7000 ^{14}C yr BP. This unit represents an important stratigraphic and temporal marker along the first terrace cutbank, separating underlying alluvial parent materials from overlying aeolian sediments.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Unit 5

Lithology: Unit 5 ranges between ca. 2.0–2.3 m in thickness and is tentatively divided into four sub-units (5a–5d). Sub-unit 5d is *ca.* 0.40 m thick and is present only near section T1.28 where it directly overlies clay-rich Unit 4. This sub-unit consists of a wedge-like assemblage of massive brown to light yellowish brown (10YR 5/3–6/4) sandy loam with three thin (*ca.* 3–5 cm), intervening (*i.e.*, compounded or multistory), very dark grey (10YR 3/1) incipient soil horizons. Pedogenic features are indicated by dark colors and high organic carbon contents, subangular blocky structural development, and high FD values. Molluscs were not found in Sub-unit 5d. Boundaries between pedogenic and non-pedogenic horizons throughout Unit 5 are generally clear and wavy. AMS dating of charcoal recovered at a depth of 2.45 m from the lowermost pedogenic horizon from this sub-unit returned an age of 6890 ± 80 ^{14}C yr BP.

Overlying Sub-unit 5c is present along the entire terrace cutbank under study, however its stratigraphic expression varies somewhat. At section T1.28, this sub-unit is *ca.* 0.85 m thick and consists of brown to light yellowish brown (10YR 5/3–6/4) fine loamy sand with two intervening very dark grey (10YR 3/1) sandy loam pedogenic horizons, each *ca.* 5 cm thick. The non-pedogenic component of this unit (*i.e.*, directly overlying Sub-unit 5d) is massive and slightly coarser in texture with both low carbon contents and low FD values. Pedogenic horizons are indicated by darker colors and high organic carbon contents, structural development, and high FD values. At section T1.100, Sub-unit 5c is *ca.* 0.40 m thick and directly overlies clay-rich Unit 4, and although similar in parent material lithology to Sub-unit 5c at section T1.28, only a single pedogenic horizon *ca.* 0.10 m thick is present. Very few molluscs were recovered from this sub-unit, and no additional shells were found in overlying sediments at the site. AMS dating of humic acids from bulk soil collected at a depth of 1.70-1.80 m from sub-unit 5c at section T1.100 returned an age of 5970 ± 60 ^{14}C yr BP.

Sub-unit 5b is another sequence of brown to light yellowish brown (10YR 5/3–6/4) fine sandy loam with at least two intervening very dark grey (10YR 3/1) incipient soil horizons. This sub-unit is *ca.* 0.40 m and *ca.* 0.45 m thick at sections T1.28 and T1.100, respectively, and lithologic and pedogenic properties resemble those identified above for sub-units 5c and 5d. Similar to underlying Unit 4, these sub-units all slope

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

gently downward into each of the buried depressions exposed along the cutbank, indicating the pre-existence of these former channels prior to sedimentation of the above noted stratigraphic sequences.

Sub-unit 5a includes the most identifiable pedogenic sequence present along the first terrace cutbank. At section T1.28, Sub-unit 5a is *ca.* 0.50 m thick and consists of brown to light yellowish brown (10YR 5/3–6/4) fine sandy loam overprinted by a moderately developed soil sequence. Pedologic formation is evident by the predominantly very dark grey (10YR 3/1) color and high organic carbon contents, subangular blocky structure, and very high FD values. The upper boundary of this buried soil profile exhibits substantial variability in its depth below the modern terrace surface, reaching depths greater than *ca.* 2.5 m along the bottoms of the infilled depressions while occurring only *ca.* 20 cm beneath the modern surface near the middle of the cutbank section under study (Figure 5.3). AMS dating of humic acids from bulk soil collected at a depth of 1.50–1.55 m from Sub-unit 5a at section T1.100 returned an age of 3500 ± 70 ^{14}C yr BP.

Interpretation: A shift to an aeolian depositional environment at Burdukovo is represented by sediments comprising Unit 5. This stratigraphic sequence is composed predominantly of very-fine grained, massive, wind-blown sand with multiple intervening, incipient pedogenic horizons having formed during periods of greater moisture availability, fostering vegetation growth and greater surface stability. The source area for this wind-blown sediment is thought to be primarily from the deflation of local floodplain surfaces and sand bars of the Selenga River which were exposed during periods of low water levels, perhaps related to increased regional aridity. Boundaries between pedogenic horizons and aeolian sediments are clear and smooth, suggesting both relatively frequent and rapid changes in the stability of landscape conditions. Charcoal from near the base of Unit 5 was radiocarbon dated to *ca.* 6890 ^{14}C yr BP, thus providing both an upper bracketing age for sediments representing the underlying lacustrine sequence (Unit 4) and an approximation for the onset of aeolian deposition and perhaps increased early–middle Holocene aridity, which may reflect a more widespread trend prevalent across the upper Selenga River basin (*i.e.*, Northern Mongolia Plateau). This pattern of oscillating intervals of aeolian sedimentation and incipient pedogenic

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

development is characteristic of site formation processes at Burdukovo spanning the entire middle and late Holocene periods.

Unit 6

Lithology: Unit 6 is described here without formal stratigraphic sub-divisions, and includes all fine loamy sediments and pedogenic horizons that have accumulated since the cessation of soil forming processes represented by Sub-unit 5a, including the infilling of the two buried depressions present along the terrace cutbank. At Section T1.28, Unit 6 is *ca.* 0.40 m thick and consists of brown to light yellowish brown (10YR 5/3–6/4) fine sandy loam overprinted by two intervening very dark grey (10YR 3/1) pedogenic horizons, the latter of which represents the modern terrace surface. Approximately 50.0 m to the south (*i.e.*, upstream), Unit 6 occurs as a thin (*ca.* 0.20 m) surface soil directly overlying the pedogenic cycle identified in Sub-unit 5a. Additionally, Unit 6 also comprises the infill sediments of each of the buried depressions, reaching depths over *ca.* 2.50 m below surface. These infillings consist of high temporal frequency couplets of very fine sandy sediments and organic-rich incipient pedogenic horizons. As many as eight aeolian-pedogenic cycles are present in each of the two buried depressions, each ranging between *ca.* 0.10–0.50 m in thickness. The deposition of sediments comprising Unit 6 thus had the effect of leveling the previously undulating paleo-surface of the first terrace at the site. Boundaries separating aeolian sedimentation and pedogenic development are again generally clear and smooth.

Interpretation: Sediments representing Unit 6 indicate a continuation of high temporal frequency intervals of aeolian deposition and incipient pedogenic development during the late Holocene. This pattern may again reflect oscillating conditions of comparatively greater aridity and soil moisture availability at the site, respectively. A more extensive characterization of these relatively high resolution middle and late Holocene aeolian-pedogenic assemblages (i.e., Units 5 and 6), including detailed micromorphological and mineral magnetic analyses, is currently in progress and is the subject of a separate graduate thesis project in the Department of Physics, University of Alberta.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Molluscs

The malacofaunal record recovered from the Burdukovo site consists primarily of an early–middle Holocene succession of land species. Of the 25 bulk (4.0 l) sediment samples collected and processed from the site, over 25,000 individuals comprised of at least 24 terrestrial and 9 aquatic taxa are represented in the assemblage (Figures 5.6 and 5.7; Appendix B.2). Fifteen of the collected samples contained *ca.* > 800 shells (the most abundant sample comprising *ca.* > 2800 individuals), while seven samples contained *ca.* < 50 shells and three samples were non-fossiliferous. The genus *Vallonia* again dominates the assemblage, represented by over *ca.* 15,000 individuals or *ca.* 60 % of the total shells recovered. Molluscs occur in great abundance throughout much of the stratified alluvial parent materials but are generally absent in the overlying aeolian sedimentary sequence.

Zonation of the molluscan data by Two-Way Indicator Species Analysis (TWINSPAN; Hill 1979) derived three principal mollusc zones, two of which generally correspond to those designated as Brd1 and Brd3. Mollusc zones designated Brd2a, Brd2b, and Brd2c were sub-divided from a single TWINSPAN zone based on the known ecology and sequential trends of several key species. Ordination of the Burdukovo molluscan samples and species data by principal components analysis (PCA) is presented in Figures 5.8 and 5.9, respectively.

Zone Brd1: 350–390 cm (*ca.* > 10,000 ^{14}C yr BP)

Zone Brd1 represents the earliest mollusc record from the first terrace landform at Burdukovo. The assemblage exhibits a developmental sequence featuring both increasingly high abundance and species richness (up to 15 taxa at the upper boundary). The zone is dominated by the terrestrial species *Vallonia* cf. *chinensis* (*ca.* 60 %) and *Punctum pygmaeum* (up to *ca.* 20 %) along with the 'most terrestrial' of the aquatic taxa *Galba truncatula* ex. gr. *sibirica* (up to *ca.* 40 %). Other land snails present in relatively high abundance (*ca.* 5–10 %) include *Vallonia kamtschatica*, *Euconulus fulvus* agg., *Oxyloma/Succinea* spp., *Discus* spp., *Cochlicopa* cf. *lubrica*, and *Vertigo extima*. *Deroceras/Limax* spp., *Nesovitrea hammonis*, *Pupilla muscorum*, and *Gastrocopta theeli* are also present, but these taxa each comprise *ca.* < 5 % of the total assemblage. Other

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

than *Galba*, aquatic taxa are rare in this lowermost sequence. Given the stratigraphic association with bedded, sandy loam alluvial sediments, some shells from this zone may have been transported to the site. Thus the record is interpreted to reflect more an early pioneering community in the broader lower Selenga River valley rather than a proxy assemblage for specific floodplain ecological conditions. Zone Brd1 is presently not dated, though presumed to be late Pleistocene in age. A sediment sample from the base of this zone has been submitted for optically stimulated luminescence dating with results expected in early 2006.

Zone Brd2c: 300–350 cm (*ca.* > 10,000 ^{14}C yr BP)

The assemblage of Zone Brd2c marks a trend towards greater species diversity at the Burdukovo site. Shell abundance shows a peak in the center of the zone with comparatively fewer specimens at both the lower and upper zonal boundaries. Greater species richness is accounted for by the slightly increased, though still limited, presence of aquatic fauna and a few new terrestrial taxa. The assemblage is again dominated by *Vallonia* cf. *chinensis* (*ca.* 40–60 %), although *Oxyloma/Succinea* spp., *Cochlicopa* cf. *lubrica*, and *Nesovitrea hammonis* each comprise up to *ca.* 15 %. New records include the terrestrial species *Bradybaena* cf. *schrencki*, *Zonitoides nitidus*, and *Vallonia pulchella*. These latter two taxa are often associated with wet meadow and marsh environments, as is *Oxyloma/Succinea* spp. Aquatic species also become more diverse in this zone, again represented primarily by *Galba truncatula* ex. gr. *sibirica*, but also by *Anisus leucostoma*, *Hippeutis complanatus*, *Polypylus sibirica*, *Aplexa hypnorum*, *Musculium lacustre*, *Gyraulus* sp., *Stagnicola* sp., and *Radix* sp. Some of the shells from this zone may have been transported to the site with alluvial sediments during periodic flood events. The collective data suggest both generally wet conditions and relative floodplain instability at the site during the late Pleistocene.

Zone Brd2b: 250–300 cm (*ca.* 10,000 to *ca.* 8230 ^{14}C yr BP)

Zone Brd2b contains a site maximum in both mollusc abundance and species richness (*ca.* > 20 taxa present). Terrestrial fauna again dominate the sequence, exhibited by high though decreasing values (*ca.* 25–40 %) of *Vallonia* cf. *chinensis* as well as the

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

first appearance of *Vallonia costata*, which comprises between *ca.* 15–30 % of the assemblage. The presence of *V. costata* is significant in that it indicates a marked change towards moderately dry conditions at the site. Substantial decreases in *Oxyloma/Succinea* spp., *Vallonia pulchella*, and *Galba truncatula* ex. gr. *sibirica*, taxa generally associated with rather wet environments, add further support for this ecological interpretation. Other notable features of this zone include moderate levels of *Punctum pygmaeum* (*ca.* 5–15 %) and gradually increasing frequencies of both *Vallonia kamtschatica* (up to *ca.* 10 %) and *Pupilla muscorum* (up to *ca.* 7 %), as well as the first sustained presence of *Bradybaena* cf. *schrencki*. Of additional interest is the virtual absence of *Vertigo extima*, which may suggest an ecological preference for wetter habitats for this still poorly documented species in Asia. Aquatic taxa are again rare, and other than *Galba* and *Anisus leucostoma*, species are represented by individual specimens only. Charcoal recovered near the upper boundary of this zone returned an age of 8230 ± 120 ^{14}C yr BP.

Zone Brd2a: 210–250 cm (*ca.* < 8230 to *ca.* 7000 ^{14}C yr BP)

Zone Brd2a is represented initially by both very high mollusc abundance and species richness before undergoing a sharp decrease concurrent with the deposition of clay-rich Unit 4, which temporarily interrupted the malacological succession. The most significant features of this zone are the increases in *Vallonia kamtschatica* (up to *ca.* 30 %), *Vallonia pulchella* (up to *ca.* 20 %), *Pupilla muscorum* (up to *ca.* 10 %), and *Galba truncatula* ex. gr. *sibirica* (up to *ca.* 10 %), along with the abrupt decline in *Vallonia costata*. These trends suggest wetter conditions at the site. The reappearance of *Vertigo extima* and *Gastrocopta theeli* also supports this interpretation. *Vallonia* cf. *chinensis* continues its decline but still comprises up to *ca.* 30 % of the assemblage. Of additional significance are the first appearances of the terrestrial taxa *Vallonia tenuilabris*, *Pupilla sterri*, and *Vertigo antivertigo*. This latter species is typically associated with wet meadow and marsh environments. Other than *Galba*, *Anisus leucostoma*, and *Stagnicola* sp., aquatic taxa are very limited. The upper boundary of this zone is dated to *ca.* < 7370 ± 70 ^{14}C yr BP.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Zone Brd3: 180–210 cm (*ca.* < 7000 to *ca.* 6000 ^{14}C yr BP)

The uppermost molluscan zone is defined on the basis of comparatively few recovered shells (*ca.* < 50), but the composition of taxa and the association with aeolian sediments provide a rather distinct environmental signature. The low shell abundance is also accompanied by low species diversity, and of the taxa present in underlying zones, only *Vallonia tenuilabris*, *Punctum pygmaeum*, *Pupilla muscorum*, *Discus* spp., *Oxyloma/Succinea spp.*, *Euconulus fulvus* agg., *Nesovitrea hammonis*, and *Galba truncatula* ex. gr. *sibirica* are represented in Zone Brd3. However, three species appear in the record for the first time, including *Columella columella*, a species common in 'loess-like' environments, *Succinella oblonga*, a species which typically occupies poorly vegetated surfaces, and *Vertigo microsphaera*, an extremely rare form in continental East Asia, having been found at only one other locality outside of the Pacific Kuril Island chain, that being the Basovo site in the upper Lena River valley. Thus the recovery of *V. microsphaera* in the Lake Baikal region represents a major extension to the known geographical range of this species. The autecology of *V. microsphaera* is still poorly documented but its linkage with aeolian environments at Burdukovo suggests an affinity for drier conditions, at least in western Trans-Baikal. At Basovo this species is most commonly found in association with the moderately dry adapted *Vallonia costata*. These findings are rather unexpected considering that all previously known habitats for this species are from moister marine-influenced areas (Schileyko, 1984; Prozorova, 2002). The upper boundary of Zone Brd3 is dated to 5970 ± 60 ^{14}C yr BP.

Summary

Holocene Reconstruction of the Burdukovo Site

The Burdukovo first terrace cutbank exhibits a complex sequence of floodplain sedimentation and pedogenic development spanning the late Glacial and Holocene periods (Figure 5.10). This particular area of Trans-Baikal has received very limited scientific investigation, thus the present study represents an important contribution to our understanding of the paleoecology of the Selenga River corridor linking Lake Baikal to the Northern Mongolian Plateau. Floodplain development near Burdukovo began sometime in the late Pleistocene with the deposition of coarse fluvial gravels (Unit 1) and

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

fine loamy alluvium (Unit 2). The instability of this aggrading landform surface is indicated by differentially sorted sandy beds and the absence of buried soils. Associated malacofauna (Zone Brd1) are likely to represent a partly redeposited assemblage and thus are interpreted to broadly reflect a 'pioneering community' in the lower Selenga River valley. Dominant taxa include *Vallonia* cf. *chinensis*, *Punctum pygmaeum*, and *Galba truncatula* ex. gr. *sibirica.*

Overlying Unit 3 represents the sedimentation of increasingly fine alluvium followed by the initiation of pedogenic development on the floodplain after *ca.* 8230 ^{14}C yr BP. This interval of generally increased floodplain surface stability and soil formation continued until shortly after *ca.* 7370 ^{14}C yr BP. Molluscan communities begin to show greater species richness in this stratigraphic sequence, initially represented in Zone Brd2c by taxa indicative of generally moist conditions, including the species *Oxyloma/Succinea* spp., *Punctum pygmaeum*, *Vertigo extima*, *Zonitoides nitidus*, *Vallonia pulchella*, and *Galba truncatula* ex. gr. *sibirica.* However, the association of these and other fauna from Zone Brd2c with alluvial derived sediments may suggest the potential mixing with allochthonous members.

The molluscan sequence in overlying Zone Brd2b shows a distinct change in floodplain ecological conditions with the arrival of *Vallonia costata*, a species widely associated with at least moderately dry and open landscapes. The appearance of *V. costata* occurs as more moist adapted taxa, such as *Oxyloma/Succinea* spp., *Punctum pygmaeum*, *Vertigo extima*, *Vallonia puchella*, and *Galba truncatula* ex. gr. *sibirica*, begin to decline. After *ca.* 8230 ^{14}C yr BP, wetter conditions on the floodplain are indicated in Zone Brd2a by the abrupt decline in *Vallonia costata*, accompanied by increases in *Vallonia pulchella*, *V. kamtschatica*, *V. tenuilabris*, *Vertigo extima*, *Pupilla muscorum*, *Gastrocopta theeli*, and *Galba truncatula* ex. gr. *sibirica.* Shortly after *ca.* 7370 ^{14}C yr BP, the floodplain surface is rapidly transformed by the sedimentation of overlying Unit 4, which consists of a distinct silty clay loam layer deposited during a period of ponding on the floodplain. This wet interval lasted until sometime before *ca.* 6890 ^{14}C yr BP. Malacofauna associated with Unit 4 are extremely limited.

Unit 4 represents an important stratigraphic boundary within the first terrace landform. All overlying sediments consist of fine wind-blown sands with multiple

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

intervening pedogenic horizons. These aeolian deposits are preliminarily designated as Units 5 and 6. Unit 5 is divided into four sub-units (a-d), each of which varies somewhat in thickness and horizon arrangement across the cutbank due to micro-scale paleo-topography which influenced sedimentation and pedogenic processes on the aggrading floodplain/terrace. As many as eight incipient soil horizons are represented in Unit 5, ranging in age between *ca.* 6890 ^{14}C yr BP at the base of the unit and *ca.* 3500 ^{14}C yr BP near the upper boundary. Each of these pedogenic intervals are separated by very-fine sandy beds derived from the deflation of exposed local floodplain surfaces of the Selenga River during periods of low water level. This cycle of stability and instability at the site may represent alternating periods of relatively wetter conditions fostering pedogenesis and drier intervals which in turn facilitated aeolian sedimentation. The relevance of this sequence may extend far beyond that of the Burdukovo area, as the water levels of the Selenga River at the site are also related to conditions in the upper drainage basin which includes much of the Northern Mongolian Plateau. Malacofaunal assemblages are poorly preserved in the wind-blown sediments at the site, and were only recovered in very low numbers in the lower (Sub-unit 5c) portion of the aeolian sequence, designated as Zone Brd3. Despite their more limited occurrence however, a trend towards drying conditions is indicated by the species composition of this zone. By *ca.* 5970 ^{14}C yr BP, malacofauna appear to be absent in the sections under study.

Overlying Unit 6 dates to the late Holocene (*ca.* < 3500 ^{14}C yr BP) and includes the wind-blown sediments and incipient pedogenic horizons which infill the buried depressions exposed along the first terrace cutbank at the study site. These data represent a very detailed and high temporally resolved record of terrestrial landscape changes in western Trans-Baikal and provide further evidence of the sensitivity of the Burdukovo sedimentary record in documenting oscillating conditions between aeolian sedimentation, perhaps during comparatively drier intervals, and pedogenesis during periods of relative greater effective moisture and landform stability.

In summary, the Burdukovo first terrace cutbank provides a detailed record of late Glacial and Holocene floodplain and terrace development along the lower Selenga River valley in western Trans-Baikal. Alluvial sediment-soil sequences and molluscan records allow a multi-proxy paleoecological reconstruction for the site spanning the late

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Pleistocene and early Holocene. Ponding on the floodplain and subsequent dessication followed by intervals of aeolian sedimentation with frequent pedogenic overprinting provide additional evidence of climate and environmental changes at the site during the middle and late Holocene periods. These data may suggest a shift towards greater aridity in western Trans-Baikal by *ca.* 7000 ^{14}C yr BP, which may also signal a broader trend occurring across the Northern Mongolian Plateau. The implications of these data both for local and regional paleoclimate reconstructions and for understanding better the dynamic environmental context of Neolithic hunter-gatherer culture change in the Lake Baikal region will be discussed in greater detail in the following chapter.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Location/ Unit	**Depth (cm)**	**^{14}C yr BP**	**Cal. yr BP 68.3 % c.i. (1σ)**	**Cal. yr BP 95.5 % c.i. (2σ)**	**Sample Material**	**Lab #**
T1.100/ 5a	152	3500 ± 70	3685 – 3865	3630 – 3930	Bulk soil	TO-10972
T1.100/ 5c	170–180	5970 ± 60	6725 – 6805	6665 – 6945	Bulk soil	TO-11669
T1.28/ 5d	245	6890 ± 80	7660 – 7760	7585 – 7865	Charcoal	TO-10552
T1.100/ 4	219	5720 ± 430	6165 – 7010	5610 – 7505	Charred organics	TO-10551
T1.100/ 3	220–230	7370 ± 70	8150 – 8200	8010 – 8345	Bulk soil	TO-11668
T1.100/ 3	258	8230 ± 120	9025 – 9325	8980 – 9490	Charcoal	TO-10550
T1.100/ 2	340–350	5560 ± 650	5655 – 7100	4870 – 6000	Charred organics	TO-11666

Table 5.1. Burdukovo AMS radiocarbon chronology.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

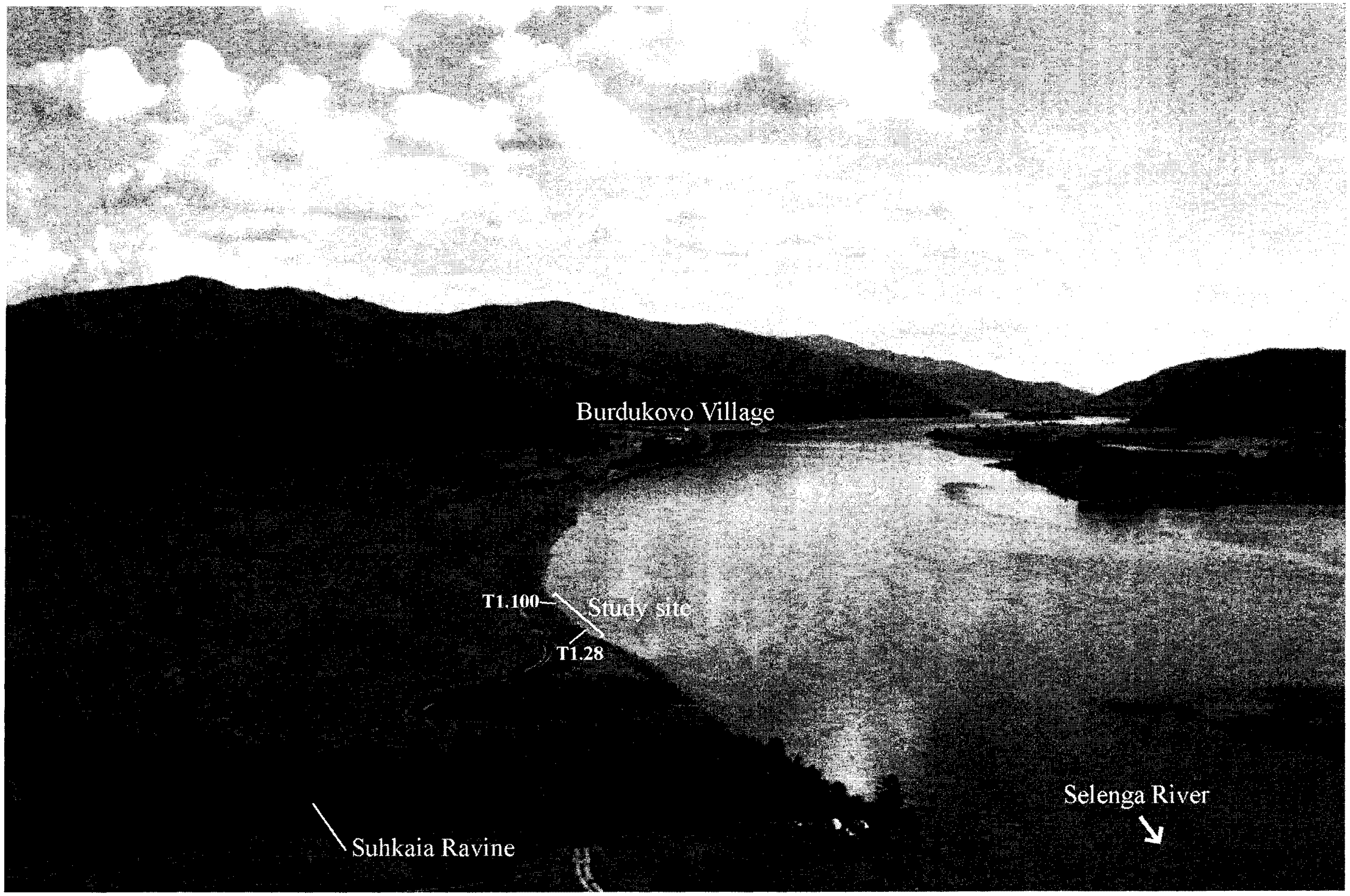


Figure 5.1. Burdukovo study site (view looking south).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

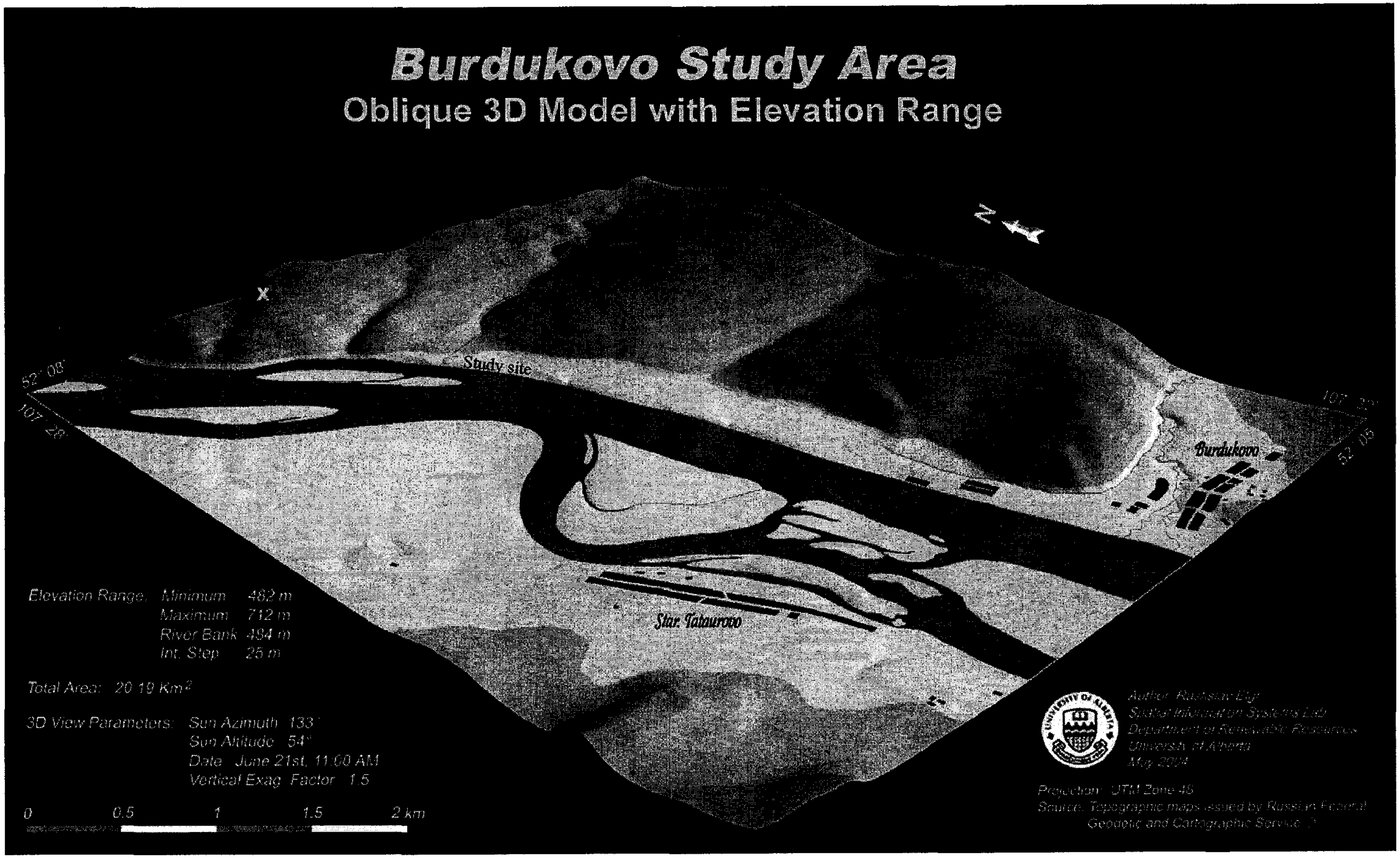


Figure 5.2. Digital elevation model of the Burdukovo study site (Figure 5.1 site photo taken at location indicated by "**x**").

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

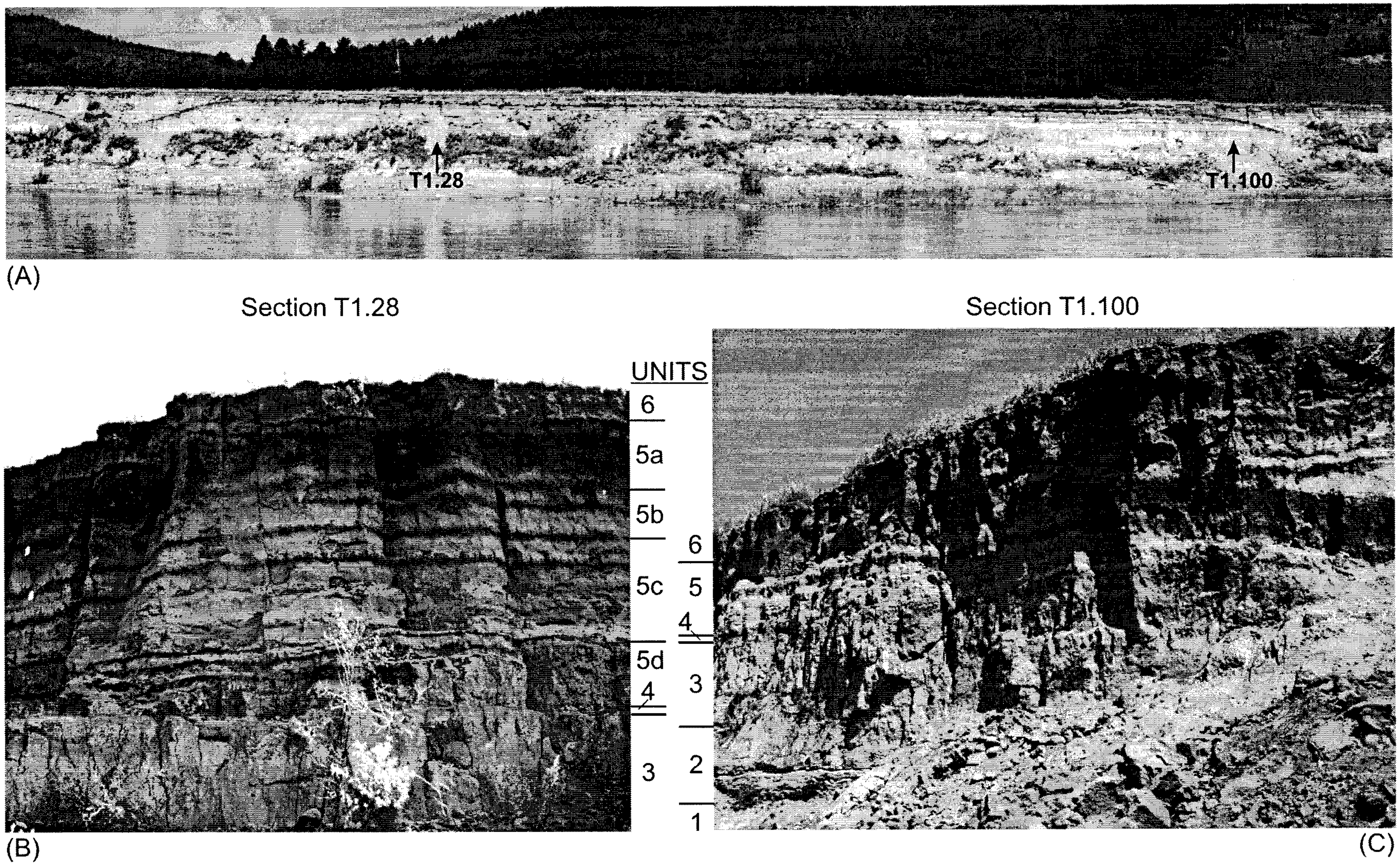


Figure 5.3. Burdukovo first terrace cutbank (A) and T1.28 (B) and T1.100 (C) study sections.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

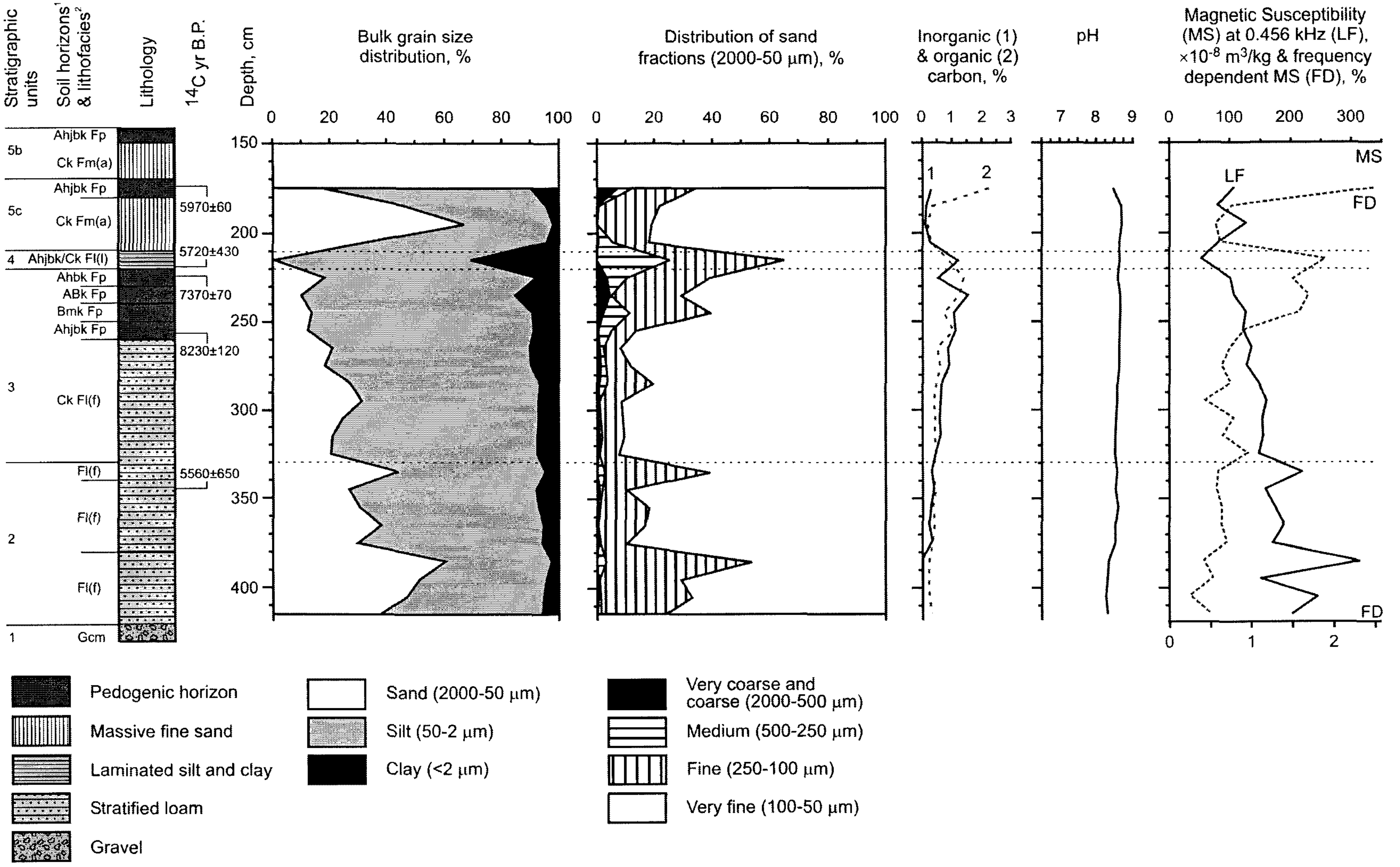


Figure 5.4. Burdukovo Section T1.100 - Stratigraphic data summary (for pedologic¹-lithofacies² explanations see Appendix A.1).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

