A palaeogeographic and geoarchaeologic study on the Colchian plain along the Black Sea coast of Georgia

Inaugural-Dissertation

zur

Erlangung des Doktorgrades

der Mathematisch-Naturwissenschaftlichen Fakultät

der Universität zu Köln

vorgelegt von

Hannes Laermanns

aus Köln

Köln, 2018

Berichterstatter/Gutachter:	Prof. Dr. Helmut Brückner
	PD Dr. Martin Kehl

Tag der mündlichen Prüfung:	19.01.2018

Abstract

The Colchian plain forms the central part of the Georgian coast. Due to its protected area between the ridges of the Greater and Lesser Caucasus and the resulting mild climate it constitutes a refugee area for thermopile species during the last glacial maximum (LGM) as well as an ideal location for early human occupation. Despite the existence of excellent geobio-archives, the number of geoarchaeological and palaeogeographical studies in the Black Sea area in general, and in Georgia in particular is – compared to e.g. the Mediterranean – rather small. Therefore, this study shall (i) decipher Mid- to Late Holocene landscape changes, with special attention given to (ii) the Holocene relative sea-level (RSL) rise. In the context of the Black Sea-level history it is of special interest (iii) whether the water level rose oscillating or continuously. Furthermore, (iv) the geoarchaeological investigations on settlement mounds shall clarify the influence of those landscape changing processes on human occupation of that region and (v) establish a chronostratigraphy that eventually verifies the mounds' Bronze age origin.

This study is based on sediment cores that were gained from different locations on the Colchian plain between the rivers Enguri and Supsa. By using sedimentological and geochemical analyses (e.g., XRF and XRD-scans, LOI measurements, laser particle analyser etc.), sediment facies shifts in the natural depositional patterns and anthropogenic influence could be determined. Age estimations were established by using AMS-radiocarbon and luminescence (IRSL) dating and rendered a chronostratigraphy.

Consequently, an extensive landscape change in the research area was proven for the last 8000 years. While the coastline stayed more or less stable due to the extensive long-shore drift, its hinterland was turned through enduring sediment infill from an open lagoon into an alluvial floodplain since 3500 cal BC. Meanwhile the RSL rose continuously from -10 m below its modern level until it reached ~-2 m between 3000 and 1000 cal BC: Subsequently, the rise decelerated until it reached its modern level. These processes contradict the theory of an oscillating RSL rise, as proposed i.e. in the Balabanov-curve for the Georgian coast. They endorse instead the model of a continuous RSL evolution of the Black Sea.

The investigated settlement mounds exemplify human occupation since at least the early 2nd millennium BC and verify archaeology-based implications of their Bronze Age origin. The stratigraphy of the settlement mounds hints rather an intentional accumulation of sediment layers than a succession of settlement layers as known from tells. The warm and humid climate that prevailed during their occupation and their environs that were dominated by extensive wetlands back that assumption and exemplify the dependence and need for adaption strategies of human settlement to their surroundings.

It was the first time, that a combination of sedimentological, geochemical and dating approaches gained further knowledge on the landscape evolution of the Colchian plain and the relative sea-level evolution and gave first insights into human settling in complex environmental conditions.

Kurzzusammenfassung

Die kolchische Tiefebene bildet den zentralen Abschnitt der georgischen Küstenniederung. Aufgrund ihrer geschützten Lage, zwischen dem Großen und Kleinen Kaukasus und dem daraus resultierenden milden Klima, stellt das Areal sowohl einen Rückzugsraum für thermophile Arten während des letzten glazialen Maximums (LGM) als auch einen Gunstraum zur Besiedlung durch den Menschen dar. Trotz hervorragender Geobio-Archive ist die Zahl paläogeographischer und geoarchäologischer Untersuchungen des Schwarzen Meeres und im Besonderen der georgischen Küste, vor allem im Vergleich zum Mittelmeerraum, bisher eher gering. Daher soll mit dieser Dissertationsarbeit (i) der mittel- bis spätholozäne Landschaftswandel entschlüsselt werden. Ein besonderes Augenmerk liegt hierbei auf (ii) der relativen Meeresspiegelentwicklung während des Mittel- bis Spätholozäns, die den Landschaftswandel maßgeblich beeinflusst hat. Besonders der Frage, (iii) ob der Meeresspiegelanstieg kontinuierlich oder oszillierend verlief, wird hier nachgegangen. Darüber hinaus wird der Einfluss des Landschaftswandels auf die menschliche Besiedlung, anhand der (iv) geoarchäologischen Untersuchungen von Siedlungshügeln entschlüsselt und (v) eine Chronostratigraphie dieser speziellen Siedlungsform erstellt.

Die durchgeführten Untersuchungen basieren in erster Linie auf Bohrungen, die in verschiedenen Lokalitäten des Untersuchungsgebietes entlang der Küste zwischen den Flüssen Enguri und Supsa abgeteuft wurden. Das gewonnene Probenmaterial wurde im Geolabor der Universität zu Köln granulometrisch und geochemisch untersucht. Anhand der durchgeführten Analysen konnten verschiedene Ablagerungsfazies definiert und Rückschlüsse auf den Landschaftswandel und anthropogenen Einfluss ermittelt werden. Datierungen mittels AMS-Radiokohlenstoffmethode und Lumineszenzverfahren (IRSL) ermöglichten eine zeitliche Einordnung der Prozesse.

Basierend auf den gewonnenen Ergebnissen konnte ein umfassender Landschaftswandel im Laufe der letzten 8000 Jahre im Untersuchungsgebiet festgestellt werden. Während die durch Küstenlängstransport geformte Küste relativ konstant blieb, verlandete(n) ab etwa 3500 v. Chr. die dahinterliegenden Lagune durch den anhaltenden fluvialen Sedimenteintrag (insbesondere des Rioni) zunehmend. Der Meeresspiegel stieg im selben Zeitraum von etwa 10 m unter seinem heutigen Niveau kontinuierlich an, erreichte zwischen 3000 und 1000 v. Chr. ein Niveau von etwa -2 m und stieg seitdem deutlich verlangsamt an bis er sein heutiges Niveau erreichte. Diese Ergebnisse widerlegen für den georgischen Küstenraum die weitverbreitete Theorie eines oszillierenden Schwarzmeer-Spiegels und belegen einen kontinuierlichen Schwarzmeeranstieg.

Anhand der untersuchten Siedlungshügel konnte eine menschliche Besiedlung seit mindestens dem Beginn des zweiten Jahrtausends v. Chr. nachgewiesen werden, was sich mit bronzezeitlichen Funden aus dem Umfeld der Hügel deckt. Die Stratigraphie der Hügel deutet auf eine gezielte Errichtung innerhalb eines kurzen Zeitraums hin, was in Anbetracht des feucht-warmen Klimas und der Entwicklung der von Sumpfland geprägten Küstenebene sinnig scheint und als beispielhafte Anpassungsstrategie auf die natürlichen Gegebenheiten gesehen werden kann.

Somit konnte erstmalig mittels verschiedener geochemischer, sedimentologischer und geochronologischer Methoden der mittel- bis spätholozäne Landschaftswandel der kolchischen Tiefebene, inklusive der relativen Meeresspiegel-Entwicklung und der menschlichen Besiedlung analysiert werden.

Acknowledgements

Firstly