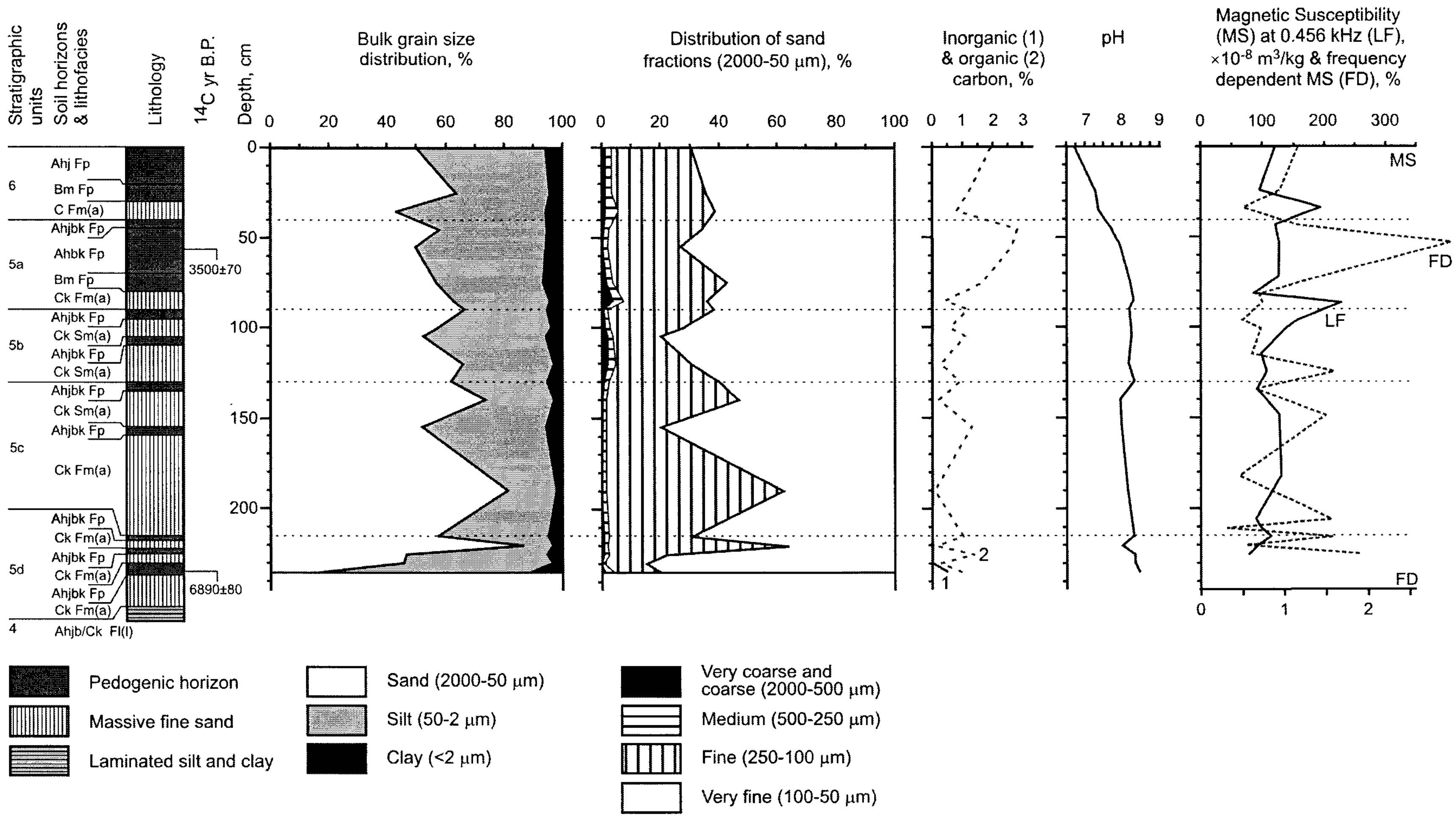


Figure 5.5. Burdukovo Section T1.28 - Stratigraphic data summary (for pedologic[1]-lithofacies[2] explanations see Appendix A.1).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

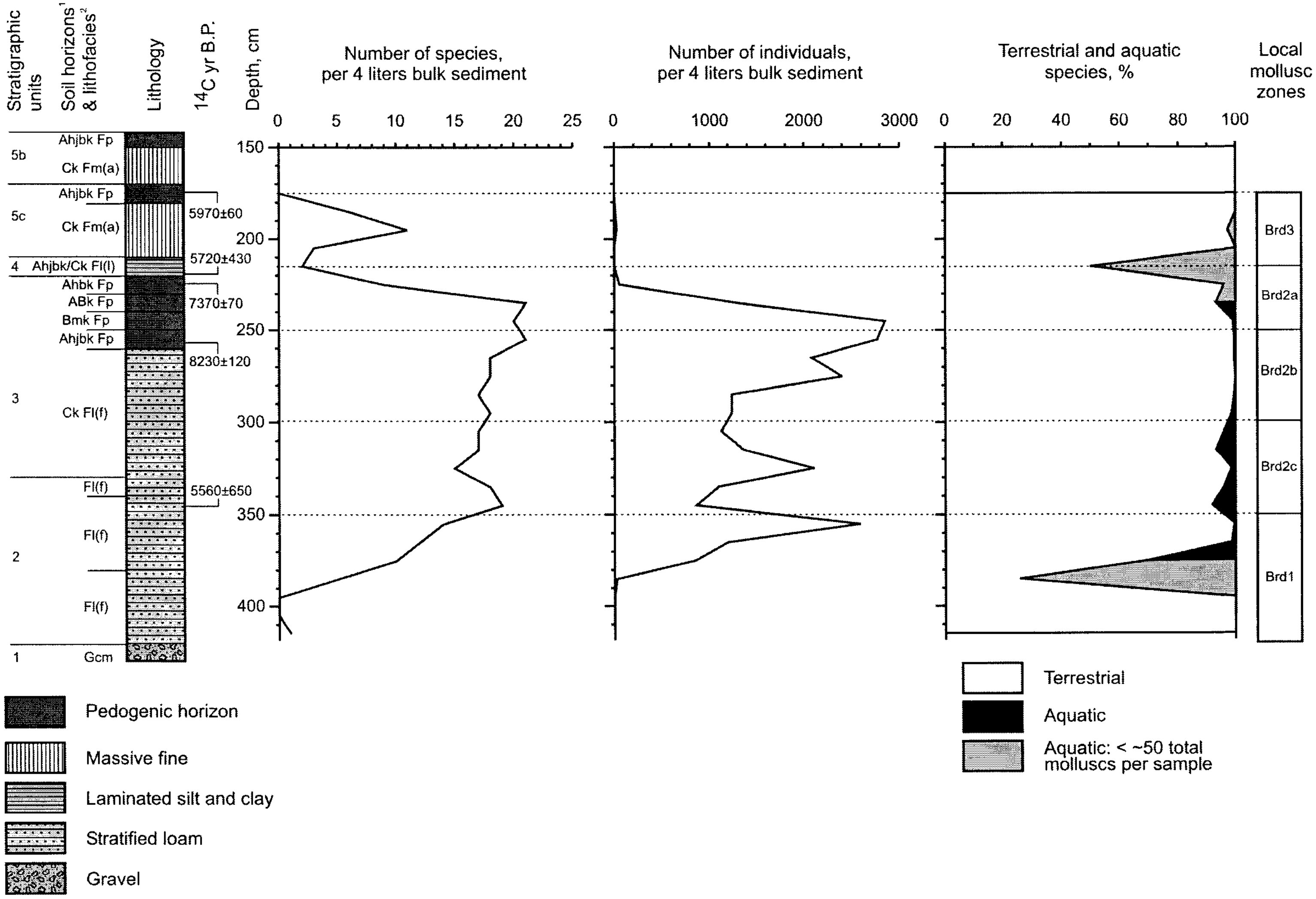


Figure 5.6. Burdukovo Section T1.100 - Ecological profile of the fossil molluscan assemblage.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

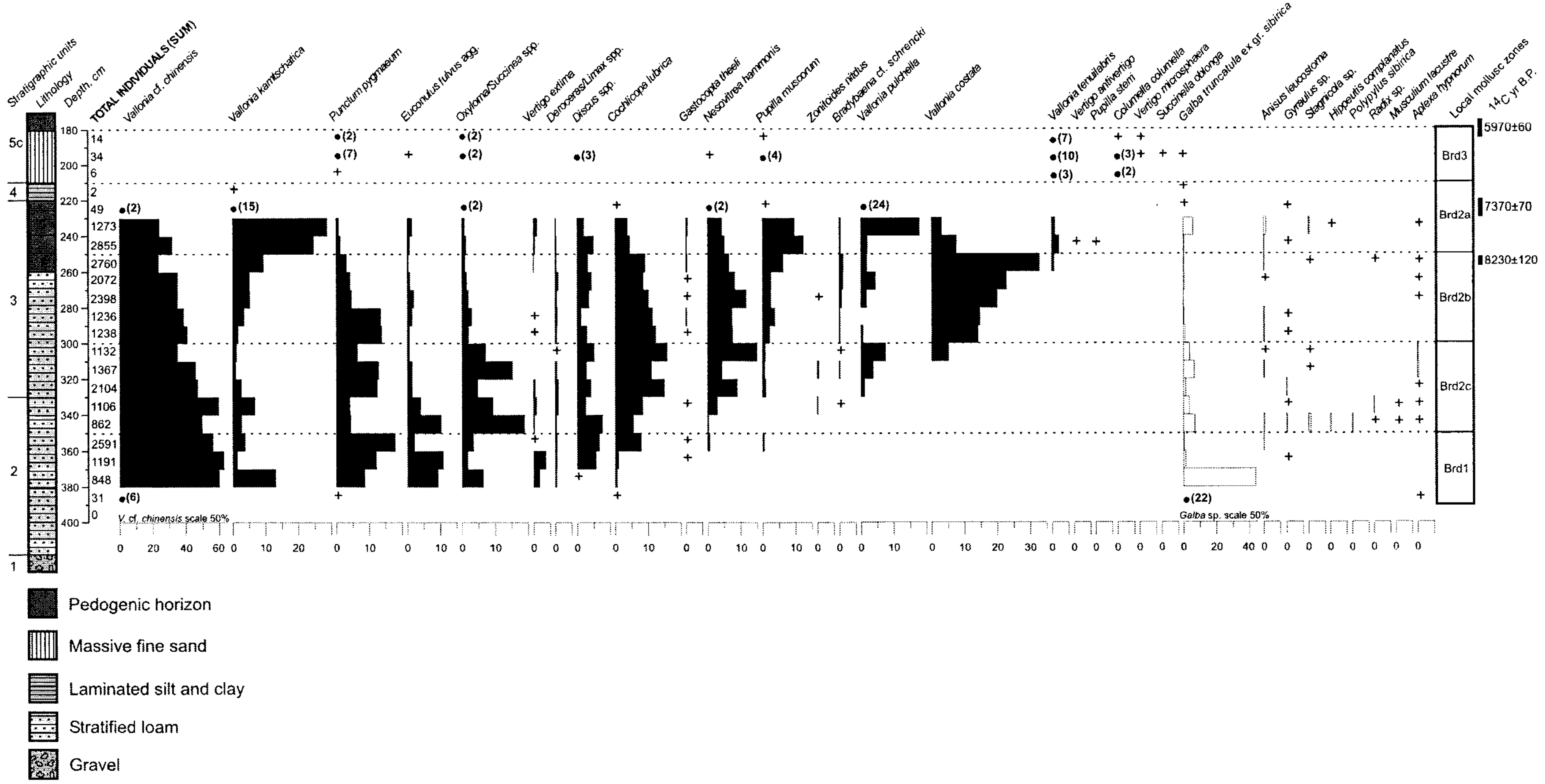


Figure 5.7. Burdukovo Section T1.100 - Mollusc frequency histogram. All values expressed as percentages of total land snails (+ indicates single shells; •(#) indicates number of shells in sample with less than 50 individuals).

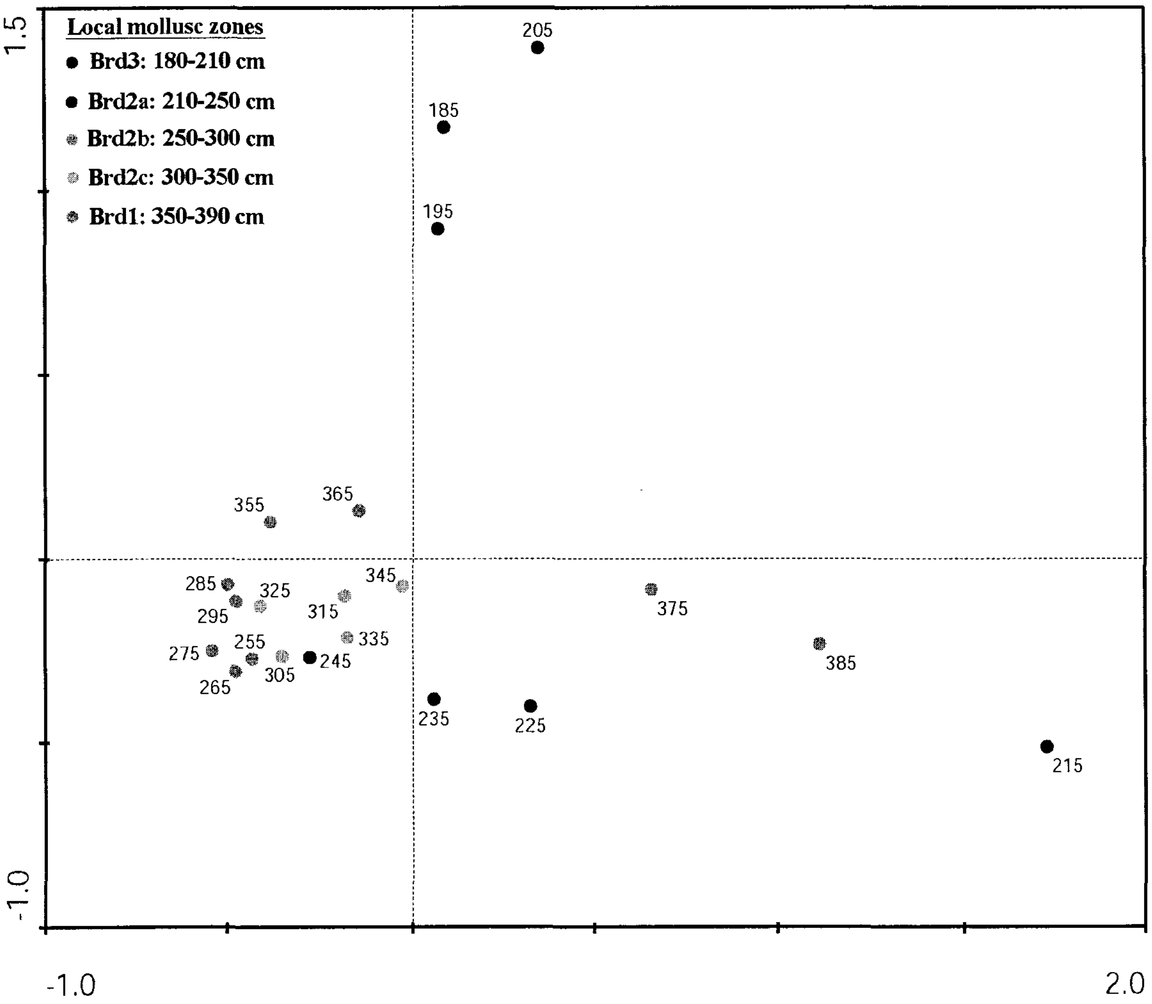


Figure 5.8. Principal components analysis (PCA) of Burdukovo mollusc samples, numbers correspond to sample depth (cm).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

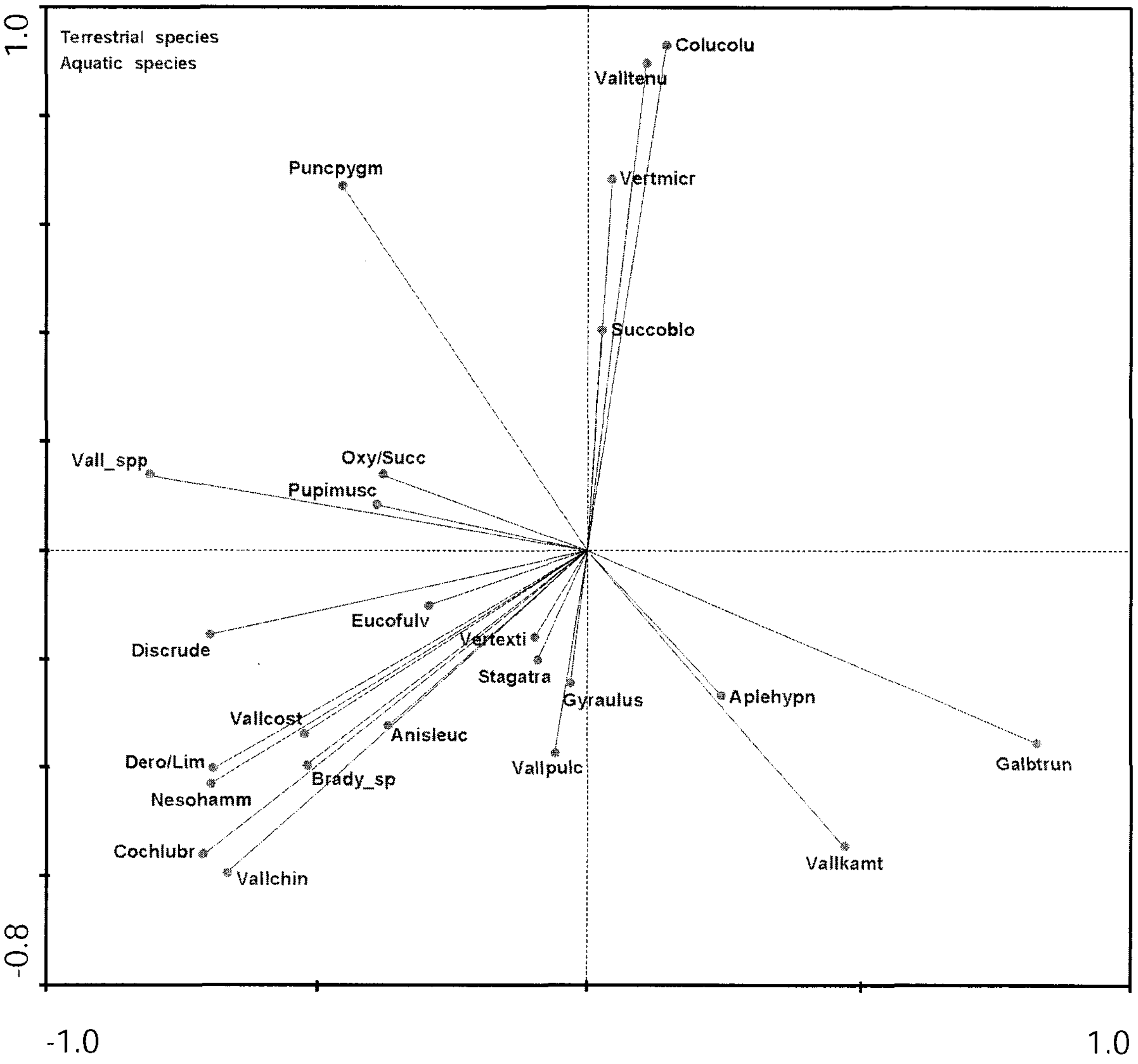


Figure 5.9. Principal components analysis (PCA) of Burdukovo mollusc species.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

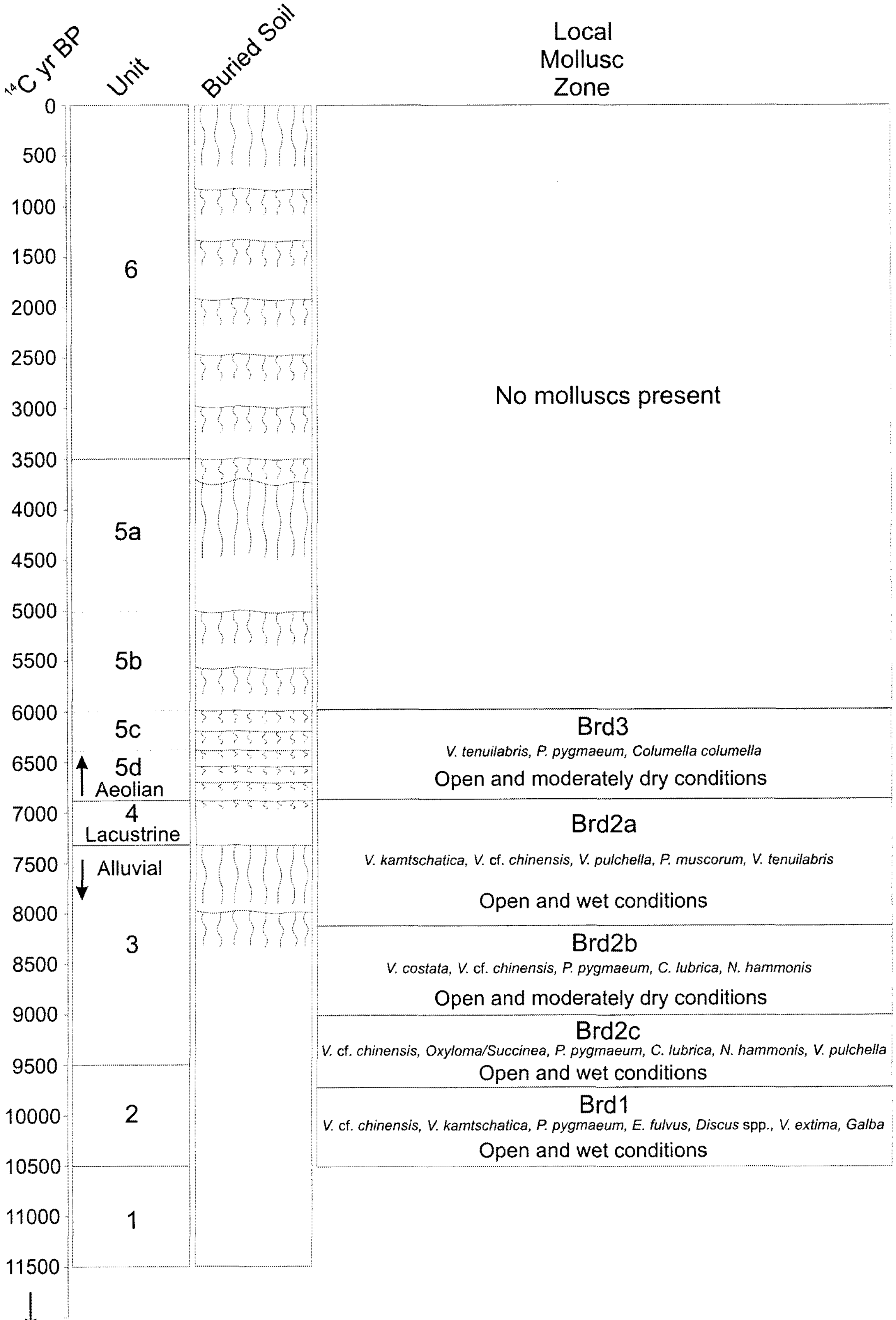


Figure 5.10. Burdukovo proxy data summary diagram.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

CHAPTER 6

Holocene Climate and Environmental Change and Neolithic Biocultural Discontinuity in the Lake Baikal Region: Discussion

Introduction

The discussion now turns to the integration of the Basovo and Burdukovo site records with other paleoecological proxy data to identify better the temporal and spatial trends of Holocene climate and environmental change both in the Lake Baikal area specifically and across continental east Asia in general. This synthesis of new research is both a timely and necessary endeavor for establishing a potential link between regional climate and cultural changes, particularly given the increase in the number of high resolution paleoecological investigations conducted throughout the broader area in recent years. This chapter then follows with an examination of the dynamic cultural processes occurring in the Cis-Baikal Neolithic within the context of contemporaneous landscape changes across the region. The objective of this discussion is to begin developing hypotheses for the middle Neolithic biocultural discontinuity in the Cis-Baikal which take into greater consideration how documented changes in climatic and environmental conditions may have led to fluctuations in local ecological systems and hence the subsistence base and adaptation strategies of resident hunter-gatherer populations. The effects of such changes through time may have thus contributed to shifting levels of social complexity during the Neolithic period. Up to now, regional early–middle Holocene climate and environmental change has not been adequately evaluated as a potential contributing factor in the archaeologically identified middle Neolithic discontinuity in the Cis-Baikal. This discussion is designed to bring this issue into broader relevancy and stimulate new research avenues for more integrated discourse among Baikal researchers.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Holocene Climate and Environmental Change in the Lake Baikal Region

Results from the Basovo and Burdukovo sites add important new details to the Holocene environmental history of the Lake Baikal region. These multi-proxy datasets document relatively high temporal resolution changes in local floodplain ecology spanning more than *ca.* 11,000 cal yr BP in areas which have received rather limited investigation to date. In fact, the Basovo record represents the first detailed reconstruction of Holocene environmental change for the upper Lena River valley, filling a noticeable gap in the spatial distribution of paleoecological study sites in the Baikal area. In contrast, a number of sites in Trans-Baikal have been reported which allows the Burdukovo sequence a more locally available context for data comparison. Much of the previous research from this region has focused on lacustrine and bog sites (Bezrukova *et al.*, 1996, 2005a, 2005b; Demske *et al.*, 2005; Karabanov *et al.*, 2000; Kataoka *et al.*, 2003; Krivonogov *et al.*, 2004; Takahara *et al.*, 2000; Tarasov *et al.*, 2002), thus the alluvial and aeolian stratigraphic contexts of the Basovo and Burdukovo datasets represent both unique and complimentary records of environmental change in the area.

The following provides a brief discussion of integrated results from Holocene climate and environmental change research in the Baikal region and surrounding areas (Figure 6.1; Table 2.1). During the late Glacial and early Holocene, many proxy records indicate a still cool but warming and wet climatic trend in the Baikal area (Bezrukova *et al.*, 2005a, 2005b; Demske *et al.*, 2005; Tarasov *et al.*, 2002). This period also corresponds to the northward expansion of the east Asian summer paleomonsoon system which brought considerably more precipitation to parts of northern China and Mongolia than today (An *et al.*, 2000; He *et al.*, 2004; Rhodes *et al.*, 1996; Tarasov *et al.*, 2000). Proxy data from both the Basovo and Burdukovo sites during this time initially suggest relatively wet environments associated with unstable floodplains host to 'pioneering' molluscan assemblages. However, an intervening period of at least moderate drying is also indicated at these sites during part of the early Holocene. For example, between *ca.* 10,500–9000 cal yr BP, low sedimentation rates and floodplain pedogenesis at Basovo are associated with both malacofauna indicative of moderately dry and open conditions and vertebrate remains which include the Ungar vole *Microtus maximowiczii*, whose present range is restricted to the drier Trans-Baikal region. These trends are also

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

consistent with the Burdukovo malacofaunal sequence which suggests an interval of moderately dry and open habitats prior to *ca.* 9000 cal yr BP. These data appear to capture at least localized environmental changes in both the upper Lena and lower Selenga river valleys respectively, and perhaps reflect an even more widespread regional pattern. For instance, evidence of relatively drier conditions during part of the early Holocene is also reported at Lake Kotokel (Tarasov *et al.*, 2002) and Dulikha bog (Bezrukova *et al.*, 2005a, 2005b) in western Trans-Baikal, and at Lake Gun in adjacent northern Mongolia (Dorofeyuk and Tarasov, 1998; Feng *et al.*, 2005; Wang *et al.*, 2004a, 2004b).

After *ca.* 9000 cal yr BP, most proxy records from across the broader region indicate either continued wet or a return to increasingly wetter climatic conditions (Bezrukova *et al.*, 2005a, 2005b; Demske *et al.*, 2005; Dorofeyuk and Tarasov, 1998; Prokopenko *et al.* 2005; Rhodes *et al.*, 1996; Tarasov *et al.*, 2000, 2002). Contrary to this general trend however are the records from Gun Lake in northern Mongolia, which suggest comparatively drier conditions at this time (Feng et al., 2005; Tarasov and Dorofeyuk, 1998; Wang et al., 2004a, 2004b). At Basovo, evidence for wetter habitats between *ca.* < 9000–7000 cal yr BP is indicated by wet adapted molluscan taxa and a peak in amphibian remains in the vertebrate record in association with renewed floodplain instability (*i.e.*, higher sedimentation rates and the cessation of pedogenic processes). At Burdukovo, a shift from dry- to wet-adapted malacofauna is also evident after *ca.* 9000 cal yr BP. Subsequent ponding on the Burdukovo floodplain occurred after *ca.* 8000 cal yr BP due to either prolonged surface flooding or the repositioning of the Selenga channel network. These wetter habitats at the site continued until sometime prior to *ca.* 7700 cal yr BP when floodplain drying and aeolian sedimentation under presumably more arid conditions becomes the dominant feature in the Burdukovo record.

The early–middle Holocene transition in both the Lake Baikal region and across continental east Asia corresponds to an interval of significant climatic and environmental variability. While many of available proxy records indicate a change from relatively wet to increasingly drier conditions, the trend towards greater aridity appears to have been transgressive in both time and space, though generally ranging between *ca.* 7500–5500 cal yr BP across the region (An *et al.*, 2000; Bezrukova *et al.*, 2005a, 2005b; Demske *et*

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

al., 2005; Fowell *et al.*, 2003; He *et al.*, 2004; Kataoka *et al.*, 2003; Kremenetski *et al.*, 2003; Peck *et al.*, 2002; Peteet *et al.*, 1998; Prokopenko *et al.*, 2005; Rhodes *et al.*, 1996; Tarasov *et al.*, 2000, 2002). Evidence of increasing aridity in the Baikal area during the onset of the middle Holocene is first recorded at sites in the Trans-Baikal region. For example, at Burdukovo a shift from alluvial to predominantly aeolian deposition occurs after *ca.* 7700 cal yr BP, with a corresponding increase in relatively dry adapted malacofauna. These data may suggest localized deflation of exposed floodplains and aeolian sedimentation under comparatively drier conditions (*i.e.*, lower water levels and poorly vegetated surfaces). Other sites in the Trans-Baikal area also indicate a drying trend at about this time, including those along the southeastern coast of Lake Baikal and in the adjacent Khamar-Daban range (Bezrukova *et al.*, 2005a, 2005b; Tarasov *et al.*, 2002). This shift to greater aridity may be reflective of a more regional pattern developing across the Selenga River catchment, which includes much of north-central Mongolia. For instance, south of Baikal, the beginning of the middle Holocene period (*ca.* 7000 cal yr BP) coincides with both the southern displacement of the east Asian summer paleomonsoon system and a trend in greater aridity recorded at sites across northern China and in parts of Mongolia (An *et al.*, 2000; Fowell *et al.*, 2003; He *et al.*, 2004; Peck *et al.*, 2002; Prokopenko *et al.*, 2005; Rhodes *et al.*, 1996).

In the Cis-Baikal, the early–middle Holocene transition at Basovo corresponds with a return to greater surface stability (*i.e.*, floodplain pedogenesis) and conditions again becoming progressively drier from *ca.* < 7000–2900 cal yr BP. While floodplain habitats appear to have favored moderately dry adapted molluscan taxa during this period, species dependent on greater moisture availability were also still locally present, suggesting rather diverse micro-environments at the site. Other sites in the Baikal region indicate that this middle Holocene drying trend began between *ca.* 6500–5500 cal yr BP (Bezrukova *et al.*, 2005a; Demske *et al.*, 2005), while still other data suggest relatively humid conditions continued until *ca.* 3200–2500 cal yr BP (Bezrukova *et al.*, 2005b, 2005c; Tarasov *et al.*, 2002).

Several studies from the broader region however show an opposite trend during this early–middle Holocene transition, with climatic shifts from relatively dry to increasingly wetter environments (Andreev and Klimanov, 1999; Blyakharchuk, 2003;

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Blyakharchuk and Sulerzhitsky 1999; Dorofeyuk and Tarasov, 1998; Feng *et al.*, 2005; Grunert *et al.*, 2000; Wang *et al.*, 2004a, 2004b). Furthermore, temperature estimates in the Baikal area also show variability during this transition. Demske *et al.* (2005) report minor cooling from *ca.* 7500–6500 cal yr BP and a subsequent Holocene thermal maximum between *ca.* 6200–5700 cal yr BP. In contrast, Karabanov *et al.* (2000) indicate that maximum thermal conditions in the Baikal region occurred between *ca.* 4200–2500 cal yr BP. These asynchronous and anomalous regional patterns during the early–middle Holocene transition suggest very complex and localized landscape responses to changing climatic conditions. However, they may also be due, at least in part, to inconsistencies in data quality and the inherent difficulties involved in establishing a precise and accurate chronological framework for reference based on multiple site records and diverse proxy sources spread out over a broad and geographically diverse area.

Following this transition to generally warmer and drier conditions in the Baikal region, several studies indicate that vegetation complexes became relatively stable with the establishment of essentially modern communities throughout the middle and late Holocene periods (Bezrukova *et al.*, 2005a, 2005b; Demske *et al.*, 2005). This is in contrast to data from Burdukovo which suggest that landscape conditions in parts of western Trans-Baikal oscillated frequently during this time. Middle and late Holocene sequences at Burdukovo consist of multiple buried pedogenic profiles overprinting variably thick wind-blown sediments. Only three of the *ca.* 15 identified buried soil horizons in association with these aeolian deposits currently have radiocarbon dates (*ca.* 7700 cal yr BP, *ca.* 6800 cal yr BP, and *ca.* 3750 cal yr BP, respectively) and molluscan assemblages are generally absent throughout these stratigraphic levels at the site. This apparent cycle of pedogenesis during comparatively wetter intervals with localized deflation and aeolian sedimentation during drier periods indicates high temporal fluctuations in landscape stability in the area, though additional dating controls are needed to build a more detailed chronological reconstruction of the middle and late Holocene site record. In the Cis-Baikal, late Holocene environments reconstructed at Basovo indicate moderately fluctuating landscape conditions with periods of high sediment accumulation separated by longer intervals of greater stability and floodplain

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

pedogenesis. Proxy data generally indicate comparatively wetter environments at Basovo between *ca.* 2900–1500 cal yr BP and perhaps greater drying after *ca.* 1500 cal yr BP.

In summary, climate and environmental change research in the broader Baikal area has increased substantially over the last decade, revealing considerable variability across the region during the Holocene. The collective record shows a general warming and wetting trend throughout the early Holocene, but a number of sites also indicate an intervening period of drier conditions in this otherwise warming-wet interval. The subsequent early–middle Holocene transition represents the most significant period of climate change in the region since the late Glacial, with conditions generally becoming increasingly warmer and more arid. The magnitude of associated environmental fluctuations was sufficient to instigate significant ecological changes on the landscape. Particularly noteworthy is that these changes generally coincide with the biocultural discontinuity in the Cis-Baikal region (Weber *et al.*, 2005). Late Holocene sequences show relatively low amplitude oscillations across much of the area, but several more localized records show greater variability.

While these data provide a general outline of Holocene climate and environmental change in the broader Baikal area, both the resolution and quality of available proxy data presently limit more detailed temporal and spatial reconstructions. Additional studies with both high resolution chronological controls and explicit climatic and environmental interpretations are needed to resolve better the paleoecological history of the region, including the apparent asynchronous and anomalous trends revealed in a number of records. Despite these limitations however, general Holocene climatic and environmental sequences are evident and these data give insights into the ecological context of hunter-gatherer culture change in the Lake Baikal area. More specifically, these records provide the basis to begin assessing the role of early–middle Holocene climate and environmental changes as potential stimuli for the identified biocultural discontinuity in the region during the middle Neolithic period.

Environmental Change and Biocultural Discontinuity in the Cis-Baikal Neolithic

The processes surrounding the middle Neolithic biocultural discontinuity in the Lake Baikal region form the basis of ongoing multidisciplinary collaborations of the

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Baikal Archaeology Project. Several hypotheses continue to be investigated which attempt to explain this hiatus in terms of social processes (*e.g.*, land use issues), but the approach presented here utilizes results from Holocene climate and environmental reconstructions as an explanatory framework for understanding better this discontinuity and the associated changes in adaptation strategies of regional Neolithic hunter-gatherer populations. Previously, relative ecological stability spanning the early Neolithic Kitoi to the late Neolithic–early Bronze Age Serovo-Glazkovo periods had been assumed (Weber *et al.*, 2002). Data presented in this dissertation however have demonstrated that conditions in both the Baikal area and surrounding regions varied significantly during this time. This discussion therefore continues by introducing several new ideas which illustrate how these climatic and environmental shifts may have contributed to the middle Neolithic biocultural discontinuity in the Cis-Baikal.

In particular, the focus of this discussion centers on the environmental context of three key issues: (1) the development of large formal cemeteries and increased social complexity among the early Neolithic Kitoi (pre-hiatus) culture and subsequent population dispersal and abandonment of these mortuary sites at the onset of the middle Neolithic period; (2) the origin or "homeland" of ensuing late Neolithic–early Bronze Age Serovo-Glazkovo (post-hiatus) groups and the processes which led to the reconfiguration of the biocultural profile among Cis-Baikal hunter-gatherers; and (3) the establishment of the late Neolithic–early Bronze Age period of social complexity among the Serovo-Glazkovo cultures.

Period	***Culture/Mortuary Complex***	***Radiocarbon (^{14}C) Age BP***	***Calibrated (cal) Age BP***	***Calibrated (cal) Age BC***
Late Mesolithic	Early Kitoi	*ca.* 8000–7000	*ca.* 8800–7800	*ca.* 6800–5800
Early Neolithic	Late Kitoi	*ca.* 7000–6100	*ca.* 7800–6900	*ca.* 5800–4900
Middle Neolithic	Hiatus	*ca.* 6100–5300	*ca.* 6900–6200	*ca.* 4900–4200
Late Neolithic	Early Serovo-Glazkovo	*ca.* 5300–4800/4400	*ca.* 6200–5400/5000	*ca.* 4200–3400/3000
Bronze Age	Late Serovo-Glazkovo	*ca.* 4800/4400–3300	*ca.* 5400/5000–3000	*ca.* 3400/3000–1000

The Development and Collapse of Kitoi Social Complexity

The Kitoi culture very likely represents an *in situ* developmental sequence with roots extending back into the Mesolithic period (Weber *et al.*, 2005). Early and middle

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Mesolithic hunter-gatherers in the Lake Baikal region remain poorly documented however (Dolukhanov, 1997; Dolukhanov and Khotinskiy, 1984; Powers, 1996; Tankersley and Kuzmin, 1998). In general, they consisted of small social groups with subsistence adaptations geared towards a broad range of foraging activities, particularly those based on the procurement of mammalian species, primarily ungulates. Climatic conditions during this time are considered to have been quite variable, though generally following a pattern of increasingly warmer and wetter environments relative to the late Glacial. These conditions may have fostered increased forest development across much of the region, however an intervening period of greater aridity documented in a number of proxy records during at least part of the early Holocene could have punctuated this trend and perhaps contributed to the localized expansion of more open (*e.g.*, forest-steppe) environments in some areas, increasing both forest edge habitats and presumably prey availability for hunter-gatherer subsistence strategies adapted to the harvesting of migratory herbivores. Wetter conditions again dominated after *ca.* 9000 cal yr BP. In general, the ecological changes associated with the expansion of forests in the Baikal region throughout much of the early Holocene may have had a substantial influence on subsistence activities, perhaps contributing to shifting adaptation strategies from hunting-dominated to a greater reliance on other resources among local hunter-gatherers.

By the late Mesolithic and early Neolithic periods, the Kitoi complex becomes an archaeologically recognized cultural group in the Cis-Baikal region. This period marks a significant change in the social organization of hunter-gatherer populations in the area as the development of large settlements and formal cemeteries indicates increased sedentism, social differentiation, and the intensification of subsistence resources (Lepofsky *et al.*, 2005; Weber *et al.*, 2002, 2005). Resource intensification among hunter-gatherers in boreal environments is widely associated with increasing use of aquatic resources (Binford, 2001; Kelly, 1995). The location of many Kitoi sites at the mouths of major tributaries (*i.e.*, areas of greatest fish abundance), along with the associated artifact "tool kits" and stable isotope evidence from Kitoi skeletons, all indicate diets rich in aquatic food sources (Weber *et al.*, 2002). These data suggest the increasing importance of and reliance on fish in the Kitoi subsistence base and that the specialized procurement of these aquatic resources may have acted as a stimulus for

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

population growth and increased sedentism and social complexity among hunter-gatherers, as is evident in the archaeological record.

Regarding the terminal Kitoi stage (*i.e.*, decline) at the end of the early Neolithic, Weber *et al.* (2002: 285) report that "low regional population density but high nucleation, socially closed communities, smaller annual range, lack of demographic growth, gender and age imbalance, and more selective (specialized) use of natural resources may have made these groups sensitive to even minor perturbations". This "intrinsic vulnerability" among the Kitoi is assumed to have played a critical role in their capacity to cope with stresses brought about by either natural or cultural processes, or a combination of the two. Similar studies have shown that even relatively minor fluctuations in environmental conditions can result in substantial changes among hunter-gatherer populations (*e.g.*, Lepofsky et al., 2005; Wolverton 2005). If the procurement of fish was a primary subsistence adaptation of Kitoi hunter-gatherers, as has been suggested, then adverse changes in the abundance or predictability (*i.e.*, seasonality) of these resources would have had a significant affect on foraging behaviors. While over-harvesting is unlikely given the technologies of the time, natural fluctuations in local riverine and lacustrine ecosystems may have originated such a response. Is there a basis for such a hypothesized ecological stress, and if so what data are needed to test its validity?

Both the collapse of the Kitoi and the biocultural discontinuity which followed coincide with the most significant period of climate and environmental change in the region during the last 10,000 years. The general trend from warming-wetter to warmer-drier conditions during the early–middle Holocene transition would have had a marked effect not only on the terrestrial environment, but on the aquatic as well. Fisheries biologists have recently begun to recognize the importance of climate change and its affects on fish ecology in both marine and freshwater environments (Beamish, 1995; Beamish and Bouillon, 1993; Beamish *et al.*, 2004; Finney *et al.*, 2000, 2002). These studies have demonstrated that changes in aquatic ecosystems can result from a number of dynamic and interrelated factors. For example, water temperature fluctuations, in association with other variables, are known to have a significant influence on fish migration patterns, abundance and carrying capacity, spawning behavior and seasonality, and larval survival rates (R. Beamish, personal communication, 2005). Such ecosystem

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

changes also promote greater competition among species and alterations in the aquatic food chain. While the science behind such studies is still in its infancy, these data do indicate that natural oscillations in climatic cycles can have a rapid and catastrophic effect on fish ecology.

Following the last glacial period, fish populations in the Baikal area likely began an ecological transformation adjusting to a dynamic post-glacial environment, similar to other biotic communities. During the early–middle Holocene transition, temperature fluctuations combined with greater aridity in the region brought further adjustments to both terrestrial and aquatic ecosystems. Both warmer and lower water levels may have led to a substantial disruption and redefinition of regional fisheries. The affects of these changing conditions were likely quite variable for fish populations in Lake Baikal itself, which is known for its ecological stability (Kozhov, 1963). Pelagic or deep water fish may have been relatively unaffected, but littoral species which inhabit the many bays and lagoons of Lake Baikal, where many of the area's archaeological sites are located, likely experienced a more direct influence by the increase in temperatures of the more shallow waters. For example, modern studies have shown that the omul' (*Coregonus autumnalis migratorius* Georgi) is known to leave the Little Sea region of Lake Baikal when water temperatures reach 18°C (Krasnoshchekov, 1981; Sorokin and Sorokina, 1988). Thus shifting thermal regimes in aquatic environments at the onset of the middle Holocene period could have had a significant affect on seasonality and other aspects of fish ecology.

This leads to the hypothesis that natural climatic and environmental changes in the Lake Baikal region during the early–middle Holocene transition caused a significant fluctuation in both riverine and shallow lagoon fish populations and this disruption in the subsistence base of resident hunter-gatherer groups acted as a contributory stimulus for the cultural discontinuity during the subsequent middle Neolithic period. It is speculated that the resulting changes in aquatic ecosystems could have contributed to less abundant, accessible, and seasonally predictable fish resources for cultures whose primary adaptive strategy was centered on fisheries harvesting. This may have resulted in subsistence resources that were insufficient or too temporally and spatially dispersed to support large, relatively sedentary populations in the Cis-Baikal, leading to both the abandonment of

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

established settlements and increased group mobility at the end of the early Neolithic. Consequently, the hiatus in both large formal cemetery use and growing social complexity spanning the middle Neolithic period had begun.

Unfortunately, very few data are available to validate this potential scenario. Evidence to date confirms only that fishing was a primary adaptive strategy among the Cis-Baikal Kitoi, that significant climate and environmental changes coincided with the termination of Kitoi culture, and that natural disruptions in aquatic ecosystems can have both rapid and profound effects on fish ecology. A number of other studies have addressed issues broadly similar to those from the Cis-Baikal middle Holocene, most notable are those from the Northwest Coast of North America (see Lepofsky *et al.*, 2005 and references therein).

To further investigatate the issue of prehistoric fluctuations in Cis-Baikal fish populations as a catalyst for middle Neolithic cultural discontinuity, a number of new datasets are needed. These include, though are not limited to, the following. First, archaeological studies focusing on habitation sites must establish better both the chronology of the site history and more specific details regarding the subsistence activities of resident hunter-gatherer groups. For example, the recovery of faunal remains, when preserved, could be used to reveal changes in either fish abundance or species selection through time, which may be related to fluctuations in local aquatic ecology. Furthermore, changes in the frequency of fishing implements in "tool kits" may be indicative of shifts in primary subsistence adaptations. Additionally, if resources become more widely dispersed on the landscape, then changes in both the spatial distribution of sites (*e.g.*, site location, types of sites) and the mobility patterns of local hunter-gatherer populations may also be suggestive of shifts in dominant subsistence activities.

From an environmental perspective, a number of approaches are required for establishing a possible link between middle Neolithic hunter-gatherer culture change in the Cis-Baikal and natural fluctuations in both local fish ecology and the terrestrial landscape. Foremost is the need for additional high resolution studies in the area which identify better the timing and character of climate and environmental changes. This also includes, when possible, attempts to quantify temperature and precipitation estimates and

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

other climatic and environmental variables. Additionally, paleobotanical studies may reveal important new details about regional vegetation dynamics under enhanced middle Holocene warming and aridity. These conditions may have led to reduced forest cover and more open habitats for migratory herbivores and game hunting. Equally important is finding suitable study sites enabling changes in fish abundance through time to be calculated. Finney *et al.* (2000, 2002) report multi-proxy investigations using $\delta^{15}N$ and other biological indices from lake sediment cores to estimate temporal changes in fish abundance. Similar studies could offer a novel approach to understand better the environmental context of Cis-Baikal hunter-gatherers if they can be successfully applied in the Lake Baikal region. However, until more data become available, both archaeological and paleoecological, natural fluctuations in prehistoric fish populations will remain an untested hypothesis for middle Neolithic cultural discontinuity in the Cis-Baikal area.

Origins of the Serovo-Glazkovo

The second point to address regarding the Cis-Baikal middle Neolithic discontinuity is the origin or homeland of the post-hiatus Serovo-Glazkovo populations which inhabited the region during the late Neolithic and early Bronze Age periods. As stated earlier, the end of the early Neolithic Kitoi (*ca.* 6900 cal yr BP) marks the beginning of a *ca.* 1000-year, if not longer (Weber *et al.*, 2005), hiatus in the use of large formal cemeteries in the Cis-Baikal area. In addition to the practice of formal cemetery use, hunter-gatherer populations also abandoned large settlements and existing subsistence modes and sociopolitical organizations, and dispersed into smaller groups spread out more evenly across the broader Baikal region (Weber *et al.*, 2005). The result of these shifting middle Holocene adaptation strategies was reduced social complexity, greater group mobility, and less intensive subsistence activities (Weber *et al.*, 2005).

A number of lines of evidence indicate that during the middle Neolithic period, the biocultural profile of hunter-gatherer populations in the Lake Baikal region experienced a significant change. Most notably are the genetic differences between the pre-hiatus Kitoi and the post-hiatus Serovo-Glazkovo groups (Mooder *et al.*, n.d.). Other differentiating characteristics include subsistence activities, diet, mobility patterns, and

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

social and political relations (Weber *et al.*, 2002). These data all suggest that a new population(s) originating from outside the Baikal region entered the area during the middle Neolithic period and contributed to the genetic and cultural make-up of resident hunter-gatherer populations. The homeland of these new immigrants, however, remains unresolved.

Several authors have inferred that western Siberia may have been the origin of Serovo-Glazkovo ancestors based on similarities in cranial characteristics, pottery traditions, and mortuary practices (Weber, 1995; Weber *et al.*, 2002; Goriunova *et al.*, 2004). Few comparative studies exist however, particularly for all other regions adjacent to Lake Baikal. Also, the territorial expansion of nomadic pastoralists across Central Asia beginning by *ca.* 6000 cal yr BP has been suggested as a possible mechanism for the western migration of new hunter-gatherer populations into the Baikal region. Weber *et al.* (2002: 288) speculate about a domino effect whereby the movements of steppe-adapted nomadic pastoralists pushed inhabitants of the northern and eastern steppe peripheries and steppe-boreal forest transition zone into neighboring areas. While such a scenario is quite conceivable, the timeline for these proposed interactions in western Siberia remains unresolved (Levine *et al.*, 2003). Another factor which has yet to be adequately assessed is the substantial climatic and environmental variability occurring at this time across continental east Asia, and its temporal and spatial affects on both subsistence resources and the adaptive strategies of cultural groups in the broader region. This issue, while difficult to examine in detail given the relative paucity of archaeological sites in many of the areas under consideration, nonetheless warrants more attention.

As outlined above, the middle Neolithic discontinuity in the Cis-Baikal was contemporaneous with significant climatic and environmental changes across the region. More specifically, many proxy records from the Baikal region indicate fluctuations from generally warming-wetter to warmer-drier conditions during the early–middle Holocene transition (Bezrukova *et al.*, 2005a, 2005b; Demske *et al.*, 2005). Outside of the immediate Baikal area at this time, the shifting influence of the east Asian summer paleomonsoon system in northern China and Mongolia is of particular interest, especially concerning the repercussions that this would have had on both local ecological conditions and the associated adaptive strategies of resident cultural groups. For example, regional

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

proxy records indicate that the early Holocene was dominated by a strengthened summer monsoon which penetrated northward into parts of northern China and Mongolia (An *et al.*, 2000; He *et al.*, 2004; Rhodes *et al.*, 1996; Tarasov *et al.*, 2000). Greater effective moisture in these presently arid and semi-arid regions would have had a significant impact on local flora and fauna, resulting in the reorganization of both terrestrial and aquatic landscapes. For hunter-gatherers in the region, these conditions may have been favorable for the territorial expansion of subsistence activities, contributing to the migration of small populations into these previously less inhabitable areas. By *ca.* 7000 cal yrs BP, however, many of the available proxy records indicate that the east Asian monsoonal front began a southward retreat and that environmental conditions in northern China and Mongolia became increasingly more arid, extending both the desert and semi-desert zones and leading to warming of lake waters, lake retraction, and salinization. Greater aridity and associated ecological fluctuations brought about by the southern retreat of the east Asian summer monsoon system during the early–middle Holocene transition may have thus acted as a stimulus for the movement of people from parts of Mongolia and northernmost China into more hospitable environments in neighboring regions.

Scientists have long debated the influence of climate change and shifting monsoonal regimes on Neolithic civilizations in China (*e.g.*, An *et al.*, 2004, 2005; Chen *et al.*, 2003, 2005; Huang *et al.*, 2000, 2003; Wenxiang and Tungsheng, 2004; Yasuda *et al.*, 2004; and references therein). From a middle Holocene perspective, the situation is somewhat different for Neolithic China compared to the Lake Baikal region as large agricultural societies are known to have developed in many parts of southeast Asia prior to *ca.* 8000 cal yrs BP (see above references). Among sedentary farmers the cultural impacts of perceived adverse climatic changes are known to be quite different than for more mobile hunter-gatherers.

However, of particular importance for understanding better the full range of potential mechanisms responsible for reconfiguring the biocultural profile of hunter-gatherers in the Lake Baikal area is how small groups of hunter-gatherers inhabiting parts of both Inner and Outer Mongolia responded to the transformations in local ecological conditions under enhanced warming and aridity at the onset of the middle Holocene. If

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

environmental conditions deteriorated to such an extent that made this region increasingly uninhabitable, then migrations out of this area may have become necessary. In such a case, a southward or eastern migration into less arid parts of China would have been met by interactions with expanding farming communities and complex socio-political organizations, which may have either absolved or at least redefined the existing hunter-gathering lifestyle. A northward migration may have been an alternative option given the comparatively low population densities combined with the relative continuity of the steppe and forest-steppe environments extending all the way to Lake Baikal. It is this latter scenario which is perhaps relevant to the origins issue of the Cis-Baikal Serovo-Glazkovo.

Very limited data are presently available however to evaluate adequately either the direct or indirect cultural consequences that shifts in the east Asian summer monsoonal front may have had on middle Neolithic hunter-gatherer populations in the Cis-Baikal. The absence of archaeological records remains largely a product of the limited-scale studies that have been conducted to date across this vast and poorly populated region and the inherent difficulties involved in locating small hunter-gatherer campsites used thousands of years ago. Nonetheless, extensive historical connections between Cis-Baikal and neighboring regions to the south are suggested, for example, by both the tradition of 'sitting burials' and genetic data. Although post-dating the identified biocultural discontinuity in the Cis-Baikal, 'sitting burials' are believed by some scholars to be older and more common in both northern Mongolia and the Trans-Baikal areas before this practice spread into the Cis-Baikal during the late Neolithic–early Bronze Age periods (Kharinskii and Sosnovskaia, 2000; Turkin and Kharinskii, 2004). Additional chronological controls are still needed, however, to authenticate this claim. Genetic data also indicate an ancestral link between late Neolithic–early Bronze Age Serovo-Glazkovo groups in the Cis-Baikal region and a *ca.* 2300 cal yrs BP cemetery population in northern Mongolia (Mooder et al., n.d.; Keyser-Tracqui *et al.*, 2003). However, these data currently establish only a historical connection between these two regions and lend few details as to the timing and long-term migration patterns of prehistoric hunter-gatherer groups. Detailed comparative studies of pottery styles and lithics, which are

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

widely used by archaeologistis to establish cultural links within a region, unfortunately have not been conducted in the broader Baikal area to date.

To begin evaluating whether early–middle Holocene fluctuations of the east Asian summer paleomonsoon system acted as a stimulus for major ecological changes and the northward displacement of resident hunter-gatherer populations from continental east Asia into the Lake Baikal region, important new data need to become available. The discovery of additional archaeological sites, particularly in Mongolia, dating to the early–middle Neolithic period is necessary for documenting and interpreting hunter-gatherer demography at this sub-continental scale. Furthermore, the recovery of new artifact collections would enable more systematic comparative studies from across the broader region. Ideally, this would also include data on mortuary traditions. More significant would be the discovery of early–middle Neolithic skeletal remains in Mongolia suitable for DNA extraction. These data would be invaluable for establishing ancestral links among Inner Asian hunter-gatherers during the middle Holocene period. And finally, if future evidence demonstrates an earlier age for the introduction of nomadic pastoralism and horse domestication in the region, then the interplay among socio-economic systems in continental east Asia during the early–middle Neolithic period would add to the complexity in understanding regional hunter-gatherer culture change in the Cis-Baikal. While the ideas presented above are entirely based on conjecture, the timing of the early–middle Holocene shift in the east Asian paleomonsoon front and the large-scale spatial influence this would have had on both the natural and cultural landscapes, warrant more detailed future consideration in its potential links to the Neolithic history of the Lake Baikal region.

Renewed Social Complexity at the Close of the Neolithic

Lastly, a few general ideas are considered regarding the environmental context of large formal cemetery use and renewed social complexity in the Cis-Baikal during the late Neolithic–early Bronze Age periods. As previously mentioned, archaeological data indicate that the Serovo inhabitants of the Cis-Baikal likely represent an incipient stage in the growth of this second period of Neolithic hunter-gatherer social complexity in the region, reflected in the development and use of a number of small (*e.g.*, rarely more than

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

10 burials) formal cemeteries (Weber *et al.*, 2005). In addition to several other cultural and biological similarities pointed out earlier (Weber, 1995; Weber *et al.*, 2002), recent genetic evidence has also established ancestral ties between the late Neolithic Serovo and subsequent Bronze Age Glazkovo people (Mooder *et al.*, n.d.). These data suggest that the post-hiatus period of large formal cemetery use and increased sedentism and social complexity among the Glazkovo was also an *in situ* process (Weber *et al.*, 2005).

Compared to the early Neolithic Kitoi, Serovo-Glazkovo groups had more broadly based subsistence strategies focused on the harvesting of both migratory herbivores and aquatic resources, including fish and the Baikal seal (*Phoca sibirica*) (Weber *et al.*, 2002). Furthermore, the environmental context associated with the development of social complexity among the earlier Kitoi and later Serovo-Glazkovo groups was also in contrast. While the Kitoi prospered under apparently more dynamic, cooler and wetter environmental conditions, the Serovo-Glazkovo interval of growing social complexity occurred during a period of comparatively more stable, warmer and more arid climate.

At first appearance, at least from an environmental perspective, these data suggest that the cyclical development of cultural complexity in the Cis-Baikal may have resulted from dissimilar factors. Although few in number, most of the available proxy records in the Baikal region which are contemporaneous with the late Neolithic–early Bronze Age period suggest either relative environmental stability and the onset of essentially "modern conditions" (Bezrukova *et al.*, 2005a; Kataoka *et al.* 2003), or only low amplitude fluctuations compared to the early–middle Holocene transition (Bezrukovo *et al.*, 2005b; Demske *et al.*, 2005; Tarasov *et al.*, 2002). In general, the warming-drying trend which characterizes the middle Holocene interval may have reduced forest coverage in at least parts of the Cis-Baikal and surrounding areas and expanded the forest-steppe ecotone, increasing the mosaic of open areas and forest edge habitats. Additionally, archaeological data from post-hiatus cultures also show that aquatic resources constituted a significant part of the food base. Thus in a similar vein to the postulated disruption of fish populations during the early Neolithic Kitoi period, it is also possible to conjecture that the greater environmental stability at the close of the Neolithic may have contributed to an increase in the abundance and predictability of regional fisheries. These conditions

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

of habitat expansion for migratory herbivores and greater availability of aquatic resources may have been instrumental in the processes leading to increased sedentism and use of large formal cemeteries during the late Neolithic–early Bronze Age Serovo-Glazkovo period. Combined with the influx of new hunter-gatherer cultures and traditions into the Cis-Baikal, growing social complexity may be expected. This is exactly what the archaeological record demonstrates.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

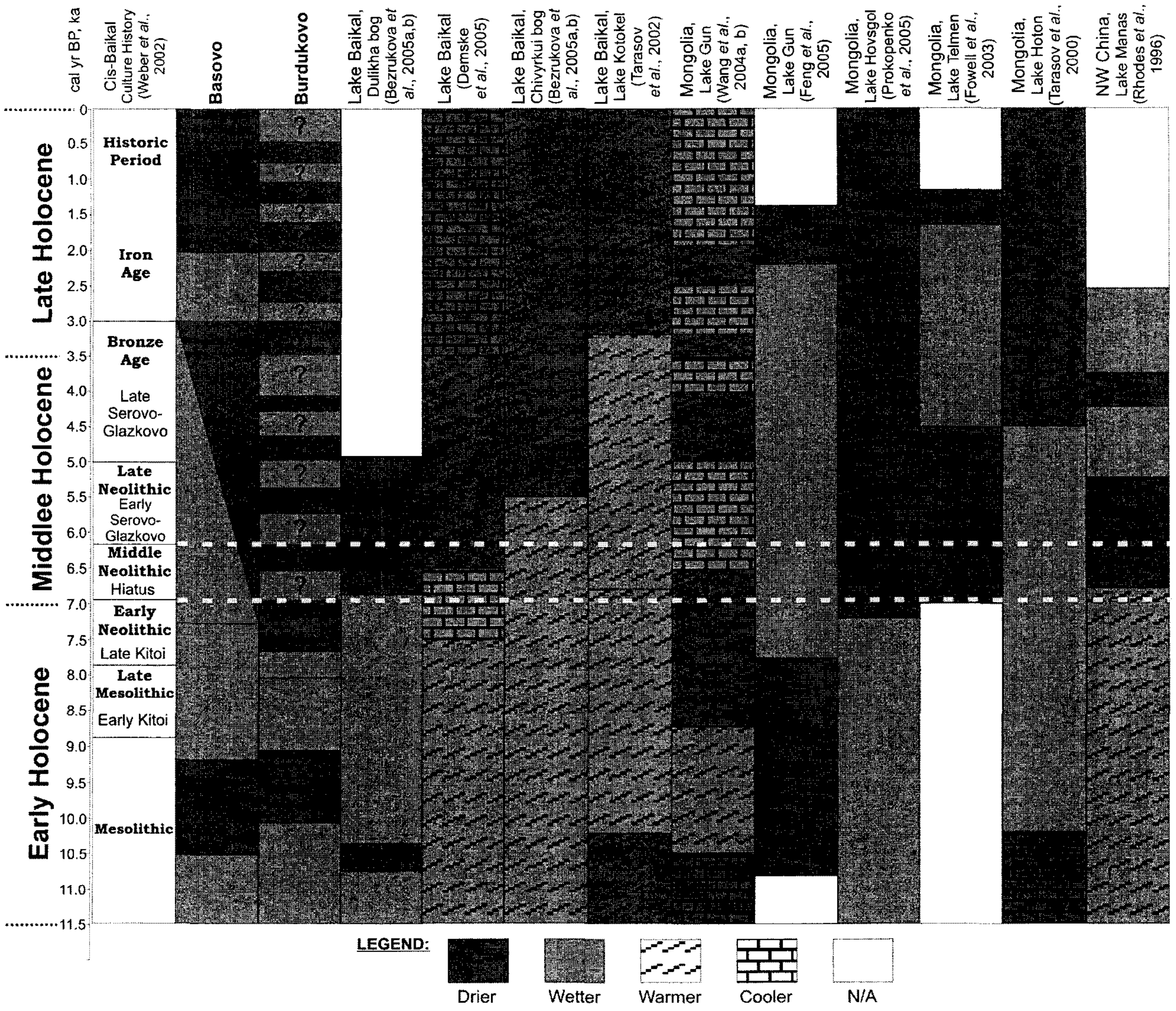


Figure 6.1. Generalized Results from Paleoclimate Proxy Records from the Lake Baikal Region and Mongolia/China.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

CHAPTER 7

Conclusions and Future Research

The research presented in this study contributes new perspectives on the Holocene environmental and cultural history of the Lake Baikal region. More specifically, this dissertation has: (1) documented and interpreted multi-proxy paleoecological sequences in both the northern Cis-Baikal and western Trans-Baikal areas and integrated these data into regional environmental change reconstructions; (2) described new and scientifically unique malacological assemblages, demonstrating the potential of molluscan successions as an archive for environmental change in Siberia; and (3) synthesized the above data with the current Neolithic culture history model of the Lake Baikal region, generating new research questions to guide future study into the causal factors underlying the middle Neolithic biocultural discontinuity in the Cis-Baikal. I conclude by offering a few general remarks on these research contributions as well as the potential direction for future investigation into Holocene climate and culture change in both the Lake Baikal area and surrounding regions.

Environmental reconstruction of the Baikal Holocene

At the outset of this study, one of the first-order objectives was to reconstruct Holocene environmental changes in the Baikal area through the analysis and interpretation of previously unstudied, high resolution biostratigraphic sequences. The opportunity for such investigation was made available during a number of reconnaissance trips with Russian colleagues in the major river valleys surrounding Lake Baikal during the summers of 1999–2002. This work led to more intensive site studies in each subsequent year, and data collected from the most detailed and best resolved records (*i.e.*, the Basovo and Burdukovo sites) formed the basis from which this research proceeded.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

The Basovo sequence is particularly noteworthy in that no other detailed paleoecological work had previously been undertaken in the upper Lena River valley. Multiple buried pedogenic horizons developed within fine, stratified alluvial deposits comprise the site stratigraphic record, documenting hydrological regimes and changes in floodplain ecology spanning more than *ca*. 11,000 years BP. Remarkable to the site is the abundance and richness of terrestrial and freshwater molluscs, and to a lesser degree the record of small invertebrates, which includes the first documentation of the Ungar vole *Microtus maximowiczii* west of Lake Baikal. The collective data allow a multi-proxy reconstruction of environmental change at the site, greatly contributing to the current dearth of knowledge concerning the Holocene ecological history of the Cis-Baikal. The absence of similar studies in this area, however, and the relatively local-scale nature of much of the Basovo data presently limit the extent to which broader correlation with other regional reconstructions can adequately be developed. On the other hand, these data are an invaluable archive for examining changes in site-specific environmental conditions. Future paleoecological research in the upper Lena River valley and across the broader Cis-Baikal will continue to refine these data by providing new study sites and associated proxy records and thus more complete temporal and spatial coverage in the area, ultimately leading to more detailed and informative local and regional interpretations, reconstructions, and comparisons.

Additionally, the Burdukovo site in western Trans-Baikal provided an equally important and complimentary record for this study. These data include high temporal resolution stratigraphic sequences of both alluvial and aeolian origin with over a dozen intervening pedogenic horizons dating to the Holocene period. Though not as abundant and rich as the Basovo site, the malacofaunal succession at Burdukovo is again quite rare for the region. The collective multi-proxy data document significant environmental changes at the site through time, which may also be indicative of conditions prevailing across the broader Selenga Basin in northern Mongolia. Several other paleoecological investigations from lake and bog sites in the area have been conducted in the last few years, and results both from these studies and that of the present work provide the basis to begin developing more detailed reconstructions of Holocene environmental change in the Trans-Baikal. It is also significant to note that research at the Burdukovo site served to

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

open up the existing study region of the Baikal Archaeology Project to both the Trans-Baikal and neighboring Northern Mongolian Plateau, creating new fieldwork opportunities in regions to the south of Baikal and new perspectives for understanding better the complex interactions between climate and culture change during the dynamic Inner Asian Holocene.

The Basovo and Burdukovo site records make a small but significant contribution to our growing understanding of Holocene environmental change in the Lake Baikal region. While relatively few detailed Holocene studies have been conducted in the area thus far, the pace of research has quickened considerably in recent years, and fortunately with an emphasis on stratigraphically continuous, high temporal resolution multi-proxy datasets. As new results become available, more specific details concerning the nature and timing of climatic and environmental changes will emerge, enabling more enhanced reconstructions and further insights into both local and regional trends as well as the significance of asynchronous and anomalous site records.

As is always the case when few existing studies are available in a region, the call for addition field research is routinely sounded. The situation for the Baikal region and much of continental east Asia is no different. Most productive will be those future studies which are implemented by a team of specialists with explicit research questions in mind. Attention to temporal resolution in site datasets will be particularly beneficial to researchers whose questions require empirical data about climate and environmental shifts beyond just a generalized level for adequate testing. This is precisely the case for BAP researchers in addressing the relative importance of environmental change as a contributory stimulus for middle Neolithic biocultural discontinuity in the Cis-Baikal.

In addition to new study sites and greater efforts to better resolve chronological sequences is the need for improved methods of both quantifying and interpreting results and integrating diverse lines of paleoecological data in the broader Baikal region. All proxy sources have their own inherent limitations and challenges for use in paleoclimate reconstructions, and overcoming these analytical and interpretive obstacles will be best achieved through multidisciplinary team efforts. As new field data continue to develop, more complete multi-site synthetic studies will be possible and these proxy-based reconstructions will facilitate better comparative analyses with regional numerical

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

climate modeling results, enabling improved insights into the specific atmospheric processes controlling the climatic and environmental changes identified by field records. Results from preliminary proxy data-numerical modeling inter-comparisons in the Baikal region are currently in development as part of a collaborative study by BAP researchers (see Bush, 2005).

Eurasian malacology

Rather unexpectedly, perhaps the most significant contribution of this research has turned out to be in the recovery, analysis, and interpretation of the rare and scientifically unique molluscan assemblages from the Basovo and Burdukovo study sites. These records are among the first of their kind for the entire eastern Palaearctic, and the present study is the most detailed documentation and quantification of Holocene malacofaunal successions yet conducted in Siberia. In addition to demonstrating the high potential of terrestrial and freshwater molluscan sequences as a viable and far under-utilized proxy record for environmental change in the Lake Baikal area, these data have also created both new interest and discussion and generated important new research questions for the field of Eurasian malacology.

In particular, the Basovo assemblage will long be regarded as the benchmark for Holocene molluscan studies in Siberia. The high temporal resolution of the record and the associated multi-proxy site data, combined with the continuity and abundance of well preserved shell and great species diversity and richness (*i.e.*, over 50 taxa), is unparallel for the region. The assemblage contains several species that had never previously been found in Asia, including *Vertigo parcedentata*, *Vertigo genesii*, and *Vertigo geyeri*, and greatly expanded the known geographical ranges for several other taxa, such as *Vertigo extima*, *Vertigo microsphaera*, and *Vallonia* cf. *chinensis*. The Burdukovo molluscan record is also exemplary. Furthermore, the association of some of the rare and poorly known species with more familiar taxa provides for the first time indirect evidence of their habitat affinities in Siberia. The absence of detailed modern malacofaunal research in the Baikal area underscores the need for more systematic field studies to better document species autecologies and to validate the use of indicator species and modern analog approaches in local and regional paleoecological investigations.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Thus the malacological component of this research has demonstrated the scientific gap in our knowledge of terrestrial and freshwater molluscs of the Baikal area in particular, and across Siberia in general. However, results from this work have also generated new interest in this field and future research is planned with the following goals in mind. First, extensive quantitative sampling of modern molluscan communities in the region is needed to develop more complete analog sets for comparison with fossil assemblages. This research will be designed to best identify and quantify the major environmental variables controlling the structure and composition of modern communities. Secondly, the documentation of additional molluscan sequences at sites surrounding Lake Baikal is needed to expand both the temporal and spatial coverage of malacofaunal study sites in the area. Such data will allow a better understanding of the changing distribution and composition of molluscan communities in the Baikal region through time. A similar research strategy is also needed for other parts of Siberia. These new malacological records will continue to be integral components in multi-proxy site reconstructions of environmental change, and these data combined with results from other local and regional paleoecological investigations can be used to build more robust models of late Quaternary environmental change.

Of additional interest stemming from this research are the questions raised as to whether modern (*i.e.*, Holocene) molluscan assemblages in northern latitudes provide realistic analogs for fossil assemblages from Pleistocene cold stages of Europe. Siberia is considered to be both a place where many cold adapted molluscan species originated during the Quaternary period and a main refugium from which they spread during successive cold stages (R. Preece, personal communication, 2004). The present study has demonstrated how molluscan communities in the Lake Baikal area developed following the most recent glacial period. These records can eventually be expanded and used both as analog sets to compare with Pleistocene cold stage assemblages from the western Palaearctic (*i.e.*, Europe) and to potentially refine existing regional climate reconstructions which are based in-part on malacological data.

Thus far, a major handicap in making comparative analyses of the molluscan assemblages recovered in Siberia has been the often different taxonomic nomenclature used by Russian and western scientists. The problem is compounded by the tendency of

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Russian scholars to split species and thus recognize far more taxa. A further aim of future research will be to formulate a more standardized taxonomic nomenclature by liaison with Russian and western malacologists. This should also include efforts to assemble comprehensive and well documented reference material for the permanent collections of research museums. Both the Basovo and Burdukovo assemblages, as well as all prospective materials that I am able to collect, will be deposited at the University Museum of Zoology Cambridge (UMZC) and made available for future research. In conclusion, there is still a great deal to be sorted out in the field of Siberian malacology. This work is one step towards that goal.

A climatic perspective on biocultural discontinuity in the Cis-Baikal Neolithic

The broader conceptual framework for this study was to begin developing a climatic and environmental perspective on the biocultural discontinuity in the Cis-Baikal Neolithic. This approach was rooted in the original tenets of the Baikal Archaeology Project, with the long-term objective of establishing the ecological contexts of hunter-gatherer cultural sequences in the Lake Baikal region. While current data remain far too incomplete to formulate a detailed and unified reconstruction of Holocene climate and environmental change in the area, generalized trends are becoming increasingly more apparent and this allows us to begin examining the archaeological record of Neolithic hunter-gatherer discontinuity from the perspective of fluctuating landscape conditions.

Paleoenvironmental data demonstrate that climatic conditions during the Holocene varied significantly in both the Baikal area and surrounding regions, and that associated ecological changes may have had a substantial effect on the subsistence resources and adaptation strategies of resident hunter-gatherer populations. Of particular interest is that critical environmental changes in the Baikal region, from relatively warming-wetter to warmer-drier conditions, are known to have occurred concomitantly with the archaeologically identified biocultural discontinuity during the middle Neolithic period. While specific questions of causality currently lack the appropriate resolution in empirical data, the correspondence between Holocene environmental and culture change in the Baikal area is likely more than mere coincidence.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Although the major research questions which frame the Baikal Archaeology Project originated from analyses of mortuary site records, it is increasingly evident that the answers to these same questions may ultimately lie in data derived from hunter-gatherer habitation sites. It is precisely this focus that is guiding prospective study into Neolithic culture change and continuity in the Lake Baikal area. Continued investigation of well dated, fine resolution habitation sites in the broader region is much needed to further document changes in both subsistence resources and adaptation strategies through time, and for integrated comparison with paleoecological field data.

Several research questions were raised which begin to take into greater consideration the potential influence shifting climatic and environmental regimes had on landscape conditions and associated hunter-gatherer subsistence and adaptation strategies in the broader Baikal area. These ideas centered on the role of different periods of environmental stability and variability in the development and decline in social complexity in the Cis-Baikal. It was conjectured that disruptions in the ecology of riverine and lacustrine fisheries in the Lake Baikal region may have been one consequence of greater warmth and aridity during the early–middle Holocene transition, and these changes in aquatic food resources may have contributed to the fragmentation and ultimate dissolution of the early Neolithic Kitoi culture. It was further suggested that the biocultural discontinuity which followed may be in part related to new immigrant populations moving into the Baikal area from neighboring regions in the south, whose subsistence and mobility adaptations during the middle Holocene were influenced by large-scale environmental changes associated with the shifting domain of the east Asian paleomonsoon system. Greater environmental stability and a small influx of new people into the region at the close of the Neolithic may have played an important role in the development of renewed social complexity among the early Bronze Age Glazkovo culture. Although untested and largely conjectural, these ideas nonetheless bring the record of Holocene climate and environmental change across Inner Asia into broader relevancy for understanding better the range of potential processes contributing to the middle Neolithic biocultural discontinuity in the Cis-Baikal, aiding in the development of future investigation on these issues.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Research to date has uncovered a wealth of data related to Holocene climate and culture change in the broader Baikal region. A number of questions have already derived answers, others are still being actively debated, and far many more have either only entered the discussion or have yet to be revealed. The Baikal Holocene remains a subject rich for scientific exploration.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

REFERENCES

An, C., Feng, Z., Tang, L. 2004. Environmental change and cultural response between 8000 and 4000 cal. yr BP in the western Loess Plateau, northwest China. *Journal of Quaternary Science*, 19(6), 529–535.

An, C., Tang, L., Barton, L., Chen, F. 2005. Climate change and cultural response around 4000 cal yr B.P. in the western part of Chinese Loess Plateau. *Quaternary Research*, 63(3), 347–352.

An, Z., Porter, S.C., Kutzbach, J.E., Xihao, W., Suming, W., Xiaodong, L., Xiaoqiang, L., Weijian, Z. 2000. Asynchronous Holocene optimum of the East Asian monsoon. *Quaternary Science Reviews*, 19, 743–762.

Anderson, P.M., Lozhkin, A.V., Brubaker, L.B. 2002. Implications of a 24,000-yr palynological record for a Younger Dryas cooling and for boreal forest development in northeastern Siberia. *Quaternary Research*, 57, 325–333.

Andreev A.A., and Klimanov, V.A. 1999. East Siberia (with special reference to Central Yakutia, Late Glacial and Holocene). In Velichko, A.A., Akhmetyev, M.A., Zelikson, E.M., Nechaev, V.P., Shik, S.M. (Eds.), *Climate and environment changes during the last 65 million years*. GEOS, Moscow, Russia, p. 122–127. (in Russian)

Andreev, A.A., Klimanov, V.A., Sulerzhitsky, L.D. 1997. Younger Dryas pollen records from central and southern Yakutia. *Quaternary International*, 41/42, 111–117.

Andreev, A., Tarasov, P., Siegert, C., Ebel, T., Klimanov, V.A., Melles, M., Bobrov, A.A., Dereviagin, A. Yu., Lubinski, D.J., Hubberten, H.-W. 2003. Late Pleistocene and Holocene vegetation and climate on the northern Taymyr Peninsula, Arctic Russia. *Boreas*, 32, 484–505.

Andreev, A., Tarasov, P., Schwamborn, G., Ilyashuk, B., Ilyashuk, E., Bobrov, A., Klimanov, V., Rachold, V., Hubberten, H.-W. 2004. Holocene paleoenvironmental records from Nikolay Lake, Lena River Delta, Arctic Russia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 209, 197–217.

Bazaliiskii, V.I. 2003. The Neolithic of the Baikal region on the basis of mortuary materials. In Weber, A. and McKenzie, H. (Eds.), *Prehistoric Foragers of the Cis-Baikal, Siberia*. Canadian Circumpolar Institute Press, Edmonton, Alberta, Canada, p. 37–50.

Bazarov, D.B. 1968. *Quaternary sediments and main stages of landform development on the Selenga Mountains*. Ulan-Ude Publishing House, Ulan-Ude, Russia. (in Russian)

Beamish, R.J. (Ed.). 1995. Climate change and northern fish populations. *Canadian Special Publication of Fisheries and Aquatic Sciences* 121. National Research Council of Canada, Ottawa. Ontario, Canada.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Beamish, R.J. 2005. Personal communication. Pacific Biological Station, Fisheries & Oceans Canada. Nanaimo, British Columbia, Canada.

Beamish, R.J. and Bouillon, D.R. 1993. Pacific salmon production trends in relation to climate. *Canadian Journal of Fisheries and Aquatic Sciences*, 50, 1002–1016.

Beamish, R.J., Schnute, J.T., Cass, A.J., Neville, C.M., Sweeting, R.M. 2004. The influence of climate on the stock and recruitment of pink and sockeye salmon from the Fraser River, British Columbia, Canada. *Transactions of the American Fisheries Society*, 133, 1396–1412.

Bezrukova, E.V., Mats, V.D., Letunova, P.P., Nakamura, T., Fuji, Sh. 1996. Holocene peat bogs in Prebaikalia as an object of paleoclimatic reconstructions. *Russian Geology and Geophysics*, 37(12), 72–85.

Bezrukova, E.V., Krivonogov, S.K., Abzeva, A.A., Vershinin, K.E., Letunova, P.P., Orlova, L.A., Takahara, H., Miyoshi, N., Nakamura, T., Krapivina, S.M., Kawamuro, K. 2005a. Landscapes and climate of the Baikal region in the Late Glacial and Holocene (from results of complex studies of peat bogs). *Russian Geology and Geophysics*, 46(1), 21–33.

Bezrukova, E.V., Abzeva, A.A., Letunova, P.P., Kulagina, N.V., Vershinin, K.E., Belov, A.V., Orlova, L.A., Danko, L.V., Krapivina, S.M. 2005b. Post-glacial history of Siberian spruce (*Picea obovata*) in the Lake Baikal area and the significance of this species as a paleo-environmental indicator. *Quaternary International*, 136(1), 47–57.

Bezrukova, E.V., Dan'ko, L.V., Snytko, V.A., Letunova, P.P., Orlova, L.A., Kuz'min, S.B., Vershinin, K.E., Abzaeva, A.A., Sizykh, A.P., Khlystov, O.M. 2005c. New data on vegetation change on the western shore of Lake Baikal in the Middle–Late Holocene. *Doklady Earth Sciences*, 40(2), 303–307.

Binford, L.R. 2001. *Constructing frames of reference*. University of California Press, Berkeley, California, USA.

Blyakharchuk, T.A. 2003. Four new pollen sections tracing the Holocene vegetational development of the southern part of the West Siberian Lowland. *The Holocene*, 13(5), 715–731.

Blyakharchuk, T.A. and Sulerzhitsky, L.D. 1999. Holocene vegetational and climatic changes in the forest zone of Western Siberia according to pollen records from the extrazonal palsa bog Bugristoye. *The Holocene*, 9(5), 621–628.

Blyakharchuk, T.A., Wright, H.E., Borodavko, P.S., van der Knaap, W.O., Ammann, B. 2004. Late Glacial and Holocene vegetational changes on the Ulagan high-mountain

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

plateau, Altai Mountains, southern Siberia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 209, 259–279.

Boreham, S. 2003. Personal communication. Department of Geography, University of Cambridge. Cambridge, UK.

Borren, W., Bleuten, W., Lapshina, E.D. 2004. Holocene peat and carbon accumulation rates in the southern taiga of western Siberia. *Quaternary Research*, 61, 42–51.

Boyarkin, V.M. 1973. Physical geography essays. *Geography of the Irkutsk oblast, Issue 2*. Irkutsk State University Press, Irkutsk, Russia. (in Russian)

Bullock, P., Fedoroff, N., Jongerius, A., Stoops, G., Tursina, T. 1985. *Handbook for soil thin section description.* Waine Research Publications, Albrighton, UK.

Bush, A.B.G. 2005. CO_2/H_2O and orbitally driven climate variability over central Asia through the Holocene. *Quaternary International*, 136(1), 15–23.

Chebykin, E.P., Edgington, D.N., Grachev, M.A., Zheleznyakova, T.O., Vorobyova, S.S., Kulikova, N.S., Azarova, I.N., Khlystov, O.M., Goldberg, E.L. 2002. Abrupt increase in precipitation and weathering of soils in East Siberia coincident with the end of the last glaciation (15 cal kyr BP). *Earth and Planetary Science Letters*, 200, 167–175.

Chen, Z. Wang, Z., Schneiderman, J., Tao, J., Cai, Y. 2005. Holocene climate fluctuations in the Yangtze delta of eastern China and the Neolithic response. *The Holocene*, 15(6), 915–924.

Chita hydro-meteorological observatory. 1966. Buryat Republic and Chita Oblast. Part 2: Air and ground temperatures. *Reference book for climates of the USSR. Issue 23, Gidrometeorologicheskoe Izdatelstvo*. Leningrad, Russia. (in Russian)

Chita hydro-meteorological observatory. 1974. Buryat Republic and Chita Oblast. Meteorological data for individual years. Part 2: Atmospheric precipitation, Part 3: Snow cover. *Reference book for climates of the USSR. Issue 23, Zabaikalskoe Upravlenie Gidrometeorologicheskoi Sluzhby*. Chita, Russia. (in Russian)

Clayden, S.L., Cwynar, L.C., MacDonald, G.M., Velichko, A.A. 1997. Holocene pollen and stomates from a forest-tundra site on the Taimyr Peninsula, Siberia. *Arctic and Alpine Research*, 29(3), 327–333.

Colman, S.M., Peck, J.A., Karabanov, E.B., Carter, S.J., Bradbury, J.P., King, J.W., Williams, D.F. 1995. Continental climate response to orbital forcing from biogenic silica records in Lake Baikal. *Nature*, 378, 769–771.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Colman, S.M., Jones, G.A., Rubin, M., King, J.W., Peck, J.A., Orem, W.H. 1996. AMS radiocarbon analyses from Lake Baikal, Siberia: challenges of dating sediments from a large, oligotrophic lake. *Quaternary Science Reviews*, 15, 669–684.

Coope, R. 2004. Personal communication. Royal Holloway, University of London. London, UK.

Corbet, G.B. 1978. *The Mammals of the Palaearctic Region: a Taxonomic Review.* British Museum (Natural History) and Cornell University Press. London, UK and Ithaca, NY, USA.

Demske, D., Heumann, G., Granoszewski, W., Nita, M., Mamakowa, K., Tarasov, P.E., Oberhansli, H. 2005. Late Glacial and Holocene vegetation and regional climate variability evidenced in high-resolution pollen records from Lake Baikal. *Global and Planetary Change*, 46(1–4), 255–279.

Dlussky, K. 2004. Personal communication. Laboratory of Paleomagnetism and Petromagnetism, Department of Physics, University of Alberta. Edmonton, Alberta, Canada.

Dobrovolsky, G.V. and Urusevskaya, I.S. 1984. *Soil Geography.* Moscow State University Press, Moscow, Russia. (in Russian)

Dolukhanov, P.M. 1997. The Pleistocene–Holocene transition in Northern Eurasia: environmental changes and human adaptations. *Quaternary International*, 41/42, 181–191.

Dolukhanov, P.M. and Khotinskiy, N.A. 1984. Human cultures and the natural environment in the USSR during the Mesolithic and Neolithic. In Velichko A.A., Wright, H.E., Barnosky, C.W. (Eds.), *Late Quaternary environments of the Soviet Union.* University of Minnesota Press, Minneapolis, Minnesota, USA, p. 319–327.

Dorofeyuk, N.I. and Tarasov, P.E. 1998. Vegetation and Lake Levels in Northern Mongolia in the Last 12,500 Years as Indicated by Data of Pollen and Diatom Analyses. *Stratigraphy and Geological Correlation*, 6(1), 70–83.

Ellert, B.H. and Jansen, H.H. 1996. *Soil Sampling Procedure To Estimate Changes In Carbon Storage.* Agriculture & Agri-Foods Canada Research Centre, Project # 1113-9301 (MII #34), Lethbridge, Alberta, Canada.

Evans, M.E. and Heller, F. 2003. *Environmental Magnetism: Principles and applications of enviromagnetics.* Academic Press, San Diego, California, USA.

Eyles, N., Eyles, C., Miall, A. 1983. Lithofacies types and vertical profile models; an alternative approach to the descriptive and environmental interpretation of glacial diamict

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

sequences. *Sedimentology*, 30, 393–410.

Fedotov, A.P., Chebykin, E.P., Semenov, M.Yu, Vorobyova, S.S., Osipov, E.Yu, Golobokova, L.P., Pogodaeva, T.V., Zheleznyakova, T.O., Grachev, M.A., Tomurhuu, D., Oyunchimeg, Ts., Narantsetseg, Ts., Tomurtogoo, O., Dolgikh, P.T., Arsenyuk, M.I. 2004. Changes in the volume and salinity of Lake Khubsugul (Mongolia) in response to global climate changes in the upper Pleistocene and the Holocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 209, 245–257.

Feng, Z.-D., Wang, W.G., Guo, L.L., Khosbayar, P., Narantsetseg, T., Jull, A.J.T., An, C.B., Li, X.Q., Zhang, H.C., Ma, Y.Z. 2005. Lacustrine and eolian records of Holocene climate changes in the Mongolian Plateau: preliminary results. *Quaternary International*, 136(1), 25–32.

Filippov, A.G., Shibanova, I.V., Popova, S.M. 2000. Finds of Mollusks of the Genus *Gastrocopta* in Holocene Sediments of Eastern Siberia. *Doklady Earth Sciences*, 371A(3), 466–468.

Finney, B.P., Gregory-Eaves, I., Sweetman, J., Douglas, M.S.V., Smol, J.P. 2000. Impacts of climatic change and fishing on Pacific salmon abundance over the past 300 years. *Science*, 290, 795–799.

Finney, B.P., Gregory-Eaves, I., Douglas, M.S.V., Smol, J.P. 2002. Fisheries productivity in the northeastern Pacific Ocean over the past 2,200 years. *Nature*, 416, 729–733.

Fowell, S.J., Wang, Y., Peck, J.A., Hansen, B.C.S., Khosbayar, P., Ganbold, E. 2002. Palynological indices identify mid to late Holocene changes in moisture availability at Lakes Telmen and Dood, northern Mongolia. *Proceedings of the Geological Society of America*, Denver, Colorado, USA (Abstract).

Fowell, S.J., Hansen, B.C.S., Peck, J.A., Khosbayar, P., Ganbo, E. 2003. Mid to late Holocene climate evolution of the Lake Telmen Basin, North Central Mongolia, based on palynological data. *Quaternary Research*, 59, 353–363.

Galazii, G.I. (Ed.). 1993. *Baikal Atlas*. Federal Service of Surveying and Cartography, Moscow, Russia. (in Russian)

Gale, R. 2004. *Basovo site, Upper Lena River Valley, Russia: charcoal.* Unpublished manuscript in possession of the author.

Gale, R. and Cutler, D. 2000. *Plants in Archaeology.* Westbury and Royal Botanic Gardens, Kew, UK.

Gee, G.W. and Bauder, J.W. 1986. Particle-size analysis. In Klute, A. (Ed.), *Methods of soil analysis, Part 1, Physical and Mineralogical methods- Agronomy Monograph No. 9.*

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, USA.

Gerber, J. 1996. Revision der Gattung *Vallonia* Risso 1826 (Mollusca: Gastropoda: Valloniidae). *Schriften zur Malakozoologie*, Heft 8. (in German)

Gerber, J. 2003. Personal communication. Division of Invertebrates, The Field Museum of Natural History. Chicago, Illinois, USA.

Goodfriend, G.A. 1992. The use of land snail shells in paleoenvironmental reconstruction. *Quaternary Science Reviews*, 11, 665–685.

Goriunova O.I, Novikov, A.G., Ziablin, L.P., Smotrova, V.I. 2004. *Ancient Graves at the Uliarba Cemetery on Lake Baikal: Neolithic and Paleometal*. Izdatel'stvo Unstituta Arkheologii i Etnografii SO RAN. Novosibirsk, Russia. (in Russian)

Gromov, I.M and Polyakov, I.Y. 1992. *Fauna of the USSR, Mammals Volume III, 8. Voles (Microtinae)*. Smithsonian Institution Libraries and The National Science Foundation. Washington D.C., USA.

Grunert, J., Lehmkuhl, F., Walther, M. 2000. Paleoclimatic evolution of the Uvs Nuur basin and adjacent areas (Western Mongolia). *Quaternary International*, 65/66, 171–192.

He, Y., Theakstone, W.H., Zhonglin, Z., Dian, Z., Tandong, Y., Tuo, C., Yongping, S., Hongxi, P. 2004. Asynchronous Holocene climatic change across China. *Quaternary Research*, 61, 52–63.

Hill, M.O. 1979. TWINSPAN-A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and the attributes. *Ecology and Systematics*. Cornell University, New York, USA.

Hoffmann, R.S. 1985. The correct name for the Palearctic brown, or flat-skulled, shrew is *Sorex roboratus*. *Proceedings of the Biological Society of Washington*, 98, 17–28.

Horiuchi, K., Minoura, K., Hoshino, K., Oda, T., Nakamura, T., Kawai, T. 2000. Palaeoenvironmental history of Lake Baikal during the last 23,000 years. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 157, 95–108.

Huang, C.C., Zhou, J., Pang, J., Han, Y., Hou, C. 2000. A regional aridity phase and its possible cultural impact during the Holocene Megathermal in the Guanzhong Basin, China. *The Holocene*, 10(1), 135–142.

Huang, C.C., Zhao, S. Pang, J., Zhou, Q., Chen, S., Li, P., Mao, L., Ding, M. 2003. Climatic aridity and the relocations of the Zhou culture in the southern Loess Plateau of China. *Climatic Change*, 61, 361–378.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Hutchinson, D.R., Golmshtok, A.J., Zonenshain, L.P., Moore, T.C., Sholz, C.A., Klitgord, K.D. 1992. Depositional and tectonic framework of the rift basins of Lake Baikal from multichannel seismic data. *Geology*, 20, 589–592.

International Society of Soil Science. 1998. *World Reference Base for Soil Resources: World Soil Resources Report, No. 84*. International Soil Reference and Information Center, United Nations Food and Agriculture Organisation, Rome, Italy.

Irkutsk Meteorological Agency. 2002. Personal communication. Irkutsk, Russia.

Jasinski, J.P.P., Warner, B.G., Andreev, A.A., Aravena, R., Gilbert, S.E., Zeeb, B.A., Smol, J.P., Velichko, A.A. 1998. Holocene environmental history of a peatland in the Lena River valley, Siberia. *Canadian Journal of Earth Science*, 35, 637–648.

Kaneko, Y., Nakata, K., Saitoh, T., Stenseth, N.C., Bjørnstad, O. N. 1998. The biology of *Clethrionomys rufocanus*: a review. *Researches on Population Ecology*, 4, 21–37.

Karabanov, E., Prokopenko, A.A., Williams, D.F., Khursevich, G.K. 2000. A new record of Holocene climate change from the bottom sediments of Lake Baikal. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 156, 211–224.

Kashiwaya, K. (Ed.). 2003. *Long Continental Records from Lake Baikal.* Springer-Verlag, Tokoyo, Japan.

Kataoka, H., Takahara, H., Krivonogov, S.K., Bezrukova, E.V., Orlova, L., Kropivina, S., Miyoshi, N., Kawamuro, K. 2003. Pollen record from the Chivyrkui Bay Outcrop on the eastern shore of Lake Baikal since the late glacial. In Kashiwaya, K. (Ed.), *Long Continental Records from Lake Baikal.* Springer-Verlag, Tokoyo, Japan, p. 207–218.

Kelly, R.L. 1995. *The foraging spectrum- diversity in hunter-gatherer lifeways.* Smithsonian Institution Press, Washington, D.C., USA.

Kerney, M.P., Preece, R.C., Turner, C. 1980. Molluscan and plant biostratigraphy of some Late Devensian and Flandrian deposits in Kent. *Philosophical Transactions of the Royal Society of London*, B 291, 1–43.

Keyser-Tracqui, C., Crubezy, E. Ludes, B. 2003. Nuclear and mitochondrial DNA analysis of a 2000-year old necropolis in the Egyin Gol valley of Mongolia. *American Journal of Human Genetics*, 73, 247–260.

Kharinskii, A.V. and Sosnovskaia, N.S. 2000. The Bronze Age Cemetery Khadarta IV. *Baikal'skaia Sibir' v drevnosti,* 2, 66–100. (in Russian)

Khotinskiy, N.A. 1984. Holocene vegetation history. In Velichko, A.A., Wright, H.E., Barnosky, C.W. (Eds.), *Late Quaternary environments of the Soviet Union.* University of Minnesota Press, Minneapolis, Minnesota, USA, p. 179–200.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Kienel, U., Siegert, C., Hahne, J. 1999. Late Quaternary palaeoenvironmental reconstructions from a permafrost sequence (North Siberian Lowland, SE Taymyr Peninsula)- a multidisciplinary case study. *Boreas*, 28, 181–193.

Komatsu, G., Brantingham, P.J., Olsen, J.W., Baker, V.R. 2001. Paleoshoreline geomorphology of Böön Tsagaan Nuur, Tsagaan Nuur and Orog Nuur: the Valley of Lakes, Mongolia. *Geomorphology*, 39, 83–98.

Kozhov, M.M. 1963. *Lake Baikal and its life*. W. Junk, The Hague, Netherlands.

Krasnoshchekov, S.I. 1981. *Biology of the Lake Baikal omul'*. Nauka, Moscow. (in Russian)

Kremenetski, K.V., Tarasov, P.E., Cherkinsky, A.E. 1997. The latest Pleistocene in southwestern Siberia and Kazakhstan. *Quaternary International*, 41/42, 125–134.

Kremenetski, C.V., Sulerzhitsky, L.D., Hantemirov, R. 1998. Holocene history of the northern range limits of some trees and shrubs in Russia. *Arctic and Alpine Research*, 30(4), 317–333.

Kremenetski, K.V., Velichko, A.A., Borisova, O.K., MacDonald, G.M., Smith, L.C., Frey, K.E., Orlova, L.A. 2003. Peatlands of the Western Siberian Lowlands: current knowledge on zonation, carbon content and Late Quaternary history. *Quaternary Science Reviews*, 22, 703–723.

Krivonogov, S.K., Takahara, H., Kuzmin, Y.V., Orlova, L.A., Jull, A.J.T., Nakamura, T., Miyoshi, N., Kawamuro, K., Bezrukova, E.V. 2004. Radiocarbon chronology of the Late Pleistocene-Holocene paleogeographic events in Lake Baikal region (Siberia). *Radiocarbon*, 46(2), 745–754.

Kuzmin, M.I., Williams, D.F., Logachev, N.A., Colman, S., Khakhaev, B.N., Kawai, T., Hearn, P., Horie, Sh., Pevzner, L.A., Bukharov, A.A., Fialkov, V.A. 1993. The Baikal Drilling Project: scientific objectives and recent results. *Russian Geology and Geophysics*, 34(10-11), 3–11.

Kuzmin, M.I., Williams, D.F., Kawai, T. 2000. Baikal drilling project. In Minoura, K. (Ed.), *Lake Baikal, a mirror in time and space for understanding global change processes*, Elsevier Press, Amsterdam, The Netherlands, p. 1–14.

Kuznetsov G.A. and Zharkov M.A. 1964. Geological structure and perspectives of oil-and-gas-bearing of the central Angara-Lena marginal flexure. *New data on geology, oil-and-gas-bearing and mineral resources of the Irkutsk oblast*. Nedra, Moscow, Russia. (in Russian)

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Laing, T.E., Rühland, K.M., Smol, J.P. 1999. Past environmental and climatic changes related to tree-line shifts inferred from fossil diatoms from a lake near the Lena River Delta, Siberia. *The Holocene*, 9(5), 547–557.

Lehmkuhl, F. and Lang, A. 2001. Geomorphological investigations and luminescence dating in the southern part of the Khangay and the Valley of the Gobi Lakes (Central Mongolia). *Journal of Quaternary Science*, 16(1), 69–87.

Levine, M., Renfrew, C. and Boyle, K. (Eds.). 2003. *Prehistoric steppe adaptation and the horse*. MacDonald Institute for Archaeological Research, Cambridge, UK.

Lepofsky, D., Lertzman, K., Hallett, D., Mathewes, R. 2005. Climate change and culture change on the southern coast of British Columbia 2400–1200 cal. B.P.: an hypothesis. *American Antiquity*, 70(2), 267–293.

Likhachev, I.M. and Rammel'meier, E.S. 1962. *Terrestrial mollusks of the fauna of the U.S.S.R.* Israel Program for Scientific Translations Ltd., Jerusalem, Israel.

Limondin-Lozouet, N. and Preece, R.C. 2004. Molluscan successions from the Holocene tufa of St Germain-le-Vasson, Normandy (France) and their biogeographical significance. *Journal of Quaternary Science*, 19(1), 55–71.

Lowe, J.J. and Walker, M.J.C. 1997. *Reconstructing Quaternary environments*. Longman, London, UK.

Ložek, V. 1986. Mollusca analysis. In Berglund, B.E. (Ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology*, John Wiley and Sons, New York, USA.

MacDonald, G.M., Velichko, A.A., Kremenetski, C.V., Borisova, O.K., Goleva, A.A., Andreev, A.A., Cwynar, L.C., Riding, R.T., Forman, S.L., Edwards, T.W.D., Aravena, R., Hammarlund, D., Szeicz, J.M., Gattaulin, V.N. 2000. Holocene treeline history and climate change across northern Eurasia. *Quaternary Research*, 53, 302–311.

Mackay, A. 2005. Personal communication. Department of Geography, University College London. London, UK.

Mackay, A., Flower, R., Granina, L. 2002. Lake Baikal. In Shahgedanova, M. and Goudie, A. (Eds.), *The physical geography of northern Eurasia: Russia and neighboring states*. Oxford University Press, Oxford, UK, p. 403–421.

Maslov V.P. 1947. Geology of the upper reaches of the Lena and Kirenga Rivers. *Institute of Geology of the Academy of Sciences of the USSR, Proceedings*, 85(24). Moscow, Russia. (in Russian)

Meier-Brook, C. 1983. Taxonomic studies on *Gyraulus* (Gastropoda: Planorbidae). *Malacologia*, 24(1–2), 1–113.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Meier-Brook, C. 2003. Personal communication. Tübingen, Germany.

Meyrick, R.A. 2003. Holocene molluscan faunal history and environmental change at Kloster Mühle, Rheinland-Pfalz, western Germany. *Journal of Quaternary Science*, 18(2), 121–132.

Meyrick, R.A. and Preece, R.C. 2001. Molluscan successions from two Holocene tufas near Northampton, English Midlands. *Journal of Biogeography*, 28, 77–93.

Michael, H.N. 1958. The Neolithic Age in Eastern Siberia. *Transactions, New Series*, Vol. 48, Part 2. American Philosophical Society, Philadelphia, Pennsylvania, USA.

Mooder, K.P., Schurr, T.G., Bamforth, F.J., Bazaliiski, V.I., Savel'ev, N.A. Population affinities of Neolithic Siberians: a snapshot from prehistoric Lake Baikal. *American Journal of Physical Anthropology*, in press.

Morely, D.W., Leng, M.J., Mackay, A.W., Sloane, H.J. 2005. Late glacial and Holocene environmental change in the Lake Baikal region documented by oxygen isotopes from diatom silica. *Global and Planetary Change*, 46(1–4), 221–233.

Morrison, R.B. 1998. How can the treatment of pedostratigraphic units in the North American Stratigraphic Code be improved? *Quaternary International*, 51/52, 30–33.

Murphy, C.P. 1986. *Thin section preparation of soils and sediments*. AB Academic Publishers, Berkhamsted, UK.

Nara, F., Tani, Y., Soma, Y., Soma, M., Naraoka, H., Watanabe, T., Horiuchi, K., Kawai, T., Oda, T., Nakamura, T. 2005. Response of phytoplankton productivity to climate change recorded by sedimentary photosynthetic pigments in Lake Hovsgol (Mongolia) for the last 23,000 years. *Quaternary International*, 136(1), 78–81.

North American Code of Stratigraphic Nomenclature. 1983. The North American Stratigraphic Code. *American Association of Petroleum Geologists Bulletin*, 67, 841–875.

Obruchev V.A. 1892. Early Paleozoic sediments of the Lena River between Kachugskaya and Vitimskaya Stations. *Zapiski VSIRGO*, 1(2). Moscow, Russia. (in Russian)

Ognev, S.I. 1966. *Mammals of the USSR and Adjacent countries. Volume IV Rodents*. Israel Program for Scientific Translation Ltd., Jerusalem, Israel.

Okladnikov A.P. and Larichev, V.E. 1968. Archaeological Research in Mongolia in 1967. Isv. *SO AN SSSR*. Vyp. 3, No. 11, Novosibirsk, Russia, p. 104–115. (in Russian)

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Orlov, V.N., Schvetzov, J.G., Kovalskaya, J.M, Kutascheva, T.S., Stupina, A.G. 1974. Identification and distribution of *Microtus maximowiczii* and *M. fortis* from Transbaicalia (Rodentia, Cricetidae). *Zoologicheskii Zhurnal*, 53(9), 1391–1396.

Parfitt, S.A. 2004. *Small vertebrates from Basovo, Upper Lena River, Russia.* Unpublished manuscript in possession of the author.

Pavlovskiy E.V. 1929. To the valley geomorphology of the Lena River upper reaches and Vitim River lower reaches. *Geological Bulletin*, 7(1–3). (in Russian)

Peck, J.A., Khosbayar, P., King, J.W., Fowell, S.J., Ariunbileg, S., Soninkhishig, N. 2001. The latest Holocene sedimentary environmental magnetic record from Lake Dood, Mongolia. *Proceedings of the American Geophysical Union*, San Francisco, California, USA (Abstract).

Peck, J.A., Khosbayar, P., Fowell, S.J., Pearce, R.B., Ariunbileg, S., Hansen, B.C.S., Soninkhishig, N. 2002. Mid to Late Holocene climate change in north central Mongolia as recorded in the sediments of Lake Telmen. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 183, 135–153.

Peteet, D., Andreev, A., Bardeen, W., Mistretta, F. 1998. Long-term Arctic peatland dynamics, vegetation and climate history of the Pur-Taz region, Western Siberia. *Boreas*, 27, 115–126.

Phillips, E.W.J. 1948. Identification of softwoods by their microscopic structure. *Forest Products Research Bulletin No. 22.* Department of the Environment Building Establishment, H.M.S.O., London, UK.

Piotrowska, N., Bluszcz, A., Demske, D., Granoszewski, W., Heumann, G. 2004. Extraction and AMS radiocarbon dating of pollen from Lake Baikal sediments. *Radiocarbon*, 46(1), 181–187.

Pisaric, M.F.J., MacDonald, G.M., Velichko, A.A., Cwynar, L.C. 2001. The Lateglacial and postglacial vegetation history of the northwestern limits of Beringia, based on pollen, stomate and tree stump evidence. *Quaternary Science Reviews*, 20, 235–245.

Pokryszko, B. 1993. Fen malacocenoses in Dovrefjell (S. Norway). *Fauna norv. Ser., A* 14, 27–38.

Pokryszko, B. 2003a. *Vertigo* of continental Europe- autecology, threats and conservation status (Gastropoda, Pulmonata: Vertiginidae). *Heldia*, 5(7), 13–25.

Pokryszko, B. 2003b. Personal communication. Museum of Natural History, Wroclaw University, Poland.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Powers, W.R. 1996. Siberia in the late glacial and early postglacial. In Straus, L.G., Eriksen, B.V., Erlandson, J.M., Yesner, D.R. (Eds.), *Humans at the end of the ice age: the archaeology of the Pleistocene-Holocene transition*. Plenum Press, New York, USA, p. 229–242.

Preece, R.C. 1980. The biostratigraphy and dating of the tufa deposit at the Mesolithic site at Blashenwell, Dorset, England. *Journal of Archaeological Science*, 7, 345–362.

Preece, R.C. 2004. Personal communication. University Museum of Zoology. Cambridge, UK.

Preece, R.C. and Bridgeland, D.R. 1999. Holywell Coombe, Folkestone: A 13,000 year history of an English Chalkland Valley. *Quaternary Science Reviews*, 18(8–9), 1075–1125.

Preece, R.C. and Day, S.P. 1994. Comparison of Post-glacial molluscan and vegetational successions from a radiocarbon-dated tufa sequence in Oxfordshire. *Journal of Biogeography*, 21, 463–478.

Preece, R.C. and Robinson, J.E. 1984. Late Devensian and Flandrian environmental history of the Ancholme Valley, Lincolnshire: molluscan and ostracod evidence. *Journal of Biogeography*, 11, 319–352.

Preece, R.C., Coxon, P., Robinson, J.E. 1986. New biostratigraphic evidence of the Post-glacial colonization of Ireland and for Mesolithic forest disturbance. *Journal of Biogeography*, 13, 487–509.

Preobrazhenskiy, V.S., Fadeeva N.V., Mukhina L.I., Tomilov G.M. 1959. *Types of landscapes and natural division into regions on the Buryat Autonomic Soviet Socialistic Republic*. Academy of Sciences of the USSR Press, Moscow, Russia. (in Russian)

Prokopenko, A.A., Kuzmin, M.I., Williams, D.F., Gelety, V.F., Kalmychkov, G.V., Gvozdkov, A.N., Solotchin, P.A. 2005. Basin-wide sedimentation changes and deglacial lake-level rise in the Hovsgol basin, NW Mongolia. *Quaternary International*, 136(1), 59–69.

Prokopenko, A.A., Williams, D.F., Karabanov, E.B., Khursevich, G.K. 1999. Response of Lake Baikal ecosystem to climate forcing and pCO_2 change over the last glacial/interglacial transition. *Earth and Planetary Science Letters*, 172, 239–253.

Prozorova L.A. 2002. Terrestrial mollusks. In *Flora and fauna of Kuril Island (Materials of International Kuril Island Project)*. Dalnauka, Vladivostok, Russia, p. 74–81. (in Russian)

Prozorova, L. 2003. Taxonomy and species composition of the genus *Anisus* Studer in the fauna of Russia. *Bulletin of the Russian Far East Malacological Society*, 7, 99–115.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Prozorova, L. 2004. Personal communication. Institute of Biology and Soil Science, Far Eastern Branch of the Russian Academy of Sciences. Vladivostok, Russia.

Reference Book for Climatology of the USSR. 1949. *Gidrometeorologicheskoe Izdatelstvo, Issue 22*. Leningrad, Russia. (in Russian)

Rhodes, T.E., Gasse, F., Ruifen, L., Fontes, J.-C., Keqin, W., Bertrand, P., Gibert, E., Mélières, F., Tucholka, P., Zhixiang, W., Zhi-Yuan, C. 1996. A Late Pleistocene–Holocene lacustrine record from Lake Manas, Zunggar (northern Xinjiang, western China). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 120, 105–121.

Romanchenko Z.N. (Ed.). 1990. State water cadastre, surface water. *Seria 2*, 1(15). VNIIGMID, Obninsk, Russia. (in Russian)

Schileyko, A.A. 1984. *Land mollusc suborder Pupillina of USSR fauna (Gastropoda, Pulmonata, Geophila)*. Fauna of the USSR, New Series, No. 130. Nauka, Leningrad, Russia. (in Russian)

Shahgedanova, M. and Goudie, A. (Eds.). 2002. *The physical geography of northern Eurasia: Russia and neighboring states*. Oxford University Press, Oxford, UK.

Sheldrick, B.H. and Wang, C. 1993. Particle size distribution. In Carter, M.R. (Ed.), *Soil sampling and methods of analysis*. Canadian Society of Soil Science, Lewis Publishers, Boca Raton, Florida, USA.

Sitnikova, T. 2004. Personal communication. Limnological Institute, Siberian Branch of the Russian Academy of Sciences. Irkutsk, Russia.

Snitsarenko, N.I. (Ed.). 1983. Climate of Ulan-Ude. *Gidrometeorologicheskoe Izdatelstvo*. Leningrad, Russia. (in Russian)

Soil Classification Working Group. 1998. *The Canadian System of Soil Classification*. Agriculture and Agri-Food Canada Publication 1646, NRC Research Press, Ottawa, Ontario, Canada.

Sorokin, V.N. and Sorokina, A.A. 1988. *Biology of the young of the commercial fishes of Baikal*. Nauka, Novosibirsk. (in Russian)

Sparks, B.W. 1961. The ecological interpretation of Quaternary non-marine Mollusca. *Proceedings of the Linnaean Society London*, 172, 71–80.

Starobogatov Ya. I. 1996. Eurasiatic species of the genus *Cochlicopa* (Gastropoda, Pulmonata, Cochlicopidae). *Ruthenica*, 5(2), 105–129.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Stuvier, M. and Reimer, P.J. 2005. CALIB RADIOCARBON CALIBRATION PROGRAM* Version: 5.01 (Using the IntCal04 radiocarbon calibration curve in conjunction with Stuiver, M. and Reimer, P.J. 1993. *Radiocarbon*, 35, 215–230).

Stuvier, M., Reimer, P.J., Bard, E., Beck, J.W., Burr, G.S., Hughen, K.A., Kromer, B., McCormac, F.C., v.d. Plicht, J., Spurk, M. 1998. INTCAL98 radiocarbon age calibration 24,000-0 cal BP. *Radiocarbon*, 40(3), 1041–1083.

Takahara, H., Krivonogov, S.K., Bezrukova, E.V., Miyoshi, N., Morita, Y., Nakamura, T., Hase, Y., Shinomiya, Y., Kawamuro, K. 2000. Vegetation history of the southeastern and eastern coasts of Lake Baikal from bog sediments since the last interstade. In Minoura, K. (Ed.), *Lake Baikal: A Mirror in Time and Space for Understanding Global Change Processes*. Elsevier, Amsterdam, The Netherlands, p. 108–118.

Tani, Y., Kurihara, K., Nara, F., Itoh, N., Soma, M., Soma, Y., Tanaka, A., Yoneda, M., Horota, M., Shibata, Y. 2002. Temporal changes in the phytoplanktonic community of the southern basin of Lake Baikal over the last 24,000 years recorded by photosynthetic pigments in a sediment core. *Organic Geochemistry*, 33, 1621–1634.

Tankersley, K.B. and Kuzmin, Y.V. 1998. Patterns of culture change in eastern Siberia during the Pleistocene-Holocene transition. *Quaternary International*, 49/50, 129–139.

Tarasov, P.E., Jolly, D., Kaplan, J.O. 1997. A continuous Late Glacial and Holocene record of vegetation changes in Kazakhstan. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 136, 281–292.

Tarasov, P., Dorofeyuk, N., Metel'tseva, E. 2000. Holocene vegetation and climate changes in Hoton-Nur basin, northwest Mongolia. *Boreas*, 29, 117–126.

Tarasov, P.E., Dorofeyuk, N.I., Sokolovskaya, V.T., Nakagawa, T., Makohonienko, M. 2004. Late Glacial and Holocene vegetation changes recorded in the pollen data from the Hangai Mountains, central Mongolia. In Yasuda, Y. and Shinde, V. (Eds.), *Monsoon and Civilization*. Roli Books, New Delhi, India, p. 23–50.

ter Braak, C.J.F. and Šmilauer, P. 1998. *CANOCO reference manual and user's guide to Canoco for Windows: software for canonical community ordination (Version 4).* Microcomputer Power, Ithica, New York, USA.

Turkin, G.V. and Kharinskii, A.V. 2004. The Shamanka II Cemetery: on questions of chronology and cultural affiliations of Neolithic-Bronze Age mortuary complexes at Southern Baikal. *Izvestiia Laboratorii Drevnikh Tekhnologii* 2, 124–158. (in Russian)

Tutin, T.G., Heywood, V.H., Burges, N.A., Moore, D.M., Valentine, D.H., Walters, S.M., Webb, D.A. 1964–80. *Flora Europaea*, 1–5. Cambridge University Press, England.

Uminski, T. 1962. Revision of the Palearctic forms of the genus *Discus* Fitzinger, 1833

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

(*Gastropoda, Endodontidae*). *Annales Zoologici*, 20(16), 299–333.

Velichko, A.A., Andreev, A.A., Klimonov, V.A. 1997. Climate and vegetation dynamics in the tundra and forest zone during the late glacial and Holocene. *Quaternary International*, 41/42, 71–96.

Velichko, A.A., Catto, N., Drenova, A.N., Klimanov, V.A., Kremenetski, K.V., Nechaev, V.P. 2002. Climate changes in East Europe and Siberia at the Late Glacial-Holocene transition. *Quaternary International*, 91, 75–99.

Volkov, B.B. 1975. Graves at Norovlin Uula (Mongolia). *Arkheologiia Severnoi i Tsentral'noi Azee*. Nauka, Novosibirsk, Russia, p. 76–79. (in Russian)

Waldén, H.W. 1966. On the taxonomy, nomenclature and ecology of *Nesovitrea hammonis* (Ström) and *petronella* (L. Pfeiffer). *Arch. Moll.*, 95(3/4), 161–195. (in German)

Waldén, H.W. 1986. Uber Variation, Verbreitung und Okologie von *Vertigo extima*, einer für Europa neuen und bisher als selbstandiges Taxon übersehenen Art. *Arch. Moll.*, 117(1/3), 39–59. (in German)

Wang, W.G., Feng, Z.-D., Li, X.Q., Zhang, H.C., Ma, Y.Z., An, C.B., Guo, L.L. 2004a. The Holocene abrupt climate shifts recorded in Gun Nuur lake core, Northern Mongolia. *Chinese Science Bulletin*, 49(5), 520–256.

Wang, W., Feng, Z.-D., Ma, Y., Lee, X. 2004b. A Holocene climatic record in Gun Nuur, northern Mongolia. *Proceedings of the XVI INQUA Congress*, Reno, Nevada, USA (Abstract).

Weber, A. 1995. The Neolithic and early Bronze Age of the Lake Baikal region: a review of recent research. *Journal of World Prehistory*, 9(1), 99–165.

Weber, A. 2003. Biogeographic profile of the Lake Baikal region, Siberia. In Weber, A. and McKenzie, H. (Eds.), *Prehistoric foragers of the Cis-Baikal, Siberia*. Proceedings of the first conference of the Baikal Archaeology Project, Canadian Circumpolar Press, Edmonton, Alberta, Canada, p. 51–66.

Weber, A. and McKenzie, H. (Eds.). 2003. *Prehistoric foragers of the Cis-Baikal, Siberia*. Proceedings of the first conference of the Baikal Archaeology Project, Canadian Circumpolar Press, Edmonton, Alberta, Canada.

Weber, A.W., Link, D.W., Katzenberg, M.A. 2002. Hunter-gatherer culture change and continuity in the middle Holocene of the Cis-Baikal, Siberia. *Journal of Anthropological Archaeology*, 21, 230–299.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Weber, A.W., McKenzie, H.G., Beukens, R., Goriunova, O.I. 2005. Evaluation of radiocarbon dates from the Middle Holocene hunter-gatherer cemetery Khuzhir-Nuge XIV, Lake Baikal, Siberia. *Journal of Archaeological Science*, 32, 1481–1500.

Wenxiang, W. and Tungsheng, L. 2004. Possible role of the "Holocene Event 3" on the collapse of Neolithic cultures around the Central Plain of China. *Quaternary International*, 117, 153–166.

Williams, D.F., Kuzmin, M.I., Prokopenko, A.A., Karabanov, E.B., Khursevich, G.K., Bezrukova, E.V. 2001. The Lake Baikal drilling project in the context of a global lake drilling initiative. *Quaternary International*, 80/81, 3–18.

Wolverton, S. 2005. The effects of the Hypsithermal on prehistoric foraging efficiency in Missouri. *American Antiquity*, 70(1), 91–106.

Wright, H.E. and Barnosky, C.W. 1984. Introduction to the English edition. In Velichko, A.A., Wright, H.E., Barnosky, C.W. (Eds.), *Late Quaternary environments of the Soviet Union*. University of Minnesota Press, Minneapolis, Minnesota, USA, p. xiii–xxii.

Yasada, Y., Fujiki, T., Nasu, H., Kato, M., Morita, Y., Mori, Y., Kanehara, M., Toyama, S., Yano, A., Okuno, M., Jiejun, H., Ishihara, S., Kitagawa, H., Fukusawa, H., Naruse, T. 2004. Environmental archaeology at the Chengtoushan site, Hunan Province, China, and implications for environmental change and the rise and fall of the Yangtze River civilization. *Quaternary International*, 123/125, 149–158.

Zhadin, V.I. 1965. *Mollusks of fresh and brackish waters of the USSR*. Israel Program for Scientific Translations Ltd., Jerusalem, Israel.

Zhukov, V.M. 1960. *Climate of the Buryat Autonomic Soviet Socialistic Republic*. Ulan-Ude Publishing House, Ulan-Ude, Russia. (in Russian)

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

PLATES

SCANNING ELECTRON MICROSCOPY (SEM) IMAGES OF TERRESTRIAL AND AQUATIC MOLLUSCS FROM THE BASOVO AND BURDUKOVO SITES

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

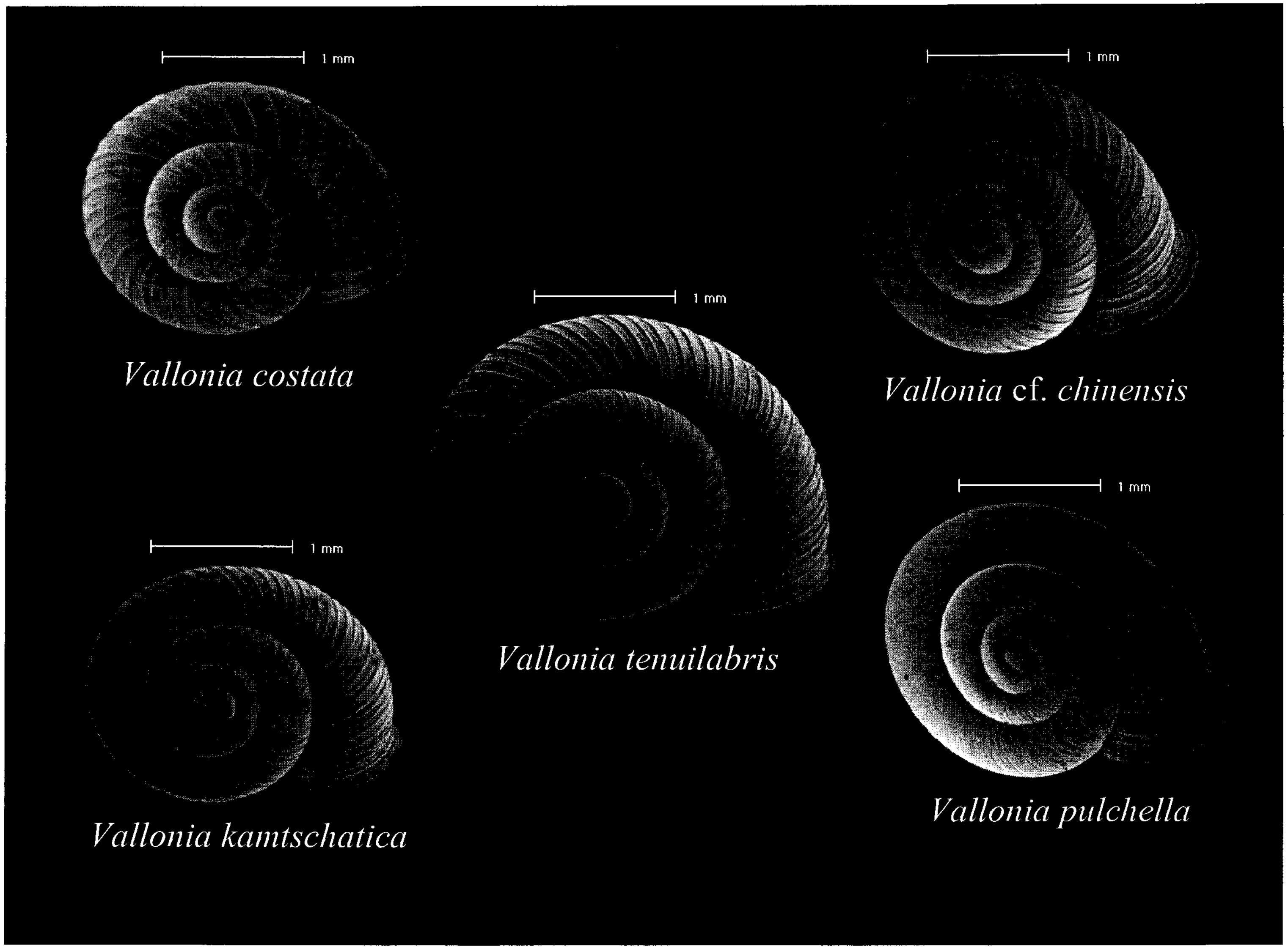


Plate A. Genus *Vallonia* – *V. costata, V.* cf. *chinensis, V. tenuilabris, V. kamtschatica, V. pulchella*, front-view (x30) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

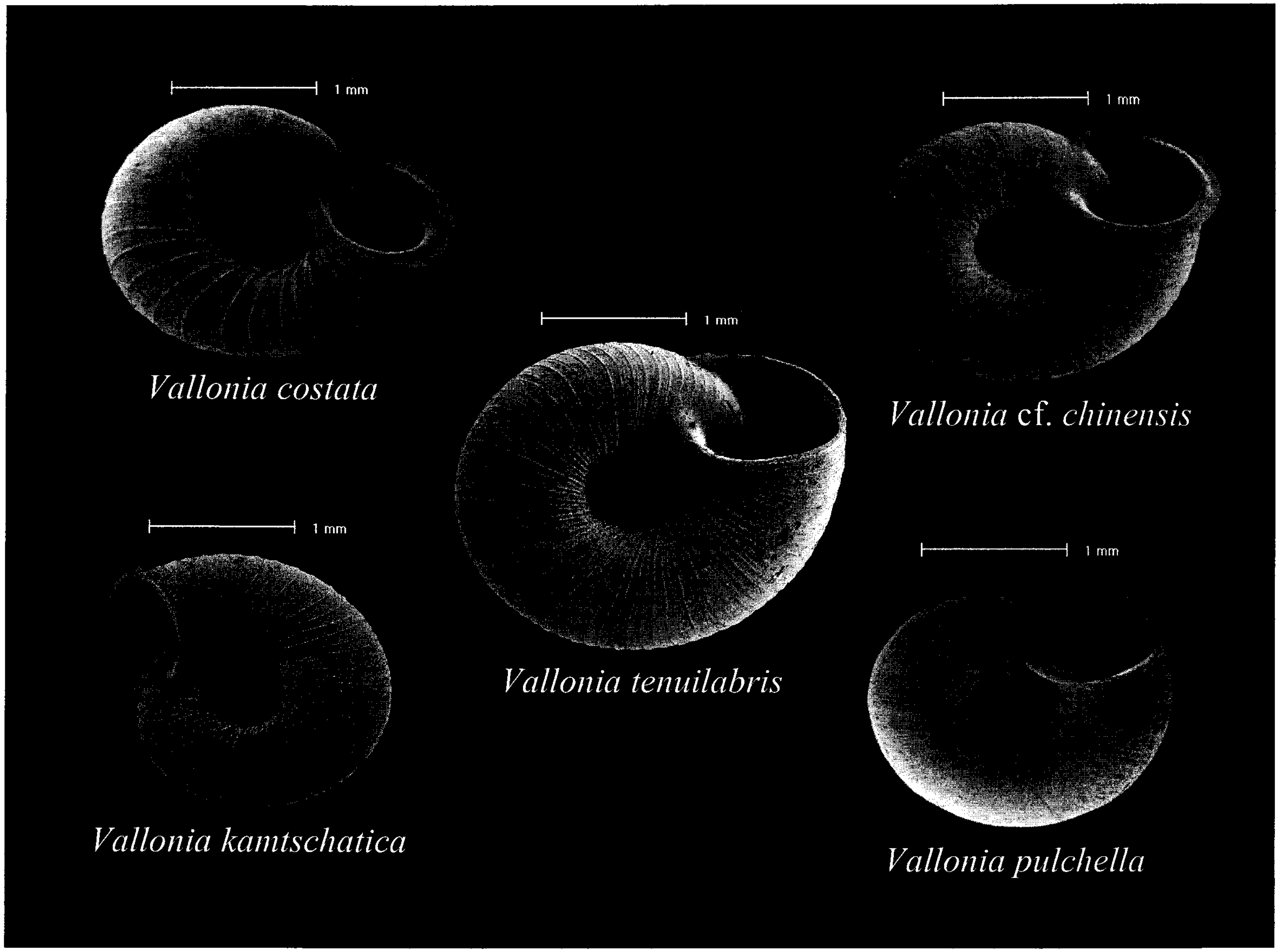


Plate B. Genus *Vallonia* – *V. costata, V.* cf. *chinensis, V. tenuilabris, V. kamtschatica, V. pulchella*, bottom-view (x30) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

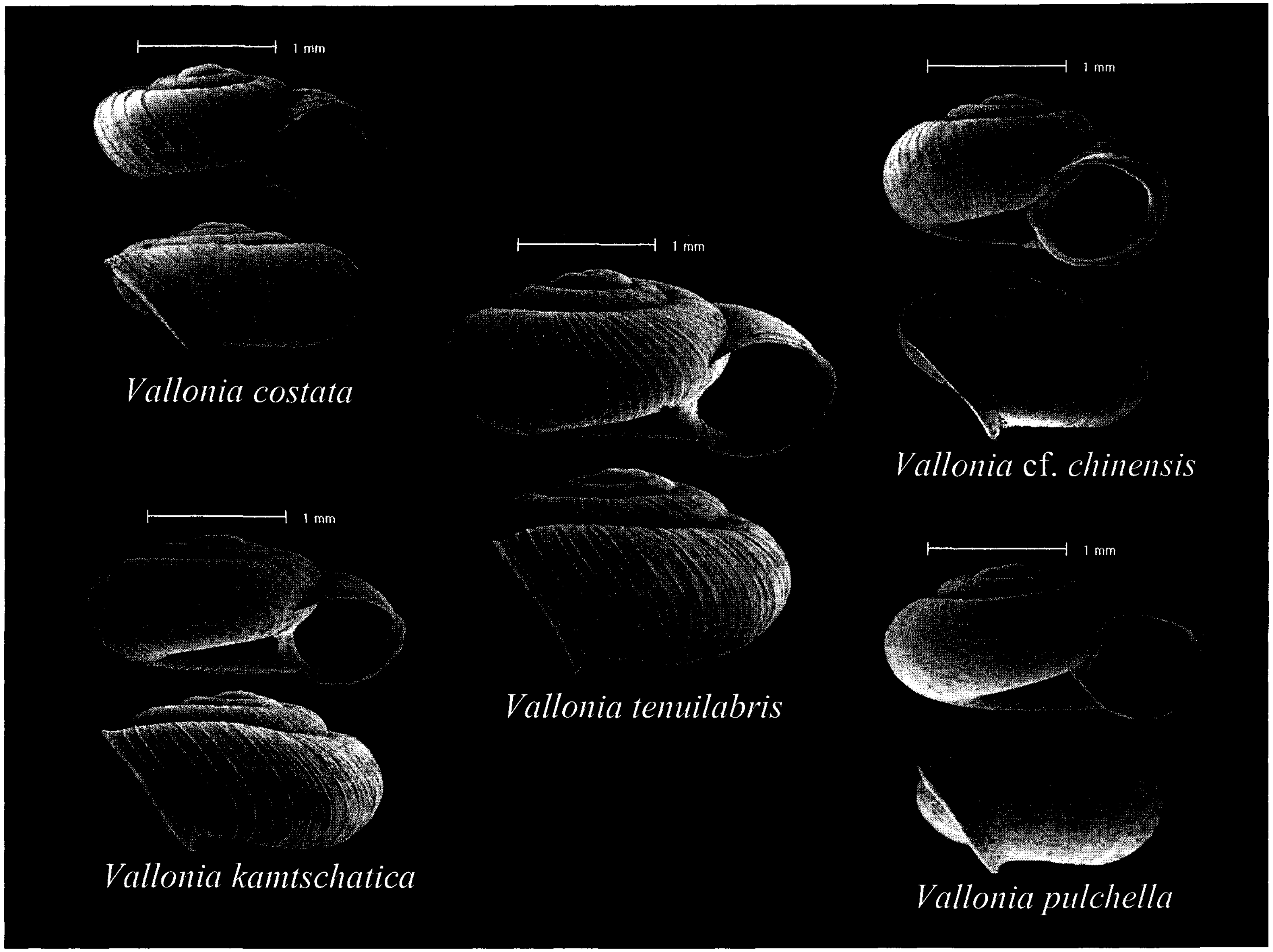


Plate C. Genus *Vallonia – V. costata, V.* cf. *chinensis, V. tenuilabris, V. kamtschatica, V. pulchella*, lateral side-view (x30) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

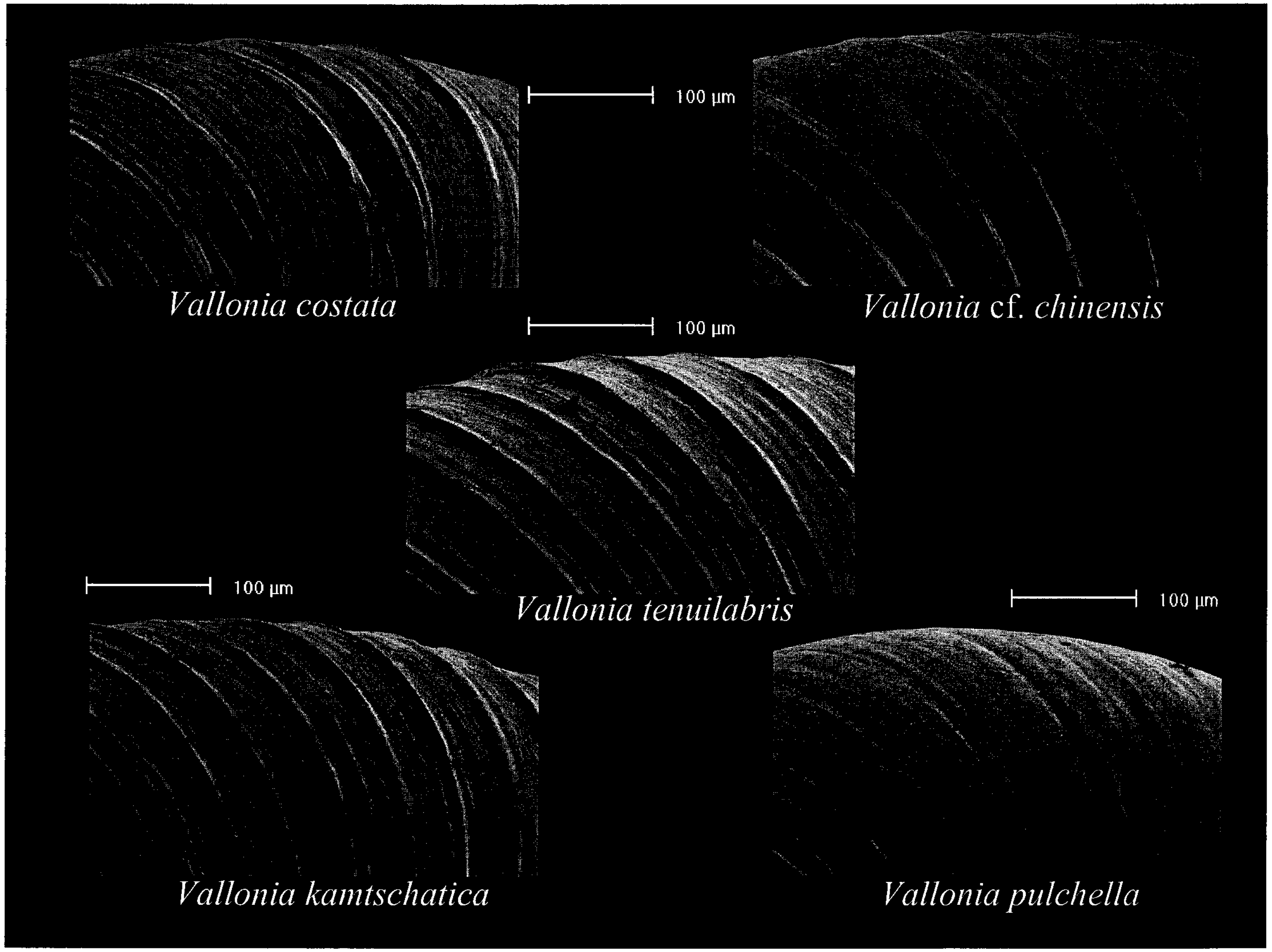


Plate D. Genus *Vallonia* – *V. costata, V.* cf. *chinensis, V. tenuilabris, V. kamtschatica, V. pulchella*, body-whorl micro-sculpture (x200) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

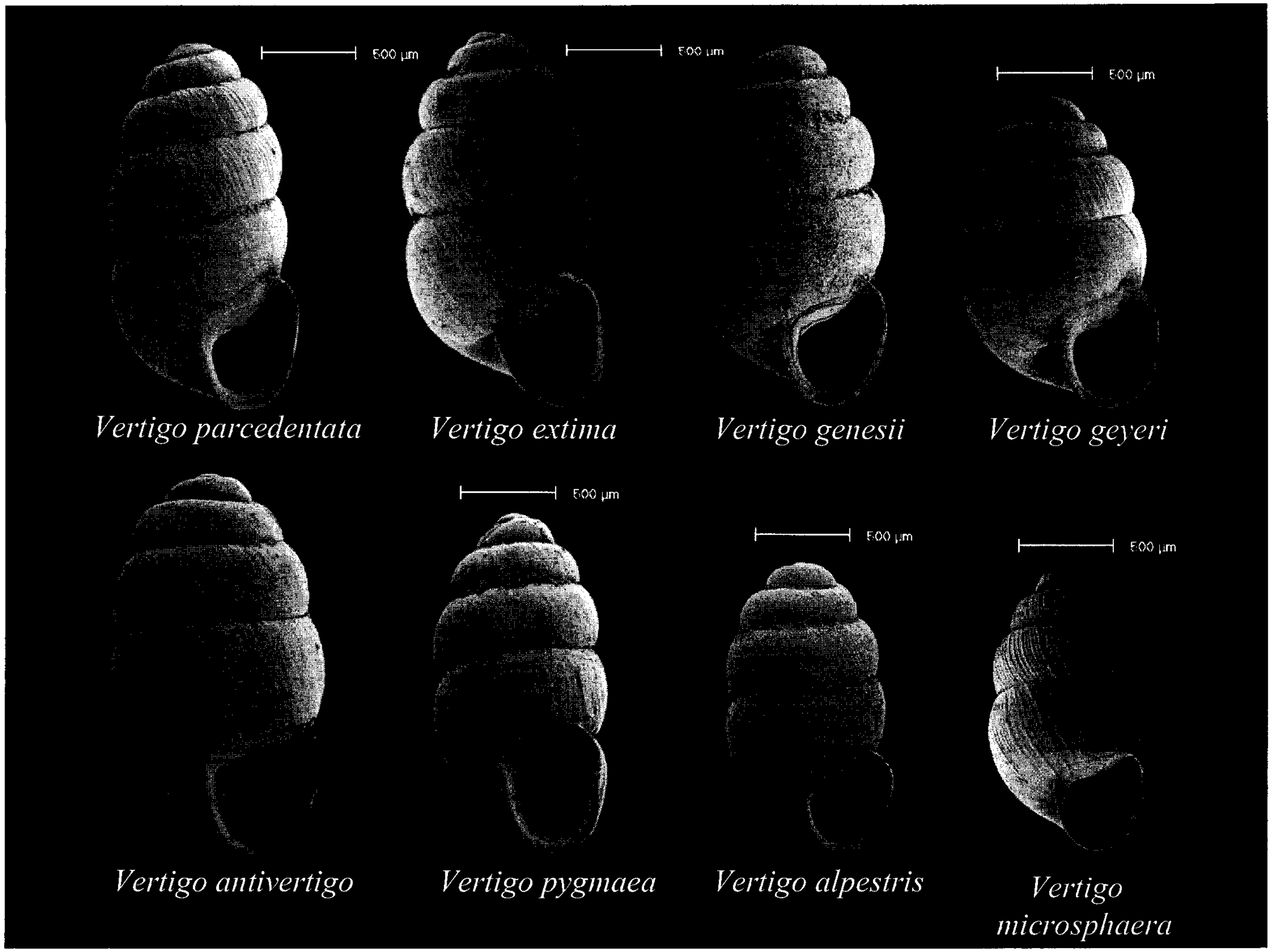


Plate E. Genus *Vertigo* – *V. parcedentata, V. extima, V. genesii, V. geyeri, V. antivertigo, V. pygmaea, V. alpestris, V. microsphaera*, front-view (x40) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

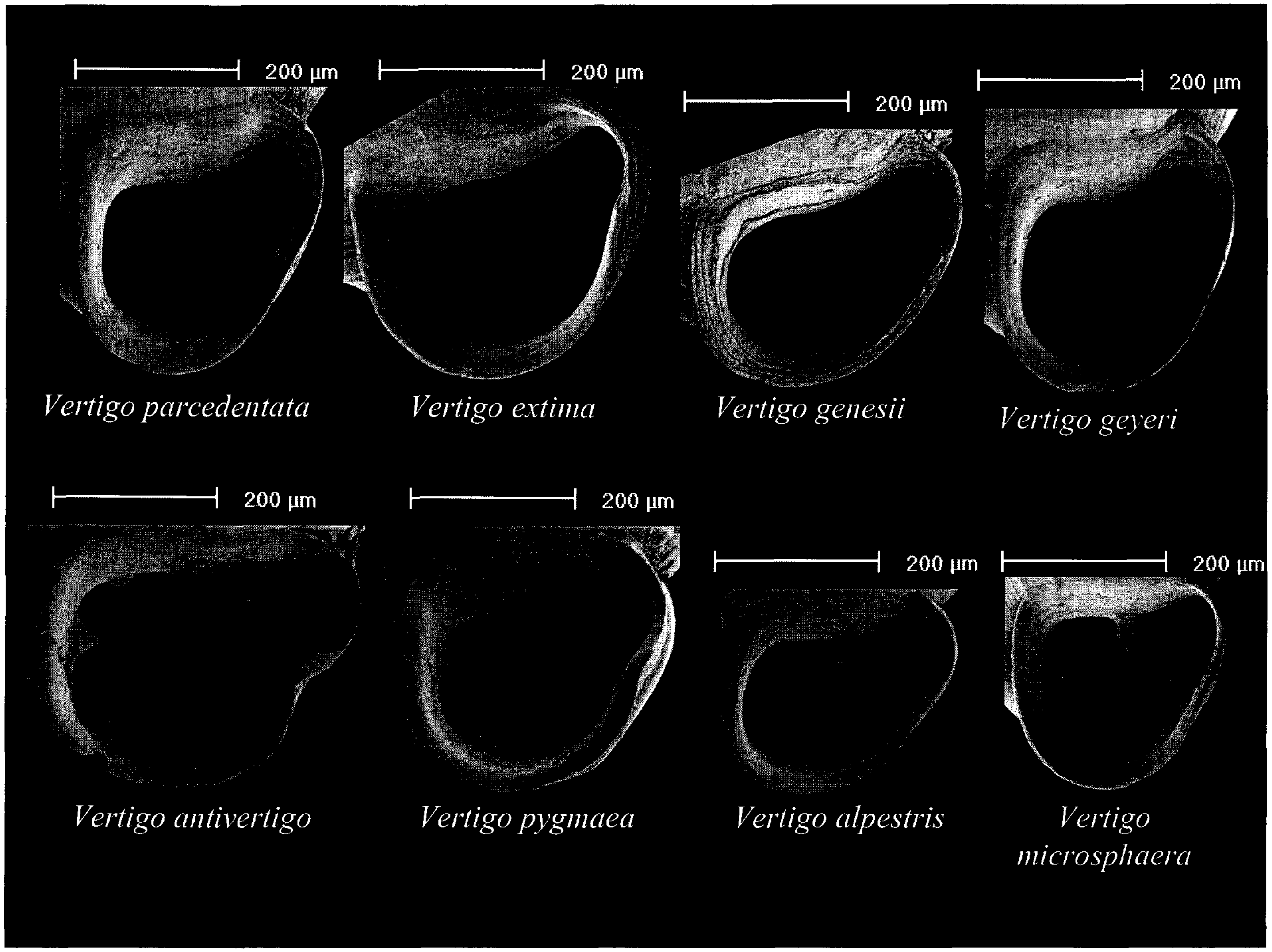


Plate F. Genus *Vertigo – V. parcedentata, V. extima, V. genesii, V. geyeri, V. antivertigo, V. pygmaea, V. alpestris, V. microsphaera*, mouth-view (x110) [Basovo].

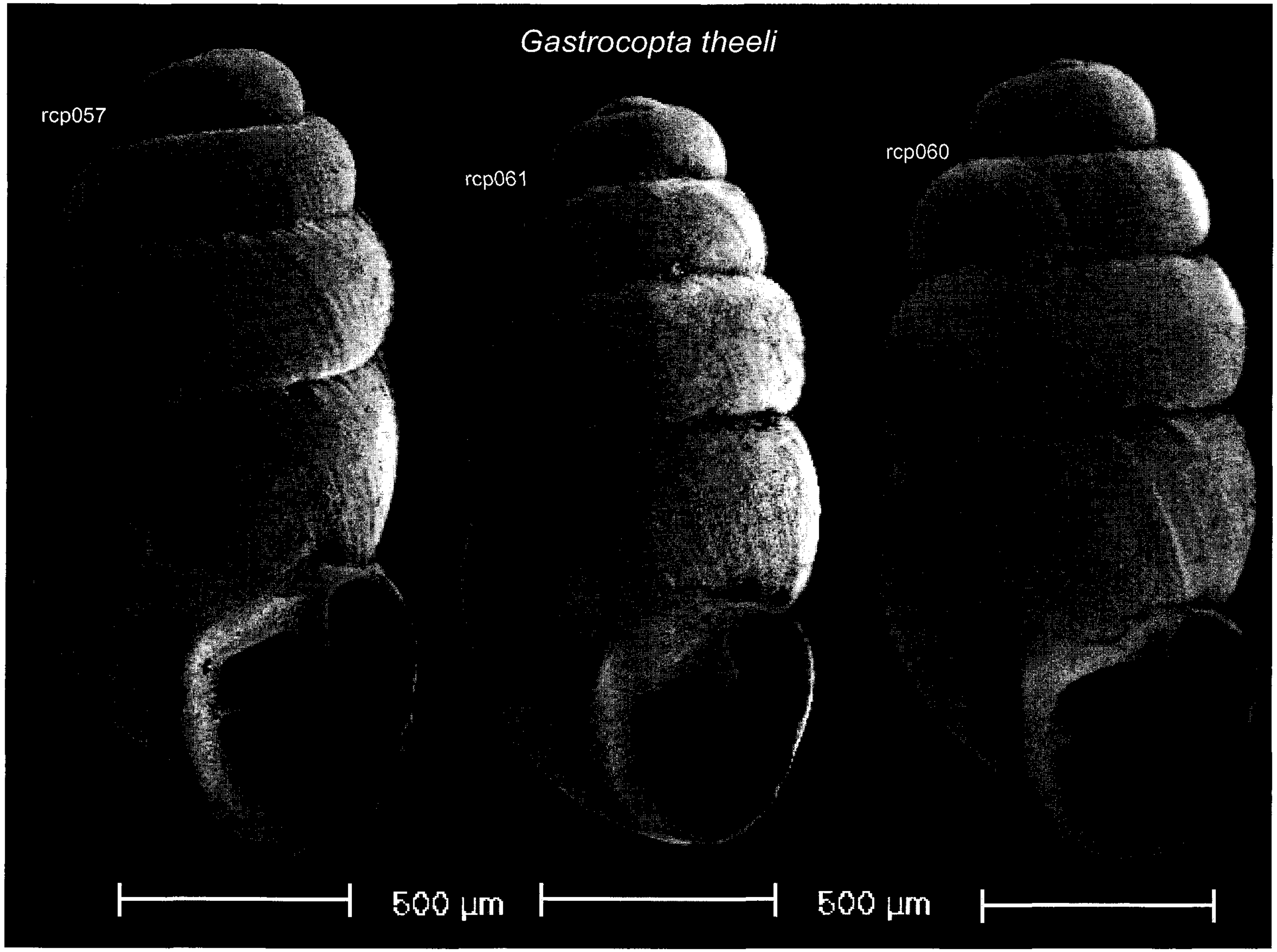


Plate G. *Gastrocopta theeli*, front-view (x40) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

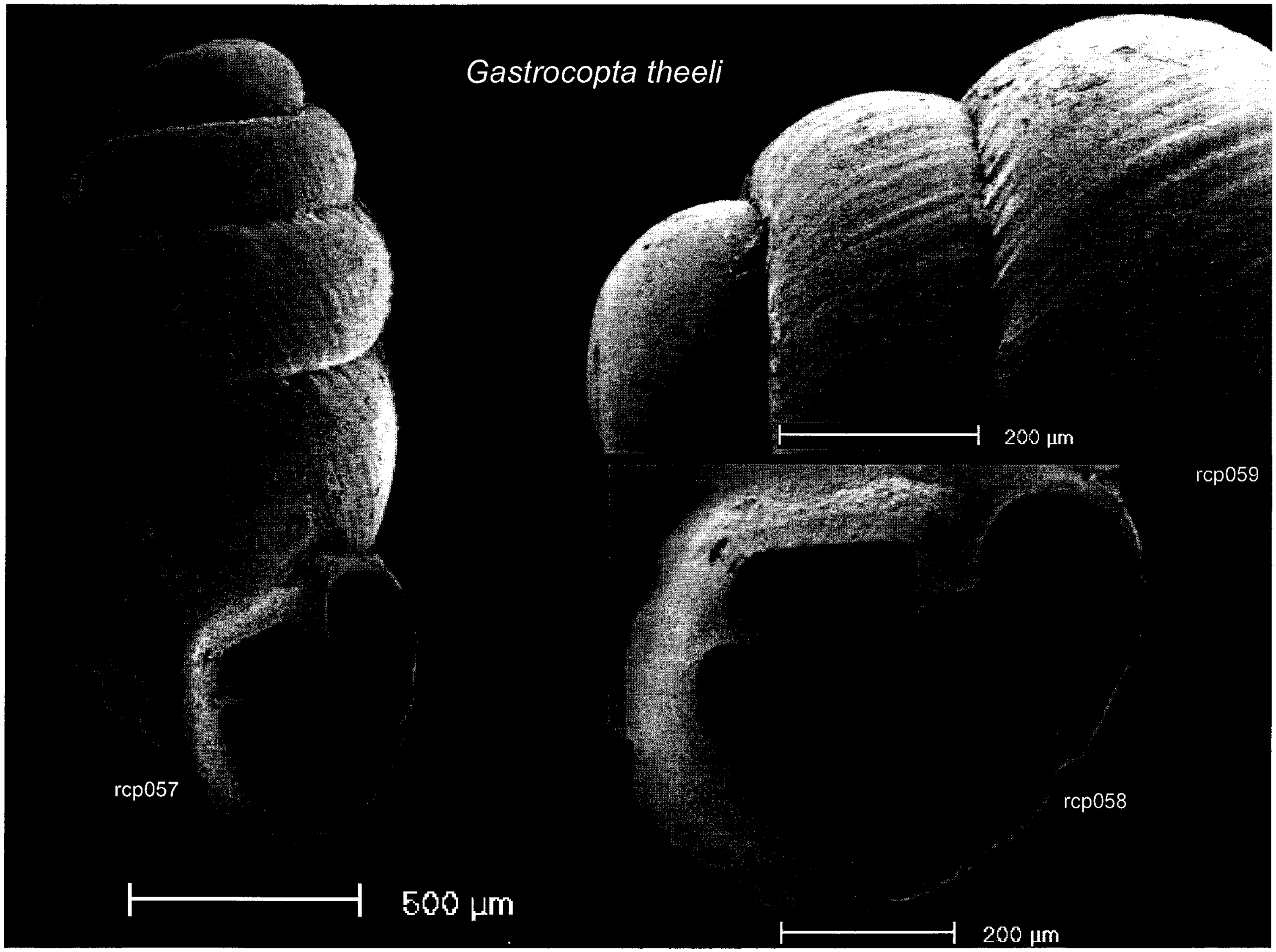


Plate H. *Gastrocopta theeli*, composite: front-view (x40), apical micro-sculpture (x140), mouth-view (x110) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

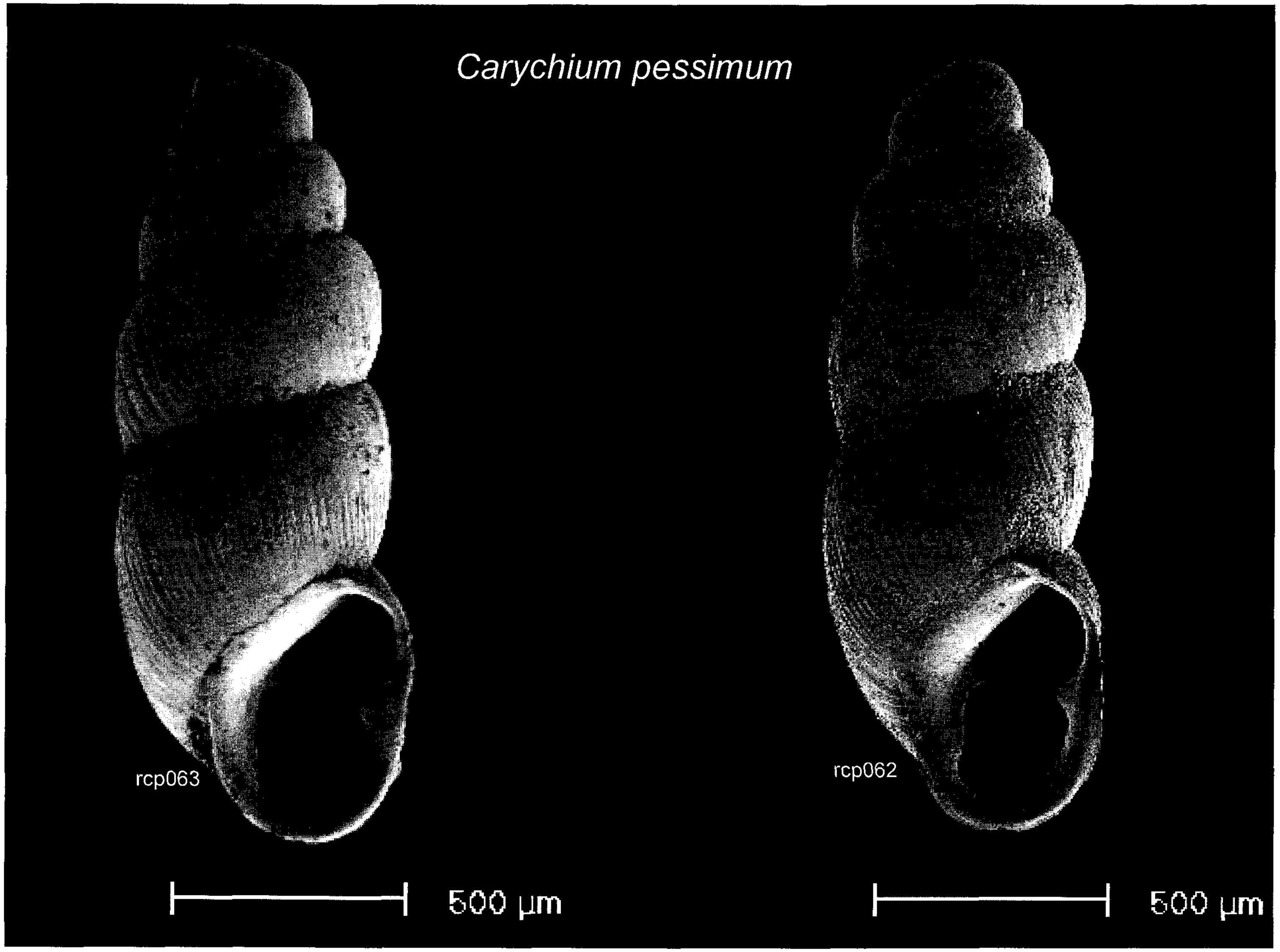


Plate I. *Carychium pessimum*, front-view (x40) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

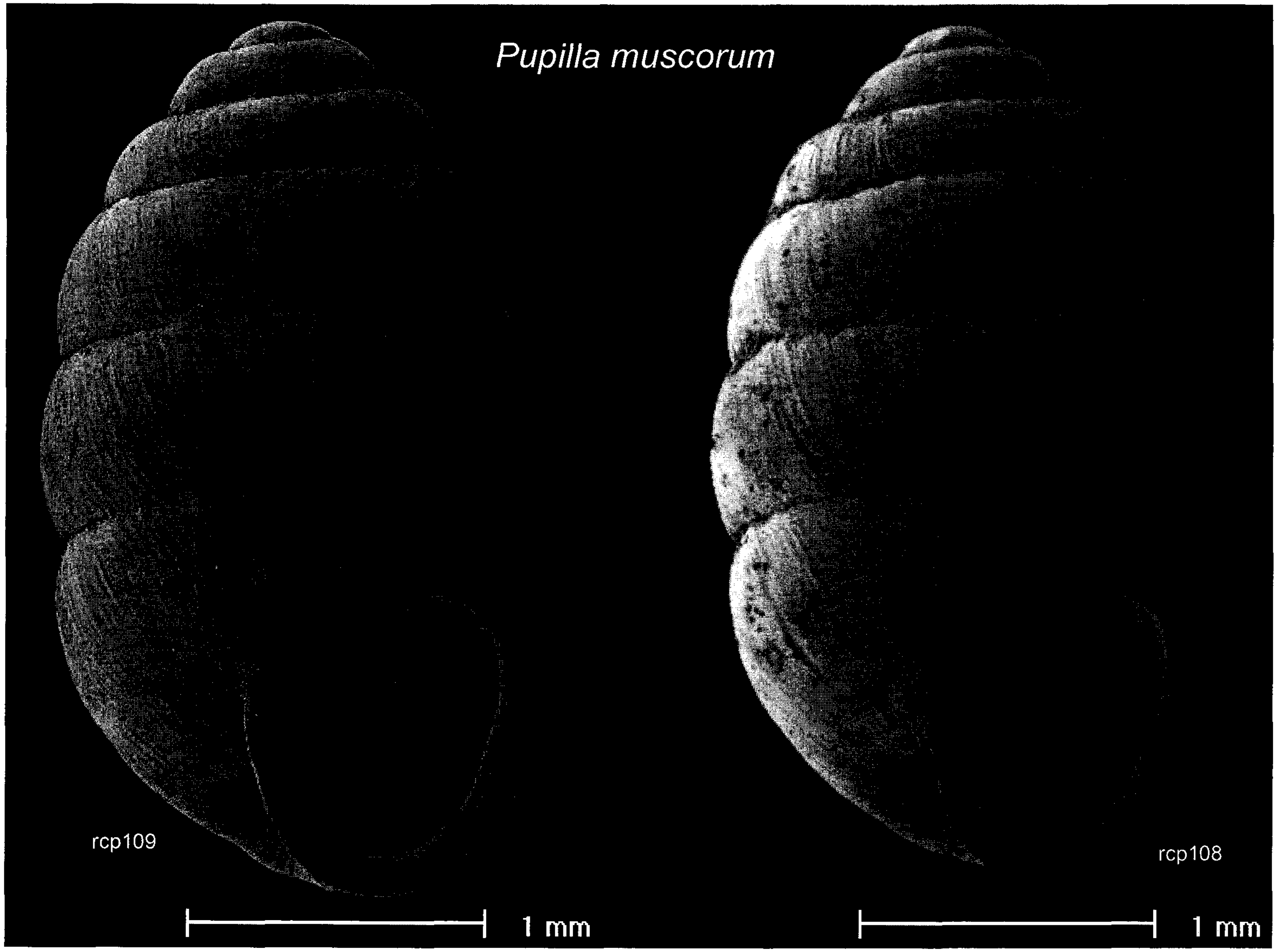


Plate J. *Pupilla muscorum*, front-view (x30) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

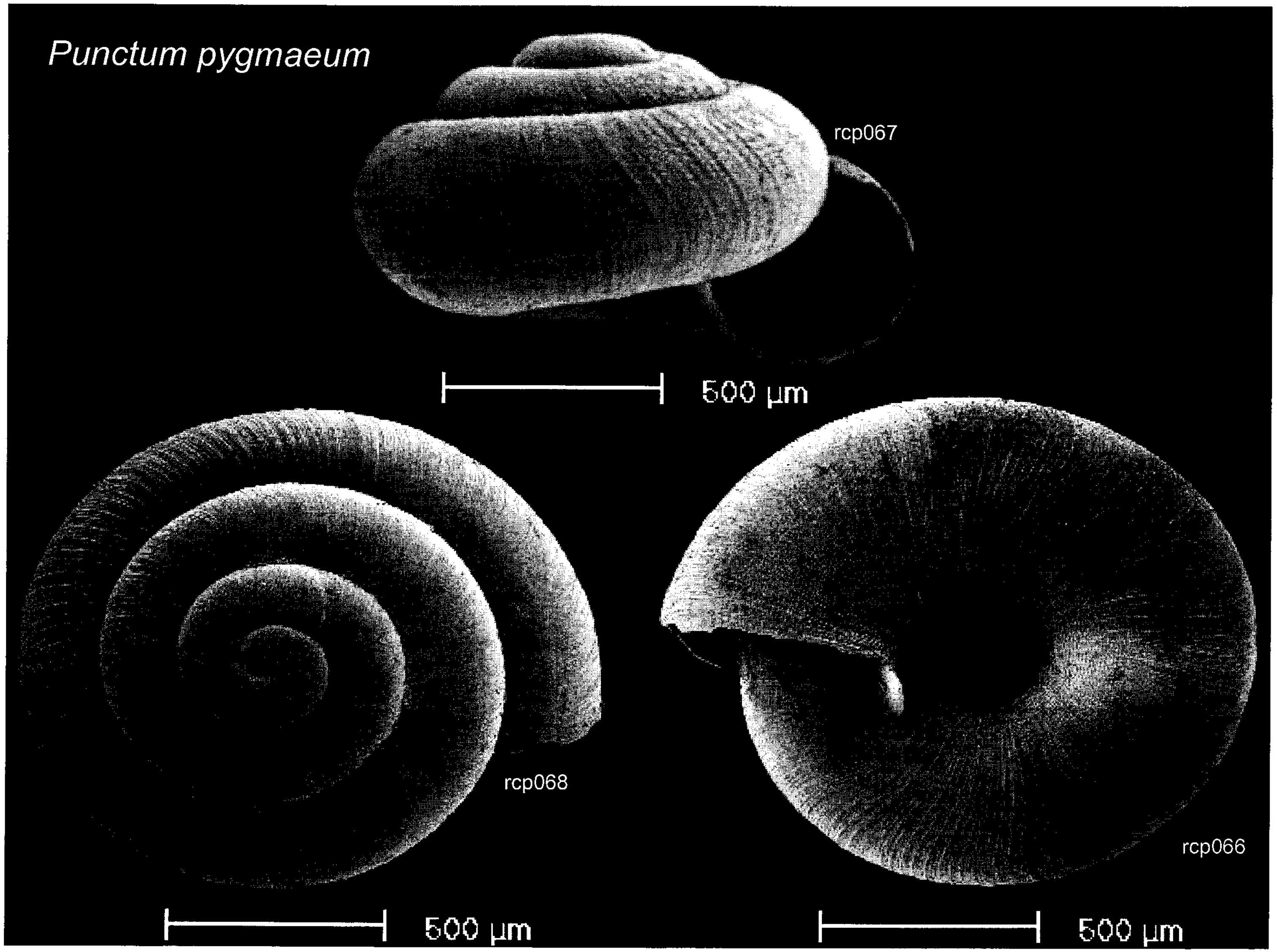


Plate K. *Punctum pygmaeum*, composite (x40): side-view, top-view, bottom-view [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

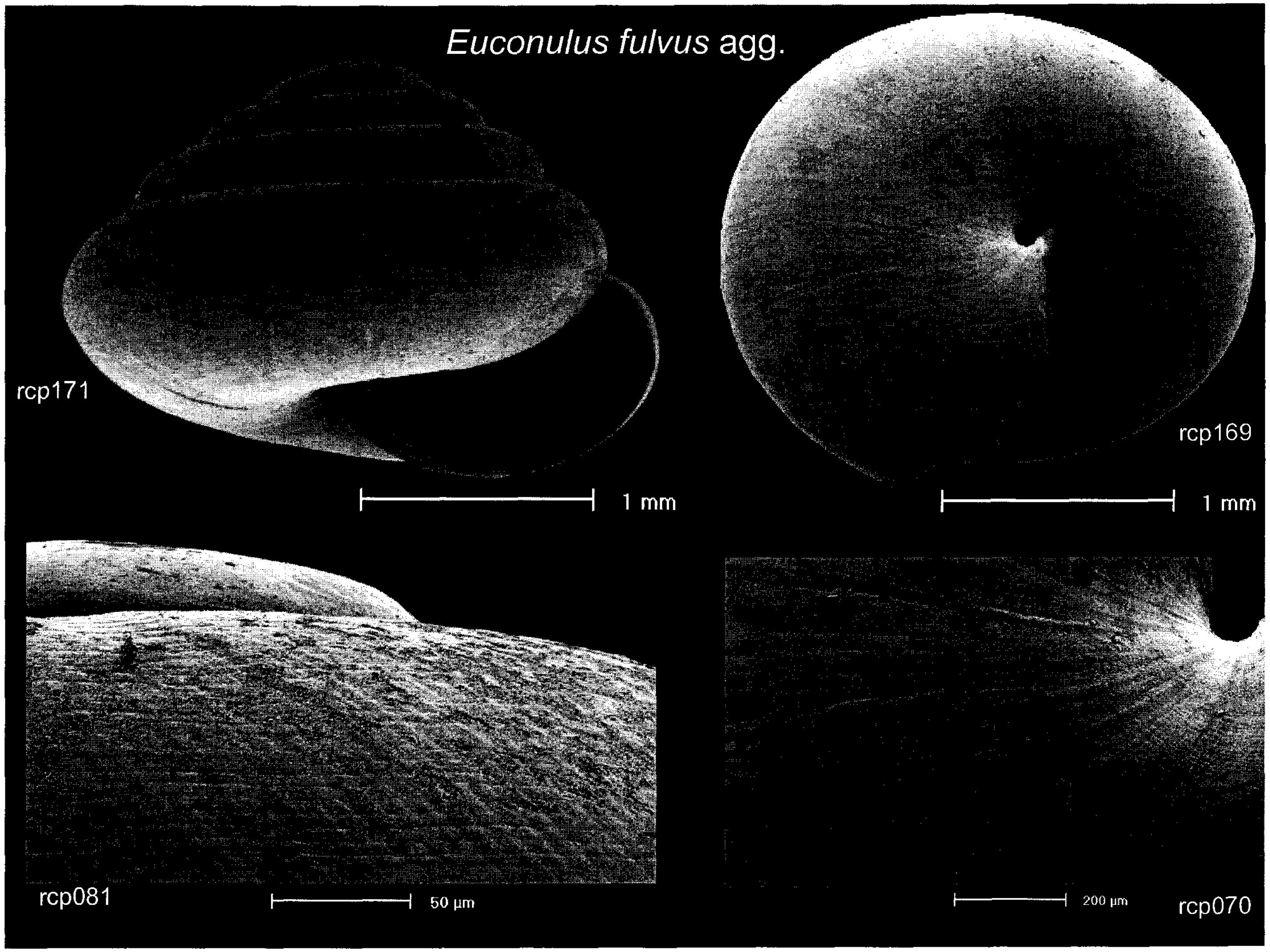


Plate L. *Euconulus fulvus* agg., composite: side-view and bottom-view (x30), apical micro-sculpture (x500), bottom-view (x120) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

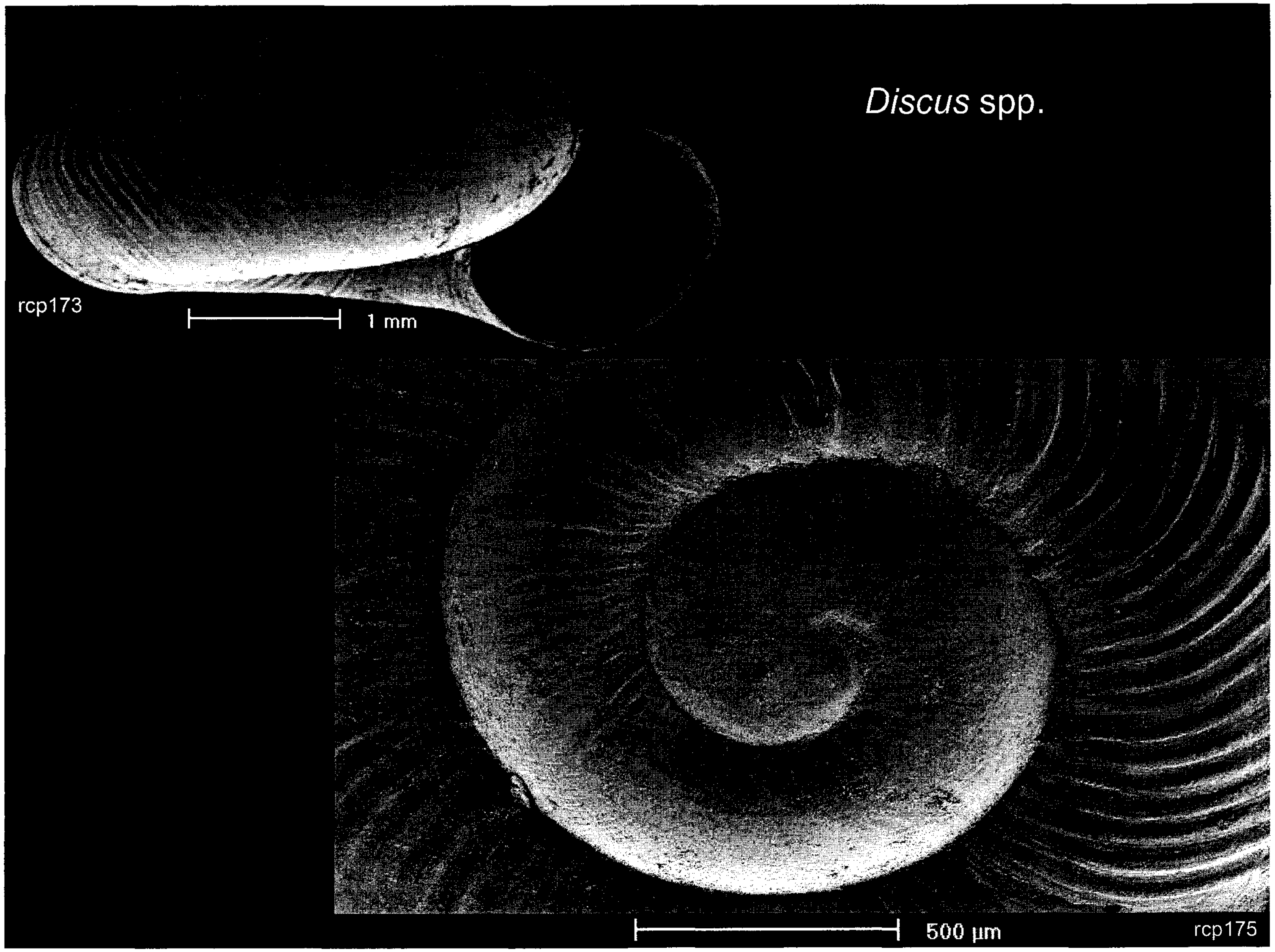


Plate M. *Discus* spp., composite: side-view (x21), apical micro-sculpture (x70) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

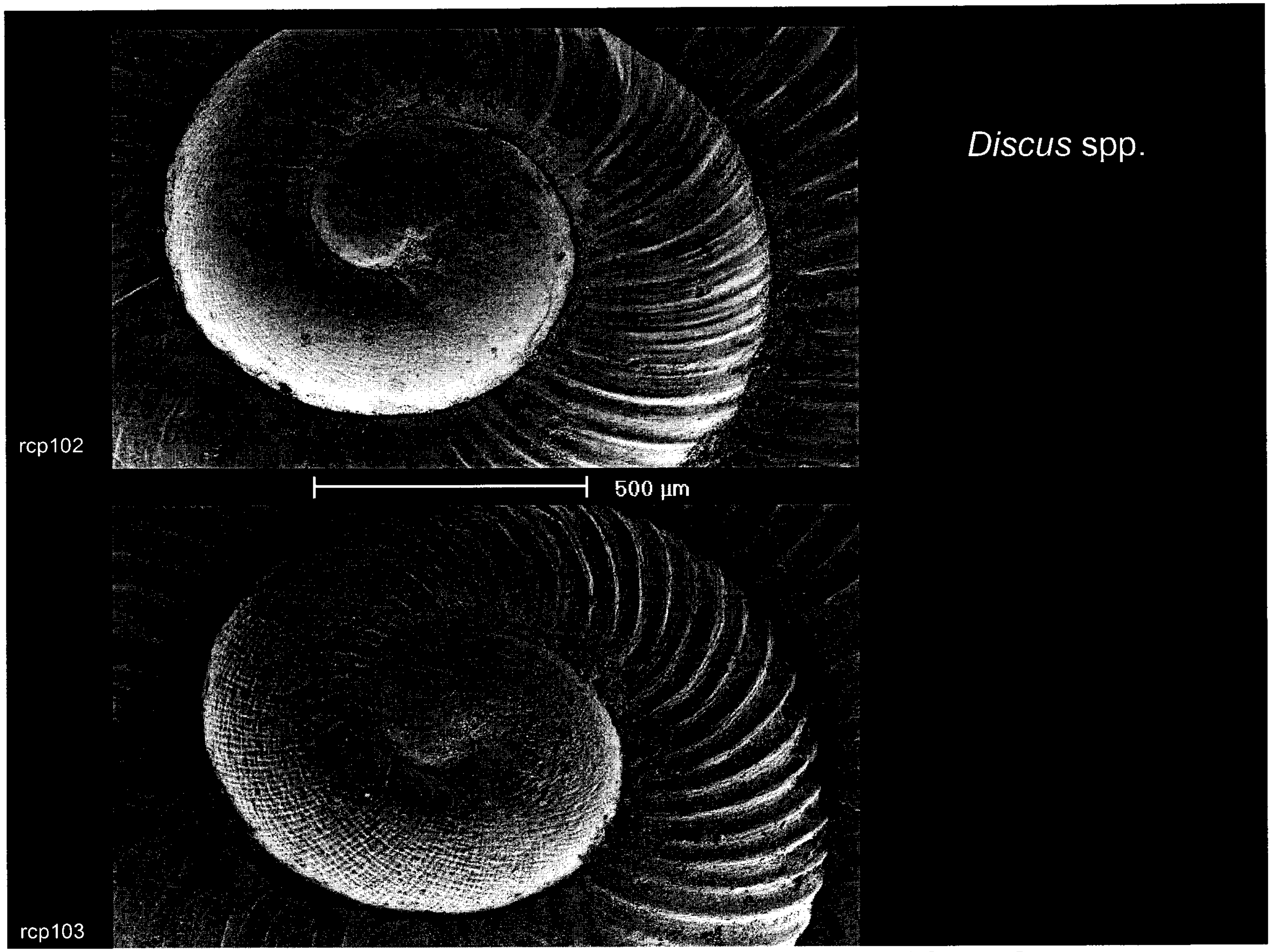


Plate N. *Discus* spp., composite: apical micro-sculpture (x70) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

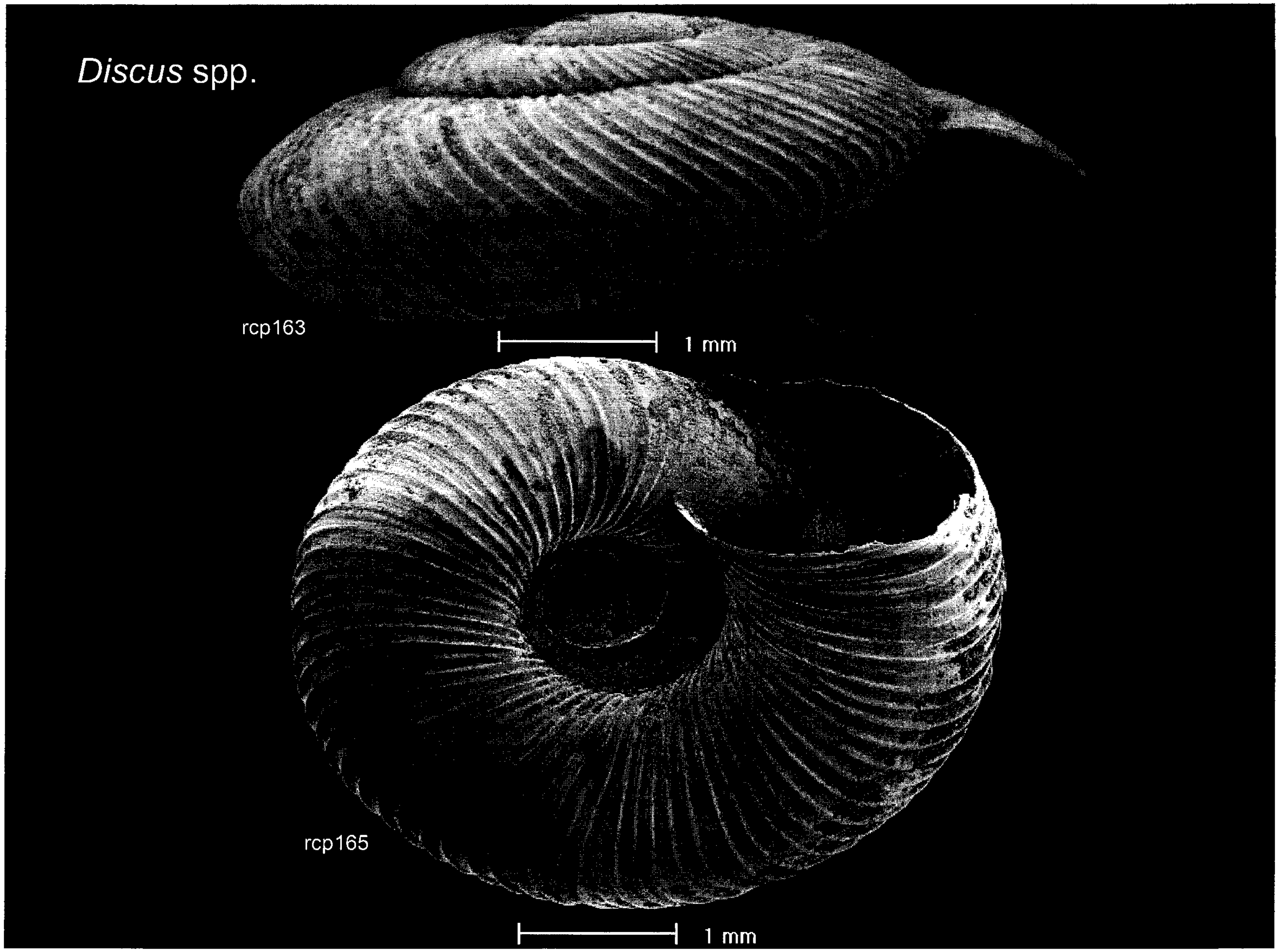


Plate O. *Discus* spp., composite (x21): side-view and bottom-view [Burdukovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

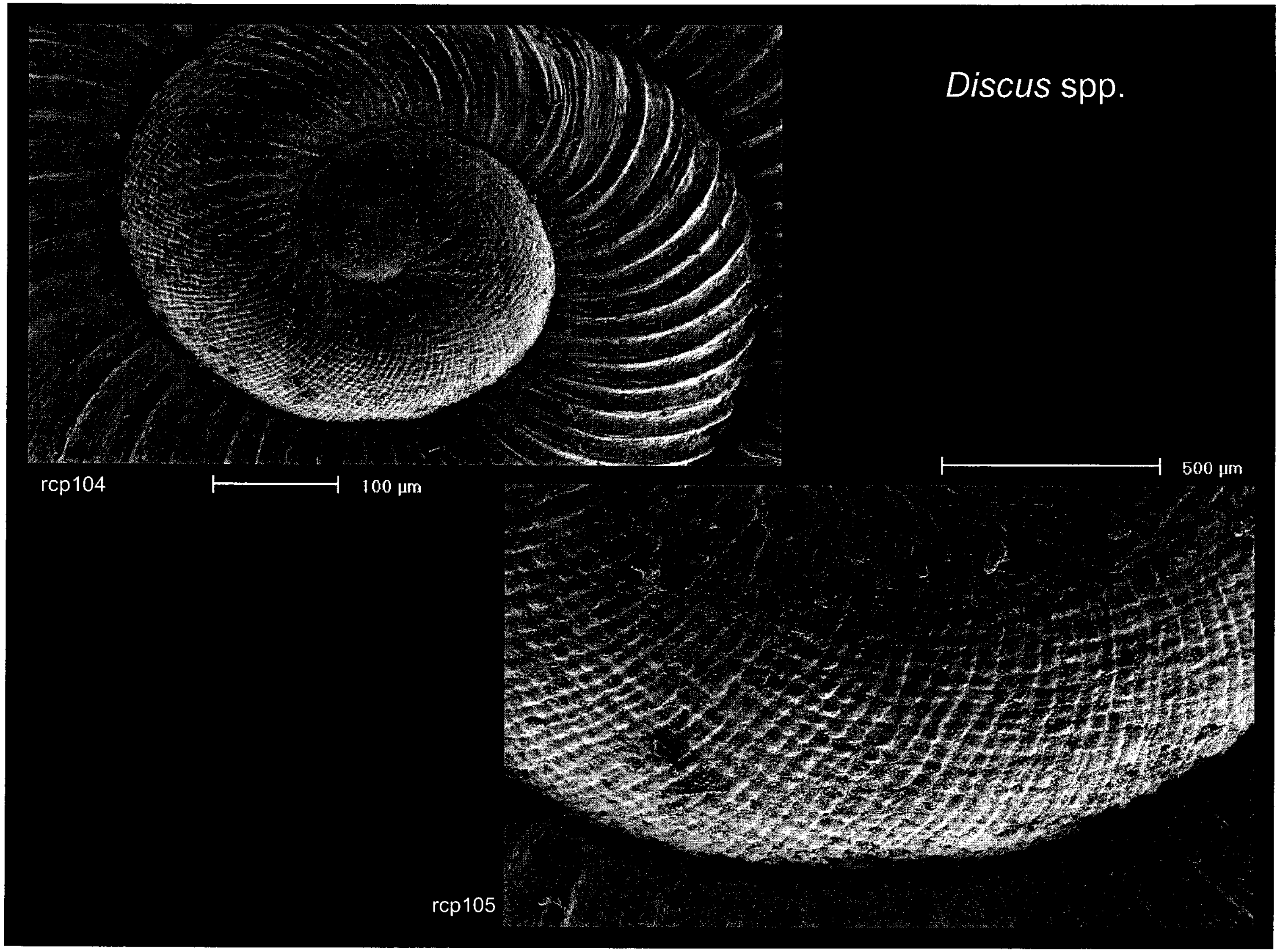


Plate P. *Discus* spp., composite: apical micro-sculpture (x70), apical micro-sculpture (x200) [Burdukovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

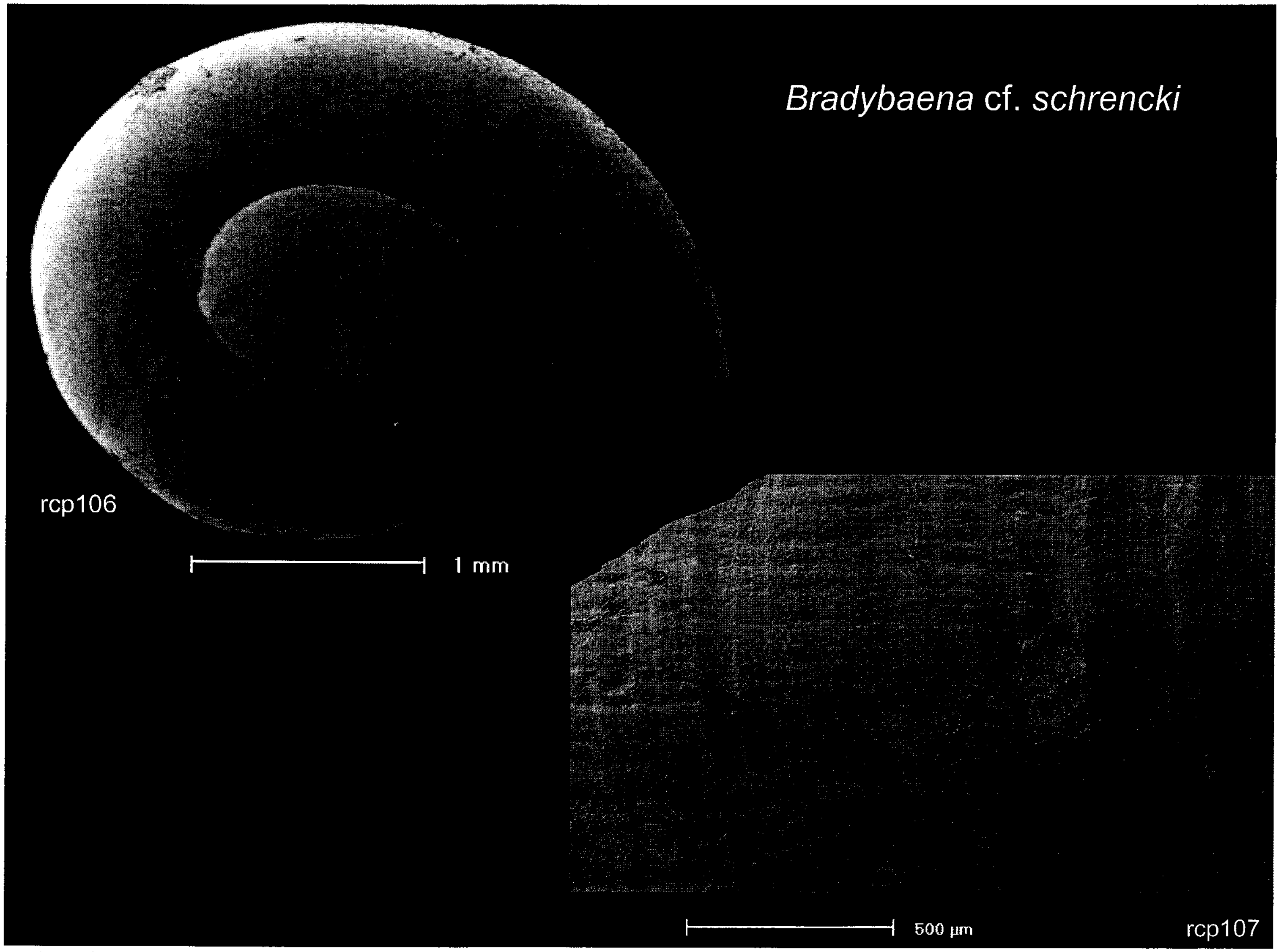


Plate Q. *Bradybaena* cf. *schrencki*, composite: front-view, juvenile (x30), body micro-sculpture (x70) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

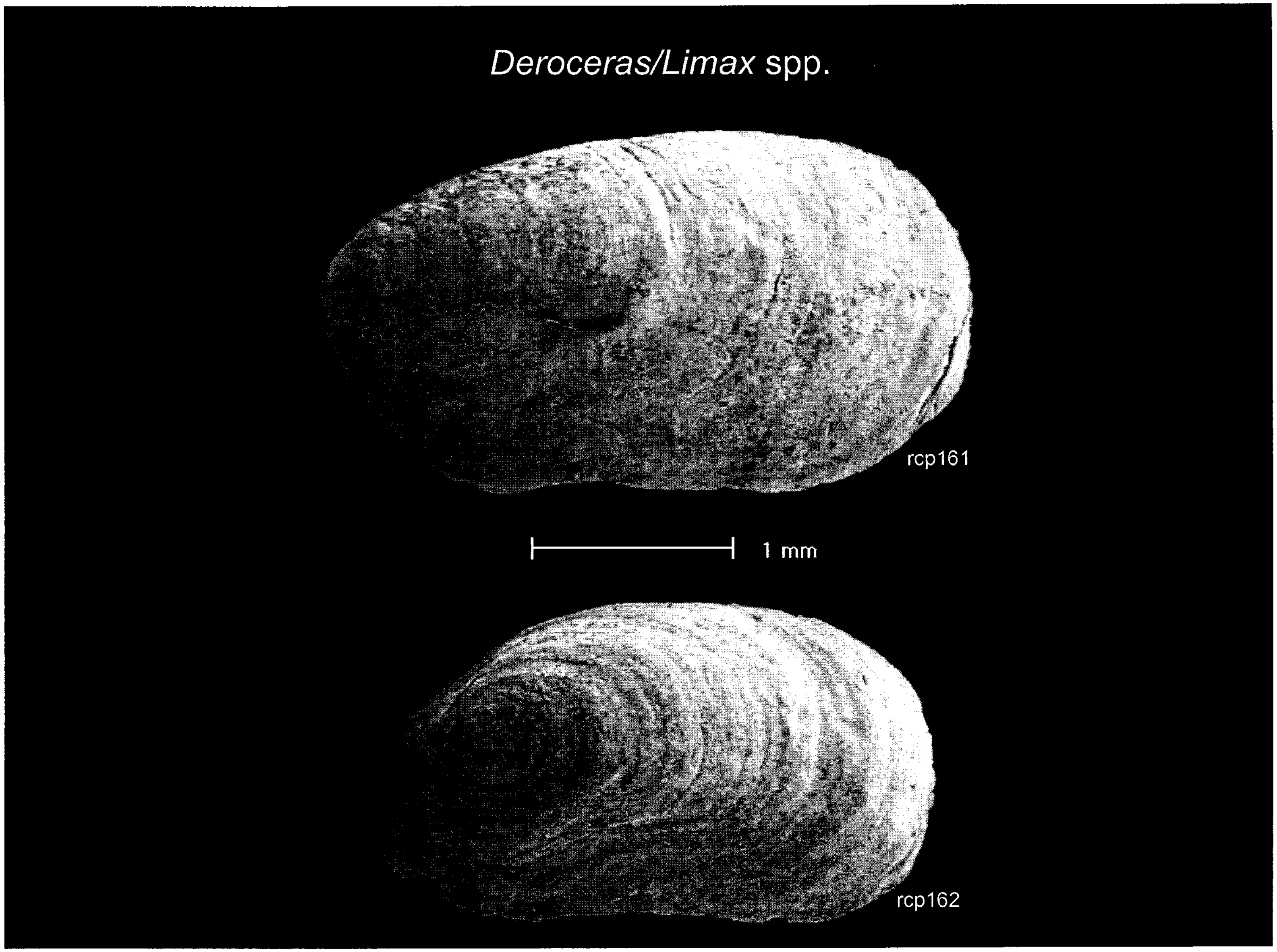


Plate R. *Limax/Deroceras*, top-view (x26) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

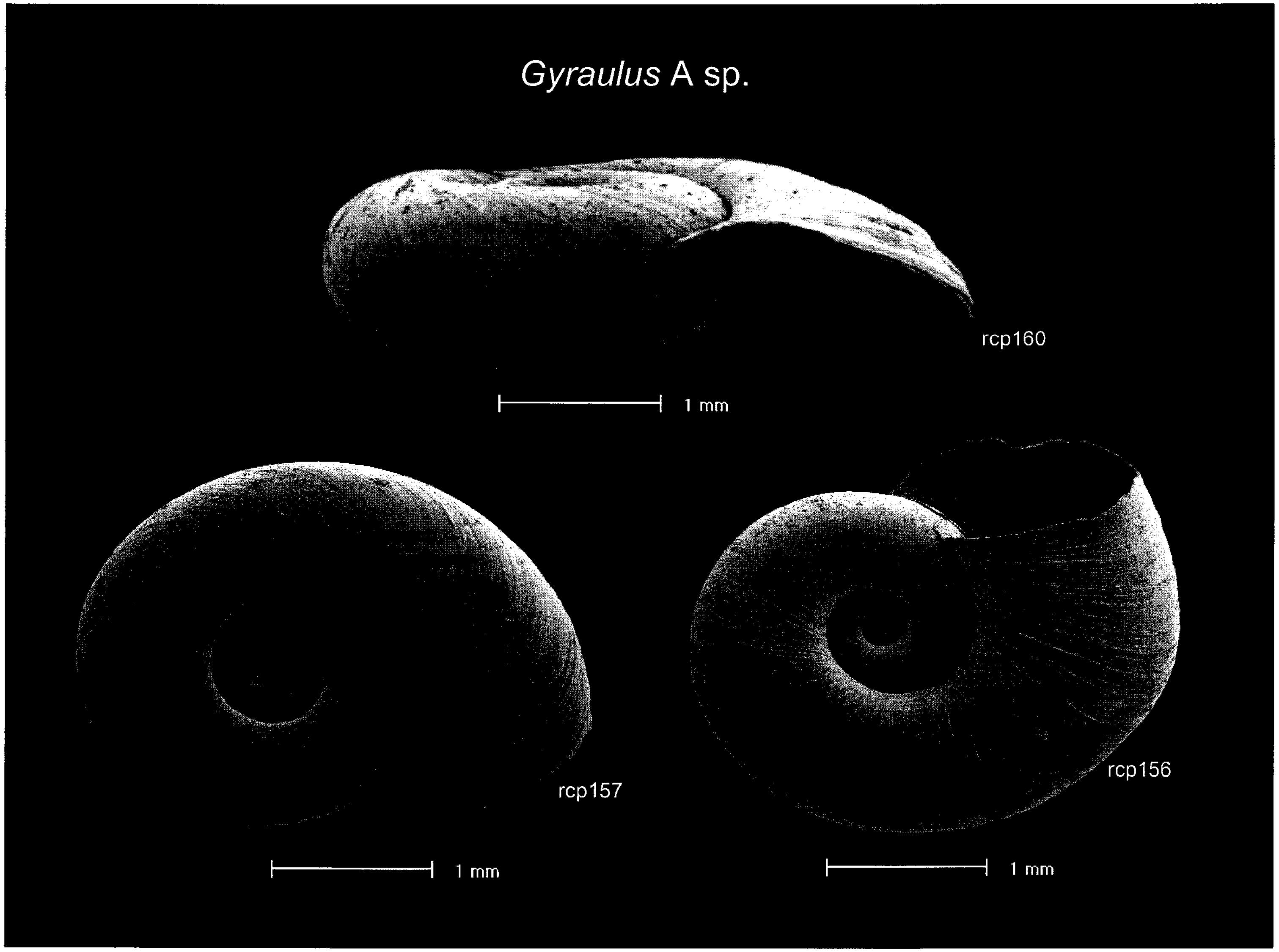


Plate S. *Gyraulus* A sp., composite (x27): side-view, top-view, bottom-view [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

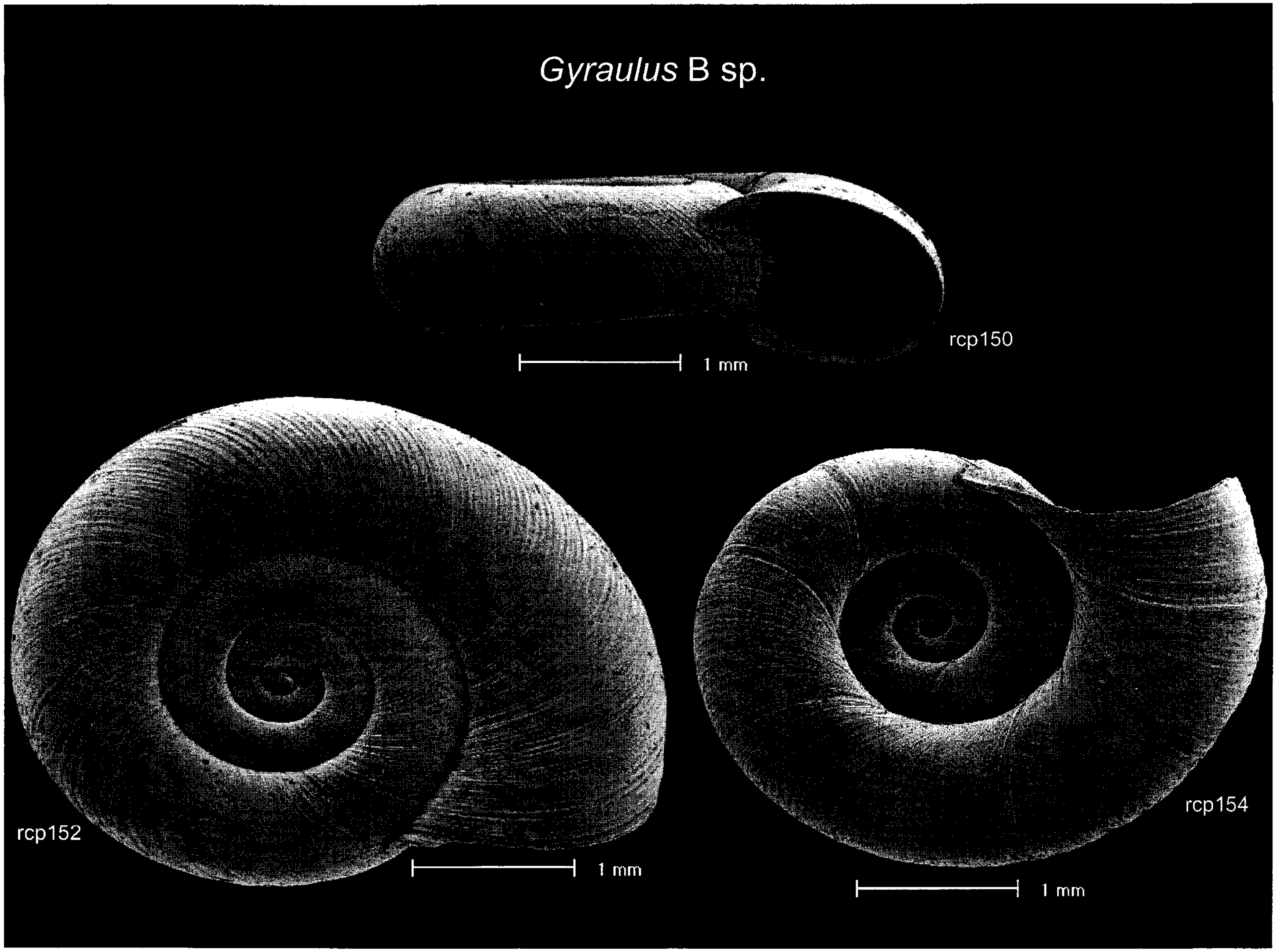


Plate T. *Gyraulus* B sp., composite (x27): side-view, top-view, bottom-view [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

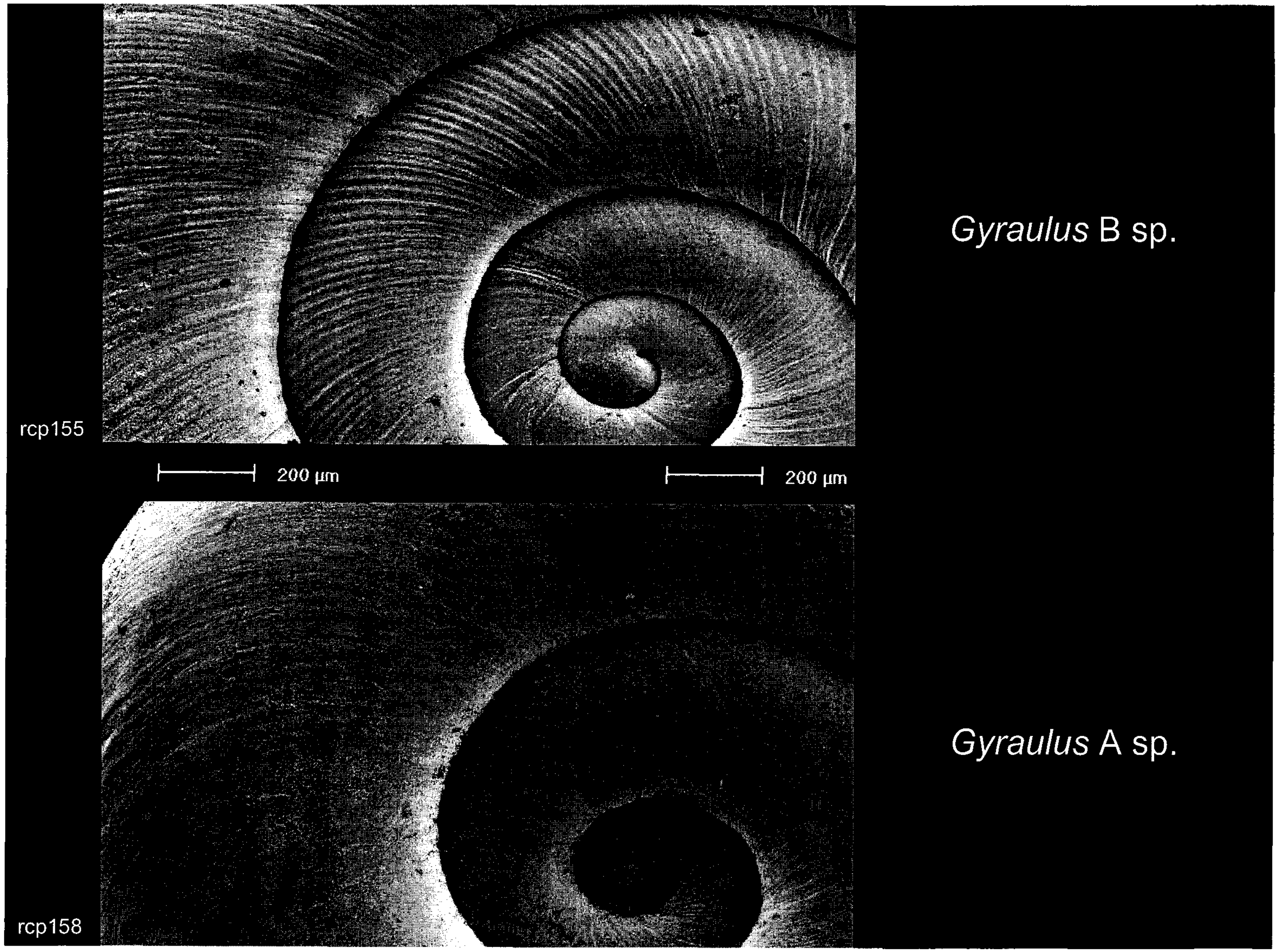


Plate U. Genus *Gyraulus*, composite: top-view (x75) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

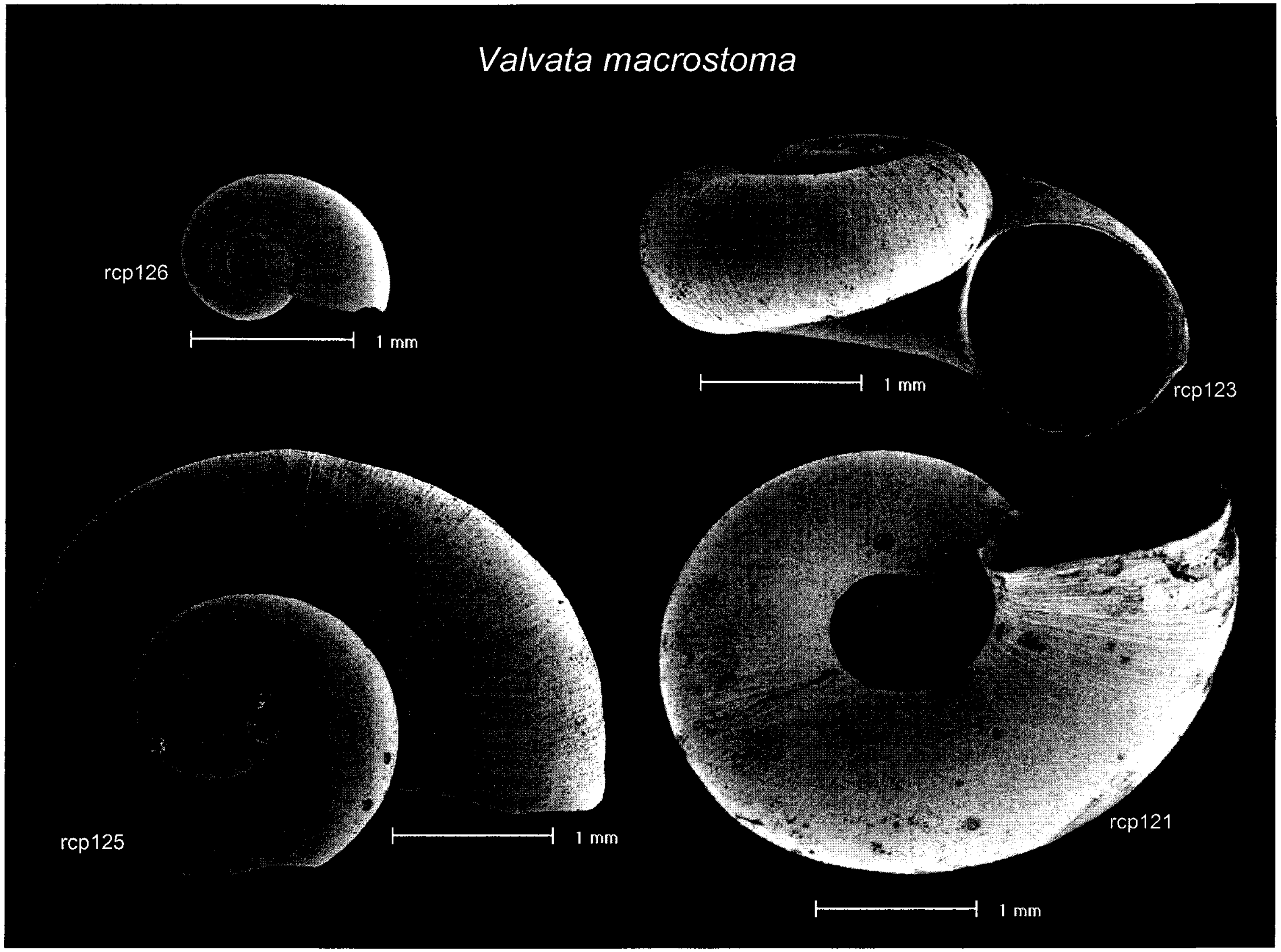


Plate V. *Valvata macrostoma*, composite (x27): front-view, juvenile, side-view, front-view and bottom-view [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

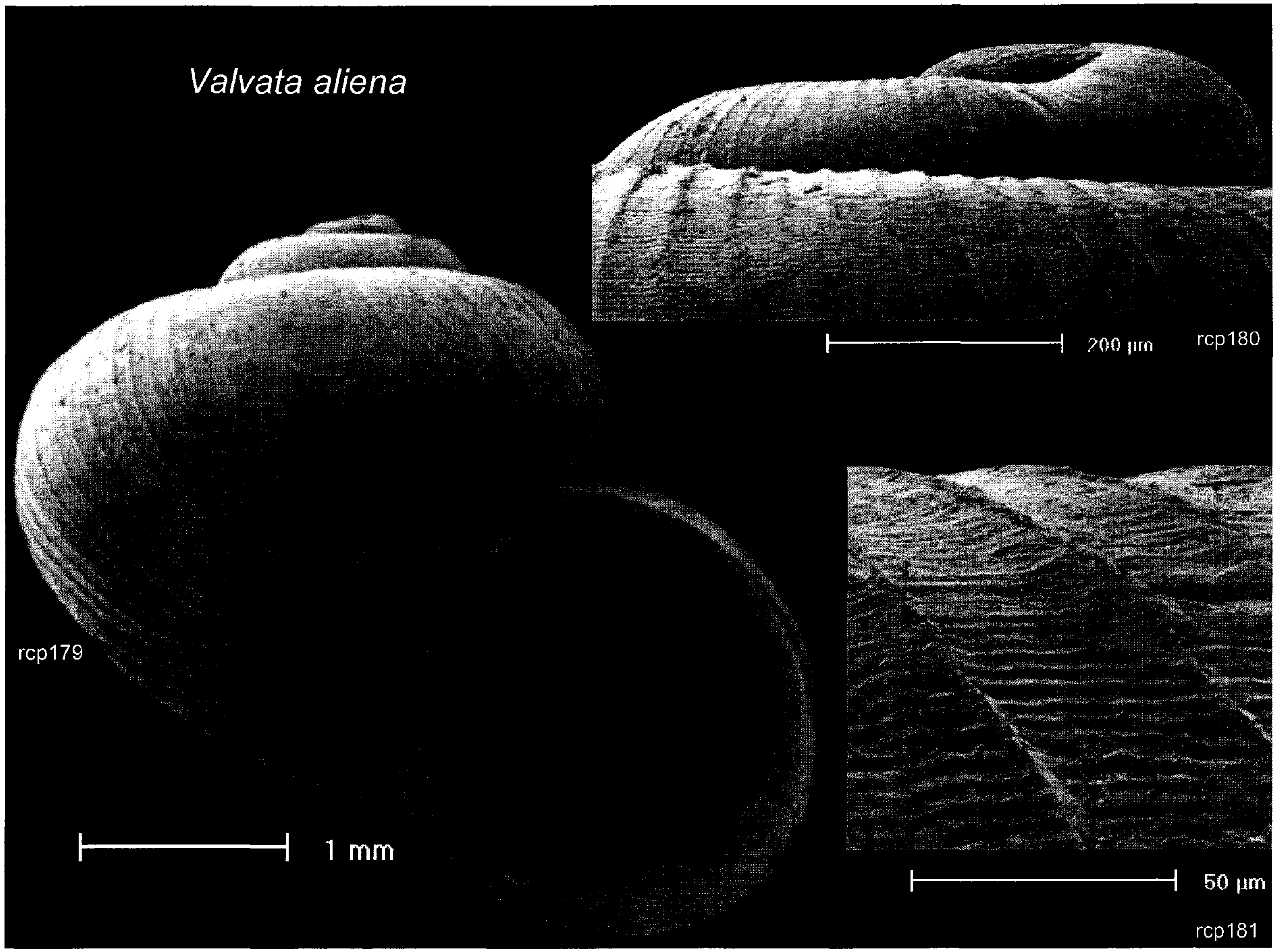


Plate W. *Valvata aliena*, composite: front-view (x 45), apical micro-sculpture (x150) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

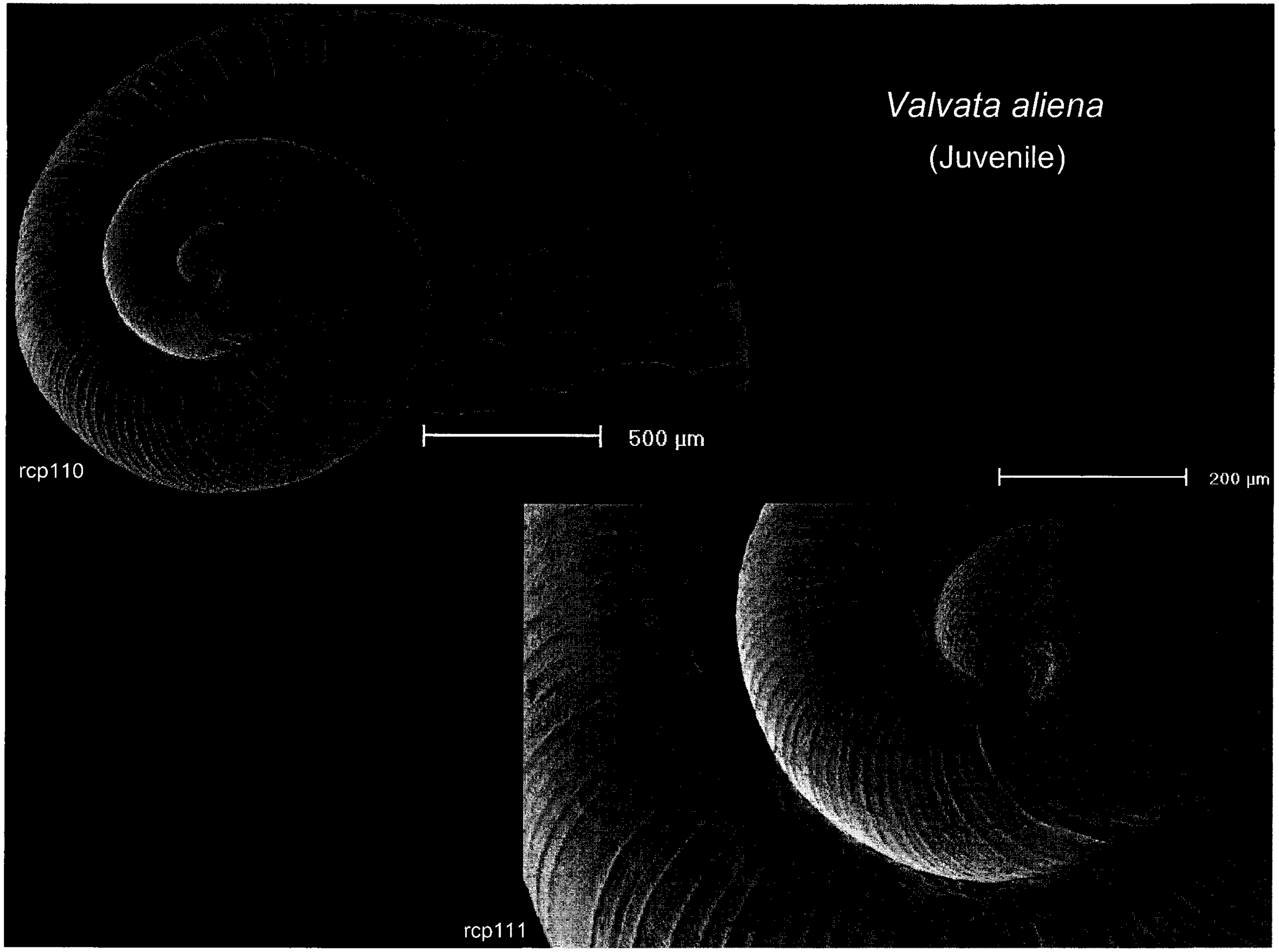


Plate X. *Valvata aliena* (juvenile), composite: side-view (x21), body micro-sculpture (x170) [Basovo].

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

APPENDICES

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

APPENDIX A:
BASOVO AND BURDUKOVO SITE STRATIGRAPHIC DATA

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix A.1. Pedologic and lithofacies explanation codes.

[1] Soil horizon designations and field description abbreviations follow The Canadian System of Soil Classification (Soil Classification Working Group, 1998).

Abbreviations used in field descriptions:

Texture – LS = loamy sand, SL= sandy loam, L = loam, SiL = silt loam, SiCL = silty clay loam, CL = clay loam, g = gravelly

Pedogenic Structure – *Grade*: 1 = weak, 2 = moderate, 3 = strong; *Class*: f = fine, m = medium, c = coarse; *Type*: sg = single-grain, gr = granular, sbk = subangular blocky, abk = angular blocky, pl = platy, pr = prismatic, m = massive (structureless)

$CaCO_3$ (reaction to dilute HCl) – e = moderately effervescent, es = strong effervescent, ev = violently effervescent, non = noncalcareous

Boundary – *Distinctness*: a = abrupt, c = clear, g = gradual; *Topography*: s = smooth, w = wavy, i = irregular, b = broken

[2] Lithofacies codes (modified from Eyles *et al.*, 1983).

Primary Classification

Code	Description
D	Diamicton
G	Gravel
S	Sand
F	Fines (loam, silt, clay)

Secondary Classification

Code	Description
Dmm	matrix-supported, massive diamicton
Gmm	matrix-supported, massive gravel
Gcm	clast-supported, massive gravel
Sm	massive sand
Sh	horizontally stratified sands
Sd	deformed/loaded sands
Fm	massive fines
Fl	laminated fines
Fd	deformed fines
Fp	pedogenic structures

Tertiary Classification (Genetic Interpretation)

Code	Description
(a)	aeolian
(r)	reworked
(l)	lacustrine/glaciolacustrine
(f)	fluvial/glaciofluvial

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix A.2. Basovo High Floodplain Sections 1 and 2 (HFS1 and HFS2) – General pedologic field descriptions.

(a) High Floodplain Section 1 (HFS1)

Unit	Horizon	Depth (cm)	Color (m)	Texture	Structure	Boundary
7	Ahjk	0-10	10YR 3/3	SL	1-2, f-m, gr	g, d
	ACk	10-23	10YR 4/3	SL	1, m, sbk	c, w
	Ahbk	23-52	10YR 3/2	SL	2, m, sbk	g, w
	Ck	52-61	5YR 4/6	SL	1, f, sg	a, w
6	ACk	61-67	7.5YR 3/4	L	1-2, f-m, sbk	g, w
	Ahbk	67-88	7.5YR 3/2	L	2, m, sbk	c, w
5	Ck	88-91	7.5YR 4/4	SL	1, f, sg	a, i-b
4	Ahbkgj1	91-115	10YR 2/1	SiL	2, m, pl	c, w
	Ahjbkgj2	115-127	10YR 4/1	CL	1, m, pl	c, i
	Ckgj	127-160	5YR 4/3	CL	2, m, pl	g, w
3	Ahbkgj	160-167	5YR 3/2	SiCL	1-2, f-m, sbk	c, w
	Ckgj	167-174	5YR 3/4	SiCL	1, f-m, sbk	c, w
2	-	174-200	5YR 4/6	L	massive	g, w
	-	200-335+	5YR 4/4	L	massive	-
1	-	335+	-	g	-	-

(b) High Floodplain Section 2 (HFS2)

Unit	Horizon	Depth (cm)	Color (m)	Texture	Structure	$CaCO_3$	Boundary
7	Ahjk	0-10	10YR 3/3	SL	1-2, f-m, gr	e	c, w
	ACk	10-29	10YR 4/3	SL	1, m, sbk	es	c, w
	Ahbk	29-56	10YR 3/2	SL	1-2, f-m, sbk	e	g, w
	Ck	56-65	5YR 4/6	SL	1, f, sg	ev	c, w
6	ACk	65-71	7.5YR 3/4	SL	1, f-m, sbk	e	c, w
	Ahbk	71-88	7.5YR 3/2	L	1-2, m, sbk	e	c, w
	Ck	88-95	5YR 4/4	SL	1, f, sg	e	a, i-b
5	Ahjbk/Ckgj	95-100	7.5YR 3/4	L	1, f-m, pl	e	c, w-b
4	Ahbkygj1	100-114	10YR 2/1	SiL	1-2, f-m, pl	e	c, w-i
	Ahjbkygj2	114-135	10YR 4/1	CL	2, m-c, pl	es	c, w-i
	Ckygj1	135-169	5YR 4/3	CL	2, m-c, pl	es	c-g, w-i
	Ckygj2	169-180	5YR 4/4	L	massive	es	c, w-i
3	ACk	180-185	5YR 3/2	SiCL	massive	es	c, w-i
	Ckygj1	185-195	5YR 3/4	SiCL	massive	es	c, i-b
	Ahbkygj	195-198	5YR 2.5/2	SiCL	massive	es	a, i-b
	Ckygj2	198-203	5YR 4/4	SiCL	massive	es	g, w
2	-	205-221	5YR 4/6	L	massive	ev	c, w
	-	221-232	5YR 4/6	SiL	massive	ev	c, w
	-	232-270+	5YR 4/6	L	massive	ev	-
1	-	270+	-	g	-	-	-

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix A.3. Basovo High Floodplain Section 2a (HFS2a) – Laboratory data.

(a) Grain-size distribution			**Total %**			**Sand Fraction %**				
Unit	**Horizon**	**Depth (cm)**	**Clay**	**Silt**	**Sand**	**VC**	**C**	**M**	**F**	**VF**
7	Ahjk	0-5	9.8	30.6	59.6	0.55	0.51	9.21	52.60	37.14
		5-10	12.9	26.8	60.4	0.08	0.15	5.02	52.15	42.60
	ACk	10-15	12.0	27.1	61.0	0	0.67	5.32	49.43	44.58
		15-20	12.3	29.1	58.6	0	0.44	7.61	45.33	46.62
		20-25	17.6	30.4	52.0	0.17	0.17	10.11	43.78	45.76
		25-29	14.8	27.2	58.0	0.22	0.48	18.49	44.98	35.83
	Ahbk	29-35	11.7	33.0	55.3	0.09	0.42	11.37	47.52	40.59
		35-40	13.2	34.3	52.4	0	0.53	6.84	54.78	37.86
		40-45	11.4	36.8	51.8	0.05	0.28	3.68	56.30	39.69
		45-50	12.6	36.3	51.1	0	0.09	3.69	58.58	37.64
		50-56	13.4	36.6	50.0	0	0.19	3.22	56.48	40.12
	Ck	56-60	13.0	14.4	72.6	0	0.06	1.10	69.82	29.02
		60-65	16.6	14.5	68.9	0	0	0.60	63.84	35.57
6	ACk	65-70	16.9	41.7	41.4	0	0.07	1.30	43.06	55.57
		70-74	17.1	35.4	47.6	0.06	0.11	1.49	45.09	53.25
	Ahbk	74-81	14.4	37.5	48.2	0	0.13	3.76	49.09	47.03
		81-85	16.2	41.3	42.5	0	0.09	8.83	55.60	35.47
	Ck	85-90	21.0	20.1	59.0	0	0	11.44	65.86	22.70
		90-95	17.4	18.0	64.6	0	0	12.49	65.17	22.34
5	Ahjbk/Ckgj	95-100	14.7	51.0	34.3	0	0.41	7.00	44.96	47.63
4	Ahbkygj1	100-105	13.8	52.0	34.2	0	0	2.05	33.92	64.03
		105-110	18.3	50.9	30.8	0.08	0.63	3.55	38.83	56.91
		110-115	22.1	50.4	27.5	0	0.46	1.83	30.50	67.20
	Ahjbkygj2	115-120	30.5	40.2	29.3	0	0.38	1.01	27.99	70.62
		120-125	30.9	43.3	25.8	0	0.21	0.93	28.50	70.37
		125-130	33.2	39.3	27.5	0.11	0.11	0.69	27.46	71.62
		130-135	32.0	40.7	27.4	0	0.22	0.90	26.94	71.94
	Ckygj1	135-140	30.1	41.3	28.6	0.10	0.20	1.18	30.15	68.37
		140-145	32.5	39.3	28.3	0	0.97	3.76	29.73	65.53
		145-150	33.2	42.0	24.8	0	0.16	1.25	11.08	87.52
		150-155	29.5	48.5	22.1	0.15	0.15	1.48	17.95	80.27
		155-160	29.1	47.4	23.4	0.13	0.25	1.01	10.89	87.72
		160-165	27.5	43.6	28.8	0	0.11	1.07	19.25	79.57
		165-170	27.5	40.3	32.2	0.11	0.22	2.40	11.14	86.14
	Ckygj2	170-175	19.5	24.8	55.7	0	0.05	3.74	53.79	42.43
		175-180	25.9	35.2	38.9	0	0.24	2.69	29.40	67.67
3	ACk	180-185	31.4	62.8	5.8	0	0.43	2.98	3.40	93.19
	Ckygj1	185-190	26.8	70.1	3.1	0.75	2.24	3.73	8.96	84.33
		190-195	28.0	67.4	4.7	0.81	0.81	1.63	3.25	93.50
	Ahbkygj	195-198	29.8	64.3	5.9	4.12	2.06	10.29	13.99	69.55
	Ckygj2	198-203	30.9	60.2	8.9	0	0.68	5.78	9.52	84.01
2	-	200-205	27.8	55.8	16.4	0.18	0.53	3.17	23.24	72.89
		205-210	22.9	53.4	23.7	0.28	1.14	4.46	28.21	65.91
		210-215	22.2	45.4	32.4	0.08	0.47	9.1	48.10	42.25
		215-220	27.5	51.1	21.5	0	0.53	17.7	47.87	33.90
	-	220-225	26.8	65.9	7.3	0	0	3.00	24.92	72.07
		225-230	29.2	56.5	14.3	0	0	1.64	19.85	78.51
	-	230-235	24.1	48.4	27.6	0	0.15	1.02	22.90	75.93
		235-240	23.8	46.5	29.7	0	0.35	1.90	21.87	75.88
		240-245	25.1	50.6	24.3	0	0.47	1.22	9.38	88.93
		245-250	23.7	45.9	30.5	0	0.08	8.23	14.94	76.75
		250-255	20.7	44.1	35.2	0.33	0.20	0.65	32.59	66.23
		255-260	25.7	40.7	33.6	0	0.06	0.29	34.07	65.58

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

(b) Biogeochemical data

			Total %				
Unit	**Horizon**	**Depth (cm)**	**Carbon**	**Organic C**	**Inorganic C**	**Nitrogen**	**pH**
7	Ahjk	0-5	4.53	3.36	1.17	0.35	7.4
		5-10	3.01	1.66	1.35	0.19	7.9
	ACk	10-15	2.80	1.27	1.53	0.15	8.1
		15-20	2.89	1.35	1.54	0.15	8.2
		20-25	2.97	1.38	1.59	0.16	8.2
		25-29	2.81	1.44	1.37	0.17	8.2
	Ahbk	29-35	3.85	2.66	1.19	0.28	8.1
		35-40	4.41	3.14	1.27	0.32	8.1
		40-45	4.47	3.19	1.28	0.31	8.1
		45-50	4.17	2.92	1.25	0.30	8.1
		50-56	3.91	2.62	1.29	0.26	8.1
	Ck	56-60	1.92	0.41	1.51	0.06	8.3
		60-65	2.16	0.55	1.61	0.08	8.3
6	ACk	65-70	3.73	2.24	1.49	0.23	8.1
	Ahbk	70-74	3.42	1.92	1.50	0.19	8.1
		74-81	4.25	3.07	1.18	0.28	8.1
		81-85	3.06	1.98	1.08	0.19	8.1
	Ck	85-90	2.52	0.61	1.91	0.07	8.3
		90-95	2.54	0.50	2.04	0.07	8.4
5	Ahjbk/Ckgj	95-100	4.74	4.03	0.71	0.31	8.1
4	Ahbkygj1	100-105	3.47	3.41	0.06	0.29	8.1
		105-110	3.61	2.82	0.79	0.25	8.1
		110-115	4.27	1.92	2.35	0.17	8.1
	Ahjbkygj2	115-120	4.51	1.45	3.06	0.13	8.2
		120-125	4.44	1.63	2.81	0.15	8.1
		125-130	4.18	1.18	3.00	0.11	8.2
		130-135	4.06	1.16	2.90	0.12	8.3
	Ckygj1	135-140	3.81	0.92	2.89	0.10	8.4
		140-145	4.46	0.69	3.77	0.07	8.4
		145-150	4.60	0.73	3.87	0.08	8.4
		150-155	4.55	0.68	3.87	0.09	8.4
		155-160	4.33	0.71	3.62	0.08	8.4
		160-165	4.14	0.65	3.49	0.07	8.4
		165-170	3.59	0.73	2.86	0.08	8.3
	Ckygj2	170-175	2.93	0.39	2.54	0.05	8.5
		175-180	3.62	0.63	2.99	0.07	8.4
3	ACk	180-185	3.83	1.44	2.39	0.15	8.4
	Ckygj1	185-190	3.93	1.46	2.47	0.15	8.4
		190-195	3.73	1.35	2.38	0.14	8.3
	Ahbkygj	195-198	3.62	1.14	2.48	0.17	8.2
	Ckygj2	198-203	2.90	0.54	2.36	0.10	8.2
2	-	200-205	2.94	0.43	2.51	0.07	8.4
		205-210	2.96	0.36	2.60	0.06	8.4
		210-215	2.82	0.34	2.48	0.06	8.3
		215-220	2.71	0.38	2.33	0.07	8.3
	-	220-225	2.67	0.34	2.33	0.07	8.4
		225-230	2.86	0.61	2.25	0.06	8.3
	-	230-235	3.05	0.28	2.77	0.06	8.4
		235-240	2.96	0.30	2.66	0.06	8.3
		240-245	3.02	0.30	2.72	0.05	8.3
		245-250	2.91	0.29	2.62	0.05	8.3
		250-255	2.78	0.29	2.49	0.05	8.3
		255-260	2.67	0.31	2.36	0.05	8.3

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix A.4. Basovo Low Floodplain Section – Field and laboratory data.

(a) Pedologic field descriptions

Unit	Horizon	Depth (cm)	Color (m)	Texture	Structure	CaCO$_3$	Boundary
4	Ahjk	0-53	10YR 2/1	L	2, f-m, pr-sbk	e	c, w
	Ck	53-97	10YR 4/3	L/SL	1, m, sbk	e	g, w-i
3	Ahjbk	97-111	10YR 3/3	SL	1, f, sbk	e	g, w-i
	ACk	111-128	10YR 4/3	SL	massive	e	c, w
	Ck	128-135	7.5YR 4/4	SL/L	massive	e	c, w
2	Ahjbk	135-150	10YR 2/2	L	1, m, sbk	e	c,w
	ACk	150-196	7.5YR 3/2	L	massive	e	a, w
1	-	196+	5YR 4/4	g	massive	-	-

(b) Grain-size distribution and biogeochemical data

			Total %						
Unit	Horizon	Depth (cm)	Clay	Silt	Sand	Carbon	Organic C	Inorganic C	pH
4	Ahjk	0-15	16.2	35.6	48.2	4.59	4.33	0.26	8.0
		15-25	20.3	37.8	41.8	3.57	3.45	0.12	8.3
		25-35	19.3	36.2	44.5	3.66	3.48	0.18	8.3
		35-45	15.8	38.2	46.1	4.45	3.85	0.60	8.3
		45-55	17.2	32.4	50.4	3.89	2.39	1.50	8.4
	Ck	55-65	19.7	28.8	51.4	3.65	1.31	2.34	8.3
		65-75	19.3	28.1	52.6	3.48	1.11	2.37	8.5
		75-85	17.8	28.7	53.5	3.42	0.98	2.44	8.2
		85-95	17.2	29.5	53.3	3.45	1.08	2.37	8.3
3	Ahjbk	95-105	20.7	36.6	42.7	3.87	1.22	2.65	8.4
	ACk	105-115	19.0	29.0	52.1	3.19	0.89	2.30	8.3
	Ck	115-125	15.3	23.6	61.1	2.73	0.77	1.96	8.2
		125-135	13.3	15.4	71.3	2.54	0.48	2.06	8.5
2	Ahjbk	135-150	17.8	28.0	54.2	3.33	0.99	2.34	8.2
	ACk	150-160	17.3	35.1	47.2	3.09	0.67	2.42	8.2
		160-196	16.7	33.7	50.0	3.01	0.63	2.38	8.1
1	-	196+	-	-	-	-	-	-	-

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix A.5. Basovo High Floodplain Section 2b (HFS2b) – Vertebrate data (after Parfitt, 2004).

Unit	Horizon	Depth	Fish	Amphibian	Small mammal	Comments
7	Ahjk	0-5 cm	-	-	-	-
		5-10	-	-	1	Rodent: mandible frag.
	ACk	10-15	1?	-	-	?Fish: tooth.
		15-20	-	-	1	Indet.
		20-25	-	-	-	-
		25-30	2	-	1	Microtinae: upper incisor.
	Ahbk	30-35	2	2	1	Microtinae: molar frag, RC.
		35-40	-	-	-	Indet.
		40-45	-	-	1	Femur (prox).
		45-50	-	-	2	*Arvicola terrestris*: LM_1; Microtinae: lower incisor (juv).
		50-55	-	-	1	Microtinae: upper molar frag.
		55-60	1	-	2	Fish: vertebrate; Microtinae: lower incisor, RC; Small mammal: phalanx.
	Ck	60-65	-	-	9	Soricidae: humerus (distal); *Sicista betulina*: LM3; small mammal: phalanx, metapodial (x3), caudal vertebra, ulna, radius (shaft & prox).
		65-70	-	-	73*	* see notes below.
6	ACk	70-75	9	-	2	*Sicista betulina*: maxilla with LM_3; Small mammal: incisor frag (rodent).
		75-80	-	-	1	Murid or birch mouse: upper incisor (dentine with post-depositional corrosion).
	Ahbk	80-85	-	5	3	Small mammal: scapula frag, tibia (shaft), astragalus.
		85-90	-	2	4	Soricidae: upper molar; Small mammal: vertebra frag, phalanx, metapodial.
	Ck	90-95	3	2	4	Microtinae: molar frag; Small mammal: vertebra, metapodial, upper incisor frag.
5	Ahjbk/Ckgj	95-100	-	-	2	Small mammal: tibia (shaft & dist), humerus (prox epiph).
4	Ahbkygj1	100-105	-	-	-	-
		105-110	-	-	1	Muridae?: upper incisor (rootlet corrosion).
		110-115	-	-	-	Indet small vertebrate.
	Ahjbkygj2	115-120	1	-	-	-
		120-125	1	1	1	Fish: vertebra; Anuran: 1; Microtinae: upper incisor frag.
		125-130	-	-	1	*Clethrionomys rufocanus*: LM_1 (digested, juvenile); Indet small vertebrate.
		130-135	-	-	-	Indet small vertebrate.
	Ckygj1	135-140	-	-	1	Indet small mammal: phalanx.
		140-145	-	-	-	Indet small vertebrate.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Unit	Horizon	Depth	Fish	Amphibian	Small mammal	Comments
		145-150	-	24	-	Anuran: 24 bone frags.
		150-155	-	-	-	Indet small vertebrate.
		155-160	-	1	2	Anuran: ilium frag; *Apodemus* sp.: M$_3$; Indet small mammal: ?caudal vertebra.
	Ckygj2	160-165	-	-	1	*Apodemus peninsulae*: M$_1$.
		165-170	-	-	4	Microtinae: molar frags (x3); Indet small mammal: metapodial frag.
3	ACk	170-175	1	11	1	Fish: cyprinid tooth; Amphibian: bone frags (including ilium); Many small frags probably also anuran (not identifiable to element); *Microtus* sp.: M^2.
		175-180	1	-	4	Fish: vertebra; Microtinae: molar frags (x4).
	Ckygj1	180-185	1	11	6	Amphibian (includes anuran ilium); Indet small mammal: metapodial, vertebrae (2), radius (proximal); Microtinae: incisor frag; Soricicidae: L. upper incisor, unicuspid.
		185-190	6	10	15	Indet small mammal: femur (shaft with distal end, distal epiphysis), vertebra frags (2), metapodial, phalanx (2), mandible (2); Microtinae: upper and lower incisor; *Microtus* sp.: M^2 (light digestion), molar frags (2); *Microtus maximowiczii*: LM$_1$.
	Ahbkygj	190-195	-	2	11	Indet small mammal: radius (prox), ulna frag, rib frag, caudal vertebra, phalanx (?burned), lower incisor frag, molar frag; *Sorex roboratus*: L upper incisor; *Clethrionomys* sp.: molar frag (heavily digested); *Microtus* sp.: M^2.
	Ckygj2	195-200	-	-	4	Indet small mammal: femur (prox shaft), upper incisor frag; *Microtus* sp.: M^2, M$_3$.
2	-	200-205	-	-	-	Indet small vertebrate.
		205-210	1	-	1	Microtinae: molar frag.
		210-215	1	-	1	Fish: vertebra; Small mammal: ?rib.

* Depth 65-70 cm- *Sorex minutus*: L lower incisor, R lower incisor, L & R mandible frags (ascending ramus), L mandible with M$_1$ (M$_2$ and unicuspid isolated), probably all from the same individual; *Sicista betulina*: 5 including 2 molars in maxilla frag; Small mammal: ulna frag, rib (x5), mandible frags. (x2), humerus (prox epiph), skull frag., metapodial (x8), astragalus (x3), calcaneus (x3), vertebra (x8), phalanges (x23), tibia (x2 distal & most of shaft), humerus (x2), radius (complete), innominate frag, incisor frags (x7).

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix A.6. Basovo High Floodplain Section 2b (HFS2b) – Wood charcoal data (after Gale, 2004).

Unit	Horizon	Depth (cm)	Taxa Identified	Comments
7	Ahjk	0-5	-	No charcoal present
		5-10	-	Charcoal too small to identify
	ACk	10-15	1 x conifer	-
		15-20	1 x *Pinus/Picea/Larix*	-
		20-25	-	Charcoal too small to identify
		25-30	-	Charcoal too small to identify
	Ahbk	30-35	3 x conifer	-
		35-40	-	Charcoal too small to identify
		40-45	1 x conifer	-
		45-50	1 x conifer	-
		50-55	1 x cf. *Picea/Larix*	-
		55-60	2 x conifer	-
	Ck	60-65	-	Charcoal too small to identify
		65-70	-	Charcoal too small to identify
6	ACk	70-75	-	Charcoal too small to identify
		75-80	-	Charcoal too small to identify
	Ahbk	80-85	1 x conifer	-
		85-90	2 x *Pinus/Picea/Larix*	-
	Ck	90-95	4 x conifer; conifer bark	-
5	Ahjbk/Ckgj	95-100	93 x *Pinus/Picea/Larix*; conifer bark; 5 x *Betula*	-
4	Ahbkygj1	100-105	3 x conifer	-
		105-110	4 x *Betula*; 1 x conifer	-
		110-115	2 x *Salicaceae*; 2 x conifer	-
	Ahjbkygj2	115-120	2 x *Salicaceae*; 2 x conifer	-
		120-125	-	Charcoal too small to identify
		125-130	-	Charcoal too small to identify
		130-135	-	Charcoal too small to identify
	Ckygj1	135-140	-	No charcoal present
		140-145	-	Charcoal too small to identify
		145-150	-	Charcoal too small to identify
		150-155	-	Charcoal too small to identify
		155-160	-	Charcoal too small to identify
	Ckygj2	160-165	-	Charcoal too small to identify
		165-170	-	Charcoal too small to identify
3	ACk	170-175	cf. *Pinus/Picea/Larix*	-
		175-180	cf. *Pinus/Picea/Larix*	-
	Ckygj1	180-185	6 x conifer	-
		185-190	2 x *Pinus/Picea/Larix*	-
	Ahbkygj	190-195	3 x *Pinus/Picea/Larix*; 7 x conifer	-
	Ckygj2	195-200	7 x *Pinus/Picea/Larix*; 1 x conifer	-
2	-	200-205	-	No charcoal present
		205-210	-	No charcoal present
		210-215	-	No charcoal present
		215-220	-	No charcoal present
	-	220-225	-	No charcoal present
		225-230	-	No charcoal present
	-	230-235	-	No charcoal present
		235-240	-	No charcoal present
		240-245	-	No charcoal present
		245-250	-	No charcoal present

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix A.7. Burdukovo Section T1.100 – Field and laboratory data.

(a) Field descriptions

Unit	Horizon	Depth (cm)	Color (m)	Texture	Structure	Boundary
5c	Ahjbk	170-180	10YR 3/1	SiL	2, m-c, sbk	c, w
	Ck	180-210	10YR 5/3-6/4	L	massive	a-c, w
4	Ahjbk/Ck	210-220	10YR 4/4	SiCL	2, m-c, abk-pl	a, s-w
3	Ahbk1	220-231	10YR 3/1	SiL	1-2, m, sbk	g, w
	ABk	231-239	10YR 4/1	SiL	1, m, sbk	g, w
	Bmk	239-250	10YR 4/2	SiL	1, m, sbk	c, w
	Ahjbk2	250-260	10YR 3/2	SiL	1-2, m, sbk	c, w
	Ck	260-330	10YR 4/2	SiL	massive	g, w
2	-	330-340	10YR 4/3-5/3	L	massive	a, w
	-	340-380	10YR 4/3-5/3	SiL	massive	a, w
	-	380-420	10YR 4/3-5/3	SL	massive	a, w
1	-	420+	-	gL	massive	-

(b) Grain-size distribution

			Total %			Sand Fraction %				
Unit	Horizon	Depth (cm)	Clay (<2μm)	Silt (50-2μm)	Sand (2000-50μm)	VC (2000-1000μm)	C (1000-500μm)	M (500-250μm)	F (250-100μm)	VF (100-50μm)
5c	Ahjbk	170-180	10.0	72.9	17.1	0	7.21	5.08	21.80	65.90
	Ck	180-190	4.6	49.0	46.4	0	0.09	0.23	21.47	78.21
		190-200	2.4	30.8	66.8	0	0.07	0.10	18.96	80.87
		200-210	4.6	63.0	32.4	0	0.45	5.07	12.46	82.02
4	Ahjbk/Ck	210-220	30.5	69.0	0.5	0	0	25.00	40.00	35.00
3	Ahbk1	220-230	8.1	74.0	18.0	0	3.67	6.74	28.59	61.00
	ABk	230-240	15.1	75.1	9.8	0	4.35	0.79	24.11	63.64
	Bmk	240-250	9.4	77.0	13.6	0	2.17	9.24	28.26	60.33
	Ahjbk2	250-260	9.1	78.8	12.1	0	0.38	4.53	8.68	86.42
	Ck	260-270	10.3	68.9	20.8	0	0.93	1.12	5.98	91.96
		270-280	10.0	72.1	17.9	0	1.41	1.81	8.45	88.33
		280-290	6.8	66.3	26.9	0	0.71	3.10	15.60	80.60
		290-300	7.2	61.8	31.0	0	0.41	0.41	7.87	91.32
		300-310	7.3	68.5	24.2	0	0.32	0.95	7.63	91.10
		310-320	7.8	71.6	20.6	0	0.89	0.89	7.46	90.76
		320-330	7.6	72.2	20.2	0	0.43	0.64	6.60	92.34
2	-	330-340	5.2	50.9	43.9	0	0.06	2.44	36.73	60.77
	-	340-350	8.1	65.4	26.5	0	0.69	1.24	8.26	89.81
		350-360	7.3	62.4	30.3	0	0.17	0.70	16.99	82.14
		360-370	5.4	56.7	37.9	0	0	0.52	16.36	83.12
		370-380	6.0	64.3	29.8	0	0.54	0.76	9.01	89.69
	-	380-390	2.9	36.8	60.3	0	0.13	3.20	50.38	46.29
		390-400	4.5	43.9	51.6	0	0.24	0.48	28.74	70.54
		400-410	5.4	48.0	46.7	0	0.28	1.14	31.55	67.03
		410-420	5.9	56.9	37.2	0	0.19	1.03	22.46	76.32
1	-	420+	-	-	-	-	-	-	-	-

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

(c) Biogeochemical data

			Total %				
Unit	**Horizon**	**Depth (cm)**	**Carbon**	**Organic C**	**Inorganic C**	**pH**	**% Nitrogen**
5c	Ahjbk	170-180	2.53	2.24	0.29	8.5	0.20
	Ck	180-190	0.45	0.33	0.12	8.7	0.05
		190-200	0.27	0.18	0.09	8.7	0.03
		200-210	0.53	0.29	0.24	8.6	0.04
4	Ahjbk/Ck	210-220	2.11	0.89	1.22	8.6	0.10
3	Ahbk1	220-230	1.92	1.39	0.53	8.6	0.13
	ABk	230-240	2.78	1.24	1.54	8.7	0.12
	Bmk	240-250	1.77	0.71	1.06	8.7	0.07
	Ahbk2	250-260	2.17	1.05	1.12	8.6	0.10
	Ck	260-270	1.36	0.50	0.86	8.6	0.06
		270-280	1.49	0.59	0.90	8.6	0.07
		280-290	1.13	0.47	0.66	8.6	0.06
		290-300	1.02	0.40	0.62	8.6	0.05
		300-310	1.02	0.44	0.58	8.5	0.05
		310-320	1.03	0.42	0.61	8.5	0.05
		320-330	0.92	0.47	0.45	8.5	0.06
2	-	330-340	0.62	0.31	0.31	8.6	0.05
	-	340-350	0.84	0.46	0.38	8.5	0.05
		350-360	0.64	0.35	0.29	8.6	0.05
		360-370	0.63	0.41	0.22	8.5	0.05
		370-380	0.67	0.34	0.33	8.5	0.05
	-	380-390	0.21	0.23	0	8.3	0.04
		390-400	0.21	0.21	0	8.3	0.04
		400-410	0.24	0.25	0	8.2	0.04
		410-420	0.30	0.31	0	8.3	0.05

(d) Magnetic susceptibility data

Unit	**Horizon**	**Depth (cm)**	**Weight (g)**	**LF Sus.**	**HF Sus.**	**Freq. Dep. %**
5c	Ahjbk	170-180	13.21	104.3	101.7	2.49
	Ck	180-190	14.80	78.7	78.1	0.76
		190-200	15.52	125.8	125.1	0.56
		200-210	15.20	82.2	81.7	0.61
4	Ahjbk/Ck	210-220	13.73	52.5	51.5	1.90
3	Ahbk1	220-230	13.64	100.3	98.8	1.5
	ABk	230-240	13.03	106.3	104.5	1.69
	Bmk	240-250	13.58	126.6	124.6	1.58
	Ahbk2	250-260	13.96	121.2	120.1	0.91
	Ck	260-270	14.49	135.6	134.6	0.74
		270-280	13.97	127.0	126.2	0.63
		280-290	14.76	147.7	146.6	0.74
		290-300	14.61	160.0	159.3	0.44
		300-310	14.69	153.8	152.6	0.78
		310-320	14.70	154.4	153.4	0.65
		320-330	14.23	147.3	145.9	0.95
2	-	330-340	14.80	219.2	217.9	0.59
	-	340-350	14.60	158.4	157.5	0.57
		350-360	14.70	174.3	173.2	0.63
		360-370	14.61	189.6	188.4	0.63
		370-380	14.77	170.9	169.7	0.70
	-	380-390	15.95	312.8	311.5	0.42
		390-400	15.35	151.4	150.6	0.53
		400-410	14.95	244.0	243.4	0.25
		410-420	14.28	203.4	202.4	0.49

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix A.8. Burdukovo Section T1.28 – Field and laboratory data.

(a) Field descriptions

Unit	Horizon	Depth (cm)	Color (m)	Texture	Structure	Boundary
6	Ahj/AC	0-20	10YR 3/1	SL	2, m-c, sbk	g, w
	Ahjb/AC	20-30	10YR 3/2	SL	2, f-m, sbk	c, w
	C	30-40	10YR 5/3-6/4	L	1, f, sg	c, w
5a	Ahjb1	40-45	10YR 3/2	SL	1, f-m, sbk	c, w
	Ahb2	45-70	10YR 3/1	SL	2, m, sbk	g, w
	ACk	70-80	10YR 3/2	SL	2, m, sbk	c, w
	Ck	80-90	10YR 5/3-6/4	SL	1, f, sg	c, w
5b	Ahjbk1	90-95	10YR 3/1	SL	1, f, sbk	c, w
	Ck1	95-105	10YR 5/3-6/4	SL	1, f, sg	c, w
	Ahjbk2	105-110	10YR 3/1	SL	1, f, sbk	c, w
	Ck2	110-130	10YR 5/3-6/4	SL	1, f, sg	c, w
5c	Ahjbk1	130-135	10YR 3/1	SL	1, f, sbk	c, w
	Ck1	135-155	10YR 5/3-6/4	LS	1, f, sg	c, w
	Ahjbk2	155-160	10YR 3/1	SL	1, f, sbk	c, w
	Ck2	160-215	10YR 5/3-6/4	LS	1, f, sg	c, w
5d	Ahjbk1	215-218	10YR 3/1	SL	1, f, sbk	c, w
	Ck1	218-222	10YR 5/3-6/4	LS	1, f, sg	c, w
	Ahjbk2	222-225	10YR 3/1	SL	1, f, sbk	c, w
	Ck2	225-230	10YR 5/3-6/4	SL	1, f, sg	c, w
	Ahjbk3	230-235	10YR 3/1	SL	1, f, sbk	c, w
	Ck3	235-255	10YR 5/3-6/4	SL	1, f, sg	c, w
4	Ahjbk/Ck	255-264	10YR 3/1	SiL	2, m-c, abk-pl	c, w

(b) Grain-size distribution

			Total %			Sand Fraction %				
Unit	Horizon	Depth (cm)	Clay (<2μm)	Silt (50-2μm)	Sand (2000-50μm)	VC (2000-1000μm)	C (1000-500μm)	M (500-250μm)	F (250-100μm)	VF (100-50μm)
6	Ahj/AC	0-20	6.0	43.7	50.2	0	1.13	1.89	27.60	69.38
	Ahbj/AC	20-30	4.6	31.9	63.5	0	1.22	1.94	32.64	64.20
	C	30-40	5.8	51.3	42.9	0	1.14	4.49	33.20	61.17
5a	Ahjb1	40-45	5.4	37.2	57.5	0	0.70	1.57	32.08	65.65
	Ahb2	45-70	5.9	44.7	49.4	0	0.66	1.21	25.19	72.94
	ACk	70-80	6.6	36.7	56.7	0	1.68	2.03	39.13	57.16
	Ck	80-90	4.4	33.2	62.4	0	4.17	3.17	28.73	63.94
5b	Ahjbk1	90-95	5.4	28.4	66.2	0	0.90	1.08	36.14	61.87
	Ck1	95-105	4.2	38.4	57.4	0	1.54	1.03	25.32	72.11
	Ahjbk2	105-110	5.7	42.3	52.0	0	2.14	1.44	16.60	79.82
	Ck2	110-130	3.0	31.1	65.9	0	2.36	2.29	25.89	69.46
5c	Ahjbk1	130-135	5.4	33.0	61.7	0	0.71	1.39	37.92	59.97
	Ck1	135-155	3.0	23.6	73.3	0	0.47	0.78	45.60	53.15
	Ahjbk2	155-160	5.8	42.5	51.8	0	0.50	0.89	18.93	79.68
	Ck2	160-215	2.4	16.5	81.1	0	0.16	1.15	60.70	36.99
5d	Ahjbk1	215-218	4.9	37.7	57.4	0	0.70	1.40	28.72	69.18
	Ck1	218-222	3.5	10.1	86.4	0	0.83	1.07	62.16	35.94
	Ahjbk2	222-225	5.5	48.1	46.5	0	0.94	1.48	19.74	77.84
	Ck2	225-230	3.7	50.8	45.6	0	0.09	0.22	15.21	84.48
	Ahjbk3	230-235	11.4	72.8	15.8	0	1.45	2.42	16.59	79.55
	Ck3	235-255	-	-	-	-	-	-	-	-
4	Ahjbk/Ck	255-264	-	-	-	-	-	-	-	-

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

(c) Biogeochemical data

			Total %				
Unit	**Horizon**	**Depth (cm)**	**Carbon**	**Organic C**	**Inorganic C**	**pH**	**% Nitrogen**
6	Ahj/AC	0-20	1.93	1.95	0	6.7	0.20
	Ahjb/AC	20-30	1.20	1.21	0	7.3	0.13
	C	30-40	0.79	0.80	0	7.4	0.09
5a	Ahjbk1	40-45	2.80	2.81	0	7.7	0.26
	Ahbk2	45-70	2.67	2.65	0.02	8.0	0.23
	ACk	70-80	1.68	1.66	0.02	8.2	0.16
	Ck	80-90	0.44	0.43	0.01	8.3	0.06
5b	Ahjbk1	90-95	1.19	1.18	0.01	8.2	0.11
	Ck1	95-105	0.61	0.59	0.02	8.2	0.08
	Ahjbk2	105-110	1.10	1.10	0	8.3	0.11
	Ck2	110-130	0.23	0.29	0	8.1	0.05
5c	Ahjbk1	130-135	0.93	0.92	0.01	8.3	0.09
	Ck1	135-155	0.21	0.22	0	8.0	0.04
	Ahjbk2	155-160	1.31	1.32	0	8.0	0.12
	Ck2	160-215	0.10	0.09	0.01	8.2	0.03
5d	Ahjbk1	215-218	1.01	1.03	0	8.3	0.09
	Ck1	218-222	0.17	0.16	0.01	8.0	0.03
	Ahjbk2	222-225	1.38	1.40	0	8.3	0.12
	Ck2	225-230	0.29	0.29	0	8.4	0.05
	Ahjbk3	230-235	1.55	1.04	0.51	8.5	0.11
	Ck3	235-255	-	-	-	-	-
4	Ahjbk/Ck	255-264	-	-	-	-	-

(d) Magnetic susceptibility data

Unit	**Horizon**	**Depth (cm)**	**Weight (g)**	**LF Sus.**	**HF Sus.**	**Freq. Dep. %**
6	Ahj/AC	0-20	14.55	120.7	119.3	1.16
	Ahjb/AC	20-30	14.56	95.3	94.4	0.94
	C	30-40	15.09	194.4	193.4	0.51
5a	Ahjbk1	40-45	14.61	121.2	119.8	1.16
	Ahbk2	45-70	14.23	127.2	123.4	2.99
	ACk	70-80	15.22	126.5	124.7	1.42
	Ck	80-90	14.97	85.9	85.3	0.70
5b	Ahjbk1	90-95	15.55	228.3	226.6	0.74
	Ck1	95-105	14.94	159.5	158.7	0.50
	Ahjbk2	105-110	15.32	138.4	137.4	0.72
	Ck2	110-130	15.58	98.0	97.4	0.61
5c	Ahjbk1	130-135	15.75	106.8	105.1	1.59
	Ck1	135-155	15.93	91.2	90.6	0.66
	Ahjbk2	155-160	14.69	127.2	125.3	1.49
	Ck2	160-215	16.06	131.0	130.4	0.46
5d	Ahjbk1	215-218	14.45	89.1	87.7	1.57
	Ck1	218-222	16.03	97.9	97.6	0.31
	Ahjbk2	222-225	13.80	113.7	111.9	1.58
	Ck2	225-230	15.22	93.3	92.8	0.54
	Ahjbk3	230-235	13.28	78.5	77.0	1.91
	Ck3	235-255	-	-	-	-
4	Ahjbk/Ck	255-264	-	-	-	-

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

APPENDIX B:
BASOVO AND BURDUKOVO MOLLUSC ASSEMBLAGE RAW COUNTS

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix B.1. Basovo High Floodplain Section 2b (HFS2b) - Mollusc raw counts (Terrestrial)

Depth (cm)	*Vallonia* spp.	*Vallonia costata*	*Vallonia* cf. *chinensis*	*Vallonia kamtschatica*	*Vallonia pulchella*	*Vallonia tenuilabris*	*Vertigo* spp.	*Vertigo alpestris*	*Vertigo antivertigo*	*Vertigo extima*	*Vertigo genesii*	*Vertigo geyeri*	*Vertigo microsphaera*	*Vertigo parcedentata*	*Vertigo pygmaea*	*Bradybaena* cf. *schrencki*	*Carychium pessimum*	*Cochlicopa* cf. *lubrica*	*Columella columella*	*Deroceras/Limax* spp.	*Discus* spp.	*Euconulus fulvus* agg.	*Gastrocopta theeli*	*Nesovitrea hammonis*	*Oxyloma/Succinea* spp.	*Punctum pygmaeum*	*Pupilla muscorum*	*Succinella oblonga*	*Zonitoides nitidus*
0-5	24	17	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
5-10	2	2	0	2	0	1	2	0	0	0	0	0	0	0	0	0	2	0	0	3	0	0	0	0	0	1	0	0	0
10-15	3	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
15-20	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0
20-25	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
25-30	11	8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	2	0	0	0
30-35	162	17	0	26	0	2	0	0	0	2	0	0	0	0	0	0	0	5	0	15	0	2	0	2	3	10	0	0	0
35-40	207	21	0	22	0	3	0	0	0	0	0	0	0	0	0	0	0	30	0	30	0	4	0	5	6	16	1	0	0
40-45	209	10	0	24	1	3	1	0	0	0	0	0	0	0	0	0	0	8	0	16	0	2	0	7	8	6	2	0	0
45-50	323	7	2	59	2	1	3	0	0	1	0	0	0	0	0	0	0	6	0	34	0	3	0	6	8	3	0	0	0
50-55	210	6	0	29	2	3	3	0	0	0	0	0	0	0	0	0	0	5	0	20	0	0	0	1	7	0	0	0	0
55-60	185	6	2	28	11	0	3	0	0	3	0	0	0	0	0	0	0	5	0	23	0	1	0	5	16	4	0	0	0
60-65	37	0	0	6	1	0	13	0	0	2	3	0	0	0	0	0	0	1	0	4	0	1	0	2	7	0	1	0	0
65-70	442	0	0	59	1	26	33	0	0	22	0	7	0	0	0	0	0	0	0	34	0	37	0	71	55	4	6	0	0
70-75	716	0	0	114	13	107	8	0	0	6	0	0	2	0	0	1	2	11	0	55	2	69	0	55	102	6	0	0	0
75-80	648	0	0	110	76	39	149	0	0	150	0	0	1	0	0	2	0	3	0	70	1	195	0	96	154	46	14	0	0
80-85	25	0	1	5	1	2	9	0	0	9	0	0	1	0	0	0	0	0	0	1	1	2	0	1	10	0	0	0	0
85-90	195	2	5	29	6	8	21	0	0	24	0	0	1	0	0	1	0	5	0	10	5	7	0	6	77	5	2	0	0
90-95	410	14	32	70	54	30	8	0	0	3	0	0	2	0	1	0	4	29	0	9	13	5	0	25	58	5	7	6	0
95-100	21	2	0	5	3	3	1	0	0	3	0	0	0	0	0	0	0	0	0	1	0	2	1	0	4	0	0	0	0
100-105	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
105-110	13	3	0	6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	0	0	0	0	0
110-115	472	25	19	58	40	0	9	0	0	10	0	0	0	0	0	0	5	13	0	7	1	5	0	13	13	14	3	0	0
115-120	1468	99	37	195	77	1	52	0	0	38	0	0	3	0	0	0	11	40	0	39	9	51	2	70	79	39	4	0	0
120-125	1321	118	152	113	132	2	20	0	0	19	0	0	0	0	0	4	8	89	0	29	6	26	0	35	36	66	4	0	0

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix B.1. Basovo High Floodplain Section 2b (HFS2b) - Mollusc raw counts (Terrestrial)

Depth (cm)	*Vallonia* spp.	*Vallonia costata*	*Vallonia* cf. *chinensis*	*Vallonia kamtschatica*	*Vallonia pulchella*	*Vallonia tenuilabris*	*Vertigo* spp.	*Vertigo alpestris*	*Vertigo antivertigo*	*Vertigo extima*	*Vertigo genesii*	*Vertigo geyeri*	*Vertigo microsphaera*	*Vertigo parcedentata*	*Vertigo pygmaea*	*Bradybaena* cf. *schrencki*	*Carychium pessimum*	*Cochlicopa* cf. *lubrica*	*Columella columella*	*Deroceras/Limax* spp.	*Discus* spp.	*Euconulus fulvus* agg.	*Gastrocopta theeli*	*Nesovitrea hammonis*	*Oxyloma/Succinea* spp.	*Punctum pygmaeum*	*Pupilla muscorum*	*Succinella oblonga*	*Zonitoides nitidus*
125-130	1400	22	119	100	118	2	16	0	1	10	0	0	1	0	1	2	6	91	0	23	5	25	1	28	58	89	8	0	1
130-135	856	11	69	95	96	22	24	0	0	25	0	0	0	0	0	2	1	61	0	15	4	17	2	27	75	17	24	0	3
135-140	789	9	49	27	39	44	121	0	0	127	0	0	0	0	0	0	0	32	0	18	1	53	0	10	356	30	59	0	0
140-145	1041	1	67	22	122	29	156	0	0	139	0	0	0	0	0	0	0	36	0	17	1	84	0	3	395	32	51	0	0
145-150	2106	6	287	18	322	33	132	0	1	99	0	0	0	0	0	0	0	65	0	18	0	92	0	21	339	31	15	0	0
150-155	4480	1	542	25	632	67	173	0	3	83	0	0	1	0	0	0	0	102	0	10	1	254	0	73	132	78	29	0	0
155-160	2540	0	332	44	200	60	80	0	3	64	0	0	0	0	0	0	0	76	0	7	1	190	1	40	120	66	46	0	0
160-165	4865	2	658	16	216	36	161	0	2	78	2	0	0	0	0	0	1	167	0	16	2	304	0	216	152	199	221	0	0
165-170	2168	7	258	26	163	21	50	0	2	48	0	0	2	0	0	1	1	72	0	2	1	157	7	73	82	129	55	0	1
170-175	2875	14	455	52	40	4	19	1	1	4	0	0	8	0	0	1	0	143	0	10	4	179	4	84	85	119	6	3	2
175-180	2471	58	273	161	14	11	11	0	1	4	0	0	39	0	0	5	0	161	0	6	11	190	1	93	38	82	14	3	0
180-185	5484	160	257	305	24	14	20	0	2	11	0	0	150	0	0	10	0	200	0	10	24	115	5	250	42	32	32	21	0
185-190	1814	184	29	210	7	24	28	5	0	4	0	0	134	0	0	20	0	231	2	7	50	118	8	175	16	19	20	24	0
190-195	998	33	2	143	0	32	42	4	0	7	0	0	12	6	0	5	0	95	0	26	22	37	0	51	10	17	26	47	0
195-200	520	1	3	153	0	20	34	6	0	5	0	1	0	0	0	0	0	42	0	51	0	4	0	6	13	49	32	28	0
200-205	369	0	8	96	0	20	26	3	0	15	0	0	0	0	0	0	0	24	0	36	0	3	0	8	8	51	12	12	0
205-210	306	0	16	24	0	36	39	3	0	27	0	0	0	0	0	0	0	11	0	36	0	7	0	9	28	146	18	8	0
210-215	328	0	31	25	0	14	48	2	0	14	0	0	0	0	0	0	0	38	0	30	0	16	0	16	26	103	18	5	0
215-220	264	0	21	3	0	14	17	0	0	2	0	0	0	0	0	0	0	16	0	15	0	6	0	3	11	17	4	0	0
220-225	104	0	7	0	0	2	0	0	0	1	0	0	0	0	0	0	0	5	0	6	0	3	0	1	2	0	1	1	0
225-230	81	0	0	3	0	12	0	1	0	0	0	0	0	0	0	0	0	3	0	3	0	2	0	3	1	1	0	0	0
230-235	23	0	0	4	0	5	0	1	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	1	1	1	0
235-240	10	0	2	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0
240-245	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
245-250	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix B.1. Basovo High Floodplain Section 2b (HFS2b) - Mollusc raw counts (Aquatic and Totals)

Depth (cm)	*Anisus leucostoma*	*Aplexa hypnorum*	*Bathyomphalus contortus*	*Galba truncatula ex. gr. sibirica*	*Gyraulus spp.*	*Gyraulus A sp.*	*Gyraulus cf. albus*	*Gyraulus crista*	*Gyraulus B sp.*	*Hippeutis complanatus*	*Lymnaea cf. fragilis*	*Radix A sp.*	*Radix B sp.*	*Polypylus sibirica*	*Stagnicola (atra) sp.*	*Valvata spp.*	*Valvata macrostoma*	*Valvata aliena*	*Pisidium casertanum*	*Pisidium nitidum*	*Pisidium henslowanum*	*Pisidium milium*	*Pisidium subtruncatum*	*Musculium lacustre*	*Sphaerium sp.*	Total aquatic	Total terrestrial	Total raw counts	Total number of species
0-5	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	49	52	6
5-10	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	15	17	9
10-15	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	6	7	13	9
15-20	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	7	10	8
20-25	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	9	6
25-30	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	27	30	8
30-35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	246	248	11
35-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	345	346	11
40-45	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	297	298	13
45-50	0	1	0	0	0	5	0	1	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	11	458	469	18
50-55	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	6	286	292	13
55-60	3	3	0	1	0	2	0	0	13	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	25	292	317	18
60-65	0	1	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	9	78	87	14
65-70	0	7	0	1	0	0	1	0	40	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	52	797	849	17
70-75	0	12	0	4	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	20	1269	1289	19
75-80	0	58	0	94	0	1	0	0	132	0	0	0	0	0	4	1	0	0	0	0	2	0	0	0	0	292	1754	2046	21
80-85	0	3	0	6	0	1	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	68	86	15
85-90	1	2	0	4	0	6	0	0	87	0	0	0	0	0	5	0	2	0	0	1	1	0	1	0	0	110	409	519	26
90-95	10	12	0	3	0	15	0	7	33	0	0	0	4	0	4	0	5	0	0	9	3	0	1	5	0	111	785	896	31
95-100	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	46	49	11
100-105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3
105-110	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	28	29	8
110-115	3	3	0	3	0	4	0	1	16	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0	36	707	743	22
115-120	26	53	11	21	0	50	0	1	74	3	1	0	30	4	20	0	6	0	0	1	0	0	0	0	0	301	2314	2615	31
120-125	18	11	3	13	0	20	2	3	19	0	0	0	21	1	16	0	2	0	0	1	0	0	0	0	0	130	2180	2310	29

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix B.1. Basovo High Floodplain Section 2b (HFS2b) - Mollusc raw counts (Aquatic and Totals)

Depth (cm)	*Anisus leucostoma*	*Aplexa hypnorum*	*Bathyomphalus contortus*	*Galba truncatula* ex. gr. *sibirica*	*Gyraulus* spp.	*Gyraulus* A sp.	*Gyraulus* cf. *albus*	*Gyraulus crista*	*Gyraulus* B sp.	*Hippeutis complanatus*	*Lymnaea* cf. *fragilis*	*Radix* A sp.	*Radix* B sp.	*Polypylus sibirica*	*Stagnicola (atra)* sp.	*Valvata* spp.	*Valvata macrostoma*	*Valvata aliena*	*Pisidium casertanum*	*Pisidium nitidum*	*Pisidium henslowanum*	*Pisidium milium*	*Pisidium subtruncatum*	*Musculium lacustre*	*Sphaerium* sp.	Total aquatic	Total terrestrial	Total raw counts	Total number of species
125-130	9	5	2	3	0	13	0	4	17	0	4	1	5	1	4	0	0	0	0	2	0	0	0	1	0	71	2127	2198	35
130-135	9	22	1	0	0	10	2	2	20	0	0	0	2	0	16	0	0	0	0	6	0	0	0	0	0	90	1446	1536	28
135-140	73	149	0	0	0	5	0	2	54	0	0	0	16	0	37	0	2	0	16	1	0	0	0	0	0	355	1764	2119	24
140-145	291	368	0	3	0	1	1	0	61	0	0	6	34	0	148	0	3	0	47	1	0	0	0	0	0	964	2196	3160	26
145-150	190	216	1	2	0	4	0	1	8	1	0	0	61	0	73	0	1	0	27	0	0	0	0	0	0	585	3585	4170	26
150-155	33	100	3	4	0	3	2	9	0	0	2	0	36	0	9	2	0	0	1	3	0	0	0	1	0	208	6686	6894	30
155-160	13	40	5	6	0	4	0	7	0	0	0	3	26	0	3	0	0	1	1	2	0	0	1	2	0	114	3870	3984	29
160-165	36	8	25	6	0	9	5	32	0	0	5	0	3	2	5	0	2	0	0	5	0	0	1	5	0	149	7314	7463	32
165-170	14	5	4	8	0	5	2	14	0	1	1	0	6	0	2	0	4	0	1	11	1	0	0	3	1	83	3326	3409	37
170-175	26	8	5	8	0	13	2	10	0	2	0	2	5	2	4	0	3	0	0	8	2	0	1	15	0	116	4113	4229	38
175-180	10	7	0	4	0	5	1	6	0	1	0	2	0	1	2	0	3	0	0	5	3	0	0	3	1	54	3647	3701	34
180-185	15	5	3	1	0	5	2	7	0	0	0	3	0	0	4	0	5	0	0	4	2	0	0	3	0	59	7168	7227	32
185-190	1	0	1	0	0	8	1	1	0	0	0	4	0	0	0	0	5	0	0	2	1	0	1	1	0	26	3129	3155	31
190-195	3	1	0	7	0	6	0	4	0	2	1	2	0	0	1	0	5	0	0	1	0	0	0	0	0	33	1615	1648	29
195-200	0	0	0	6	0	3	0	0	0	0	0	3	0	0	0	1	0	0	0	3	1	0	0	1	0	18	968	986	22
200-205	0	0	0	3	0	3	0	0	0	0	0	3	0	0	0	0	0	2	0	1	0	0	1	3	0	16	691	707	20
205-210	0	0	0	10	9	1	1	3	0	0	0	22	0	0	0	0	3	1	0	8	9	0	11	10	2	90	714	804	25
210-215	0	0	0	9	16	0	0	13	0	0	0	34	0	0	0	0	3	14	0	7	13	0	23	13	0	145	714	859	22
215-220	0	0	0	3	1	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	1	1	0	9	393	402	17
220-225	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	6	133	139	15
225-230	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	8	110	118	13
230-235	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	6	41	47	14
235-240	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	21	22	8
240-245	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	6	9	5
245-250	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	9	11	5

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Appendix B.2. Burdukovo - Mollusc raw counts

Depth (cm)	*Vallonia* spp.	*Vallonia* cf. *chinensis*	*Vallonia kamtschatica*	*Vallonia pulchella*	*Vallonia costata*	*Vallonia tenuilabris*	*Punctum pygmaeum*	*Euconulus fulvus* agg.	*Oxyloma/Succinea* spp.	*Cochlicopa* cf. *lubrica*	*Vertigo extima*	*Deroceras/Limax* spp.	*Discus* spp.	*Gastrocopta theeli*	*Nesovitrea hammonis*	*Pupilla muscorum*	*Zonitoides nitidus*	*Bradybaena* cf. *schrencki*	*Vertigo antivertigo*	*Pupilla sterrii*	*Columella columella*	*Vertigo microsphaera*	*Succinella oblonga*	*Galba truncatula* ex gr. *sibirica*	*Aplexa hypnorum*	*Gyraulus* spp.	*Anisus leucostoma*	*Stagnicola (atra)* sp.	*Hippeutis complanatus*	*Polypylus sibirica*	*Radix* sp.	*Musculium lacustre*	Total Aquatics	Total Terrestrials	Total Molluscs
170-180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180-190	6	0	0	0	0	1	2	0	2	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	14	14
190-200	9	0	0	0	0	1	7	1	2	0	0	0	3	0	1	4	0	0	0	0	3	1	1	1	0	0	0	0	0	0	0	0	1	33	34
200-210	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	6	6
210-220	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	2
220-230	19	1	8	13	0	0	0	0	2	1	0	0	0	0	2	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	2	47	49
230-240	647	78	93	58	10	3	8	18	10	45	13	2	25	6	51	116	0	5	0	0	0	0	0	70	1	0	9	4	1	0	0	0	85	1188	1273
240-250	1248	301	234	19	71	20	36	20	35	129	12	8	142	5	145	354	0	13	1	1	0	0	0	11	0	1	4	0	0	0	0	0	16	2794	2810
250-260	1206	232	93	18	323	6	86	8	27	250	2	9	91	8	180	173	0	35	0	0	0	0	0	7	1	0	3	1	0	0	1	0	13	2747	2760
260-270	934	236	35	30	154	0	87	16	31	177	0	19	91	1	171	55	0	24	0	0	0	0	0	9	1	0	1	0	0	0	0	0	11	2061	2072
270-280	1106	214	32	11	122	0	113	48	46	245	0	11	87	1	280	60	1	18	0	0	0	0	0	2	1	0	0	0	0	0	0	0	3	2395	2398
280-290	538	110	10	0	42	0	167	19	36	140	1	7	15	3	92	46	0	3	0	0	0	0	0	4	0	1	2	0	0	0	0	0	7	1229	1236
290-300	527	124	5	2	43	0	170	8	25	152	1	5	37	1	93	27	0	3	0	0	0	0	0	12	0	1	2	0	0	0	0	0	15	1223	1238
300-310	407	89	3	19	13	0	71	7	77	172	0	1	56	0	162	9	0	1	0	0	0	0	0	41	2	0	1	1	0	0	0	0	45	1087	1132
310-320	479	149	3	12	0	0	164	19	194	141	0	5	37	0	56	8	5	2	0	0	0	0	0	84	6	0	2	1	0	0	0	0	93	1274	1367
320-330	805	229	13	5	0	0	259	32	99	311	9	19	88	0	184	20	0	0	0	0	0	0	0	27	1	3	0	0	0	0	0	0	31	2073	2104
330-340	551	139	16	0	0	0	44	43	99	89	9	9	28	1	31	0	2	1	0	0	0	0	0	39	1	1	0	0	0	0	2	1	44	1062	1106
340-350	339	72	4	0	0	0	35	81	149	44	2	2	61	0	2	0	0	0	0	0	0	0	0	54	1	2	2	6	2	2	1	1	71	791	862
350-360	1249	284	19	0	0	0	463	55	89	205	1	13	177	1	14	12	0	0	0	0	0	0	0	7	0	0	2	0	0	0	0	0	9	2582	2591
360-370	610	143	3	0	0	0	143	128	20	11	43	5	68	1	0	0	0	0	0	0	0	0	0	15	0	1	0	0	0	0	0	0	16	1175	1191
370-380	375	46	10	0	0	0	51	55	37	3	10	2	1	0	0	0	0	0	0	0	0	0	0	258	0	0	0	0	0	0	0	0	258	590	848
380-390	5	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	22	1	0	0	0	0	0	0	0	23	8	31
390-400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
400-410	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
410-420	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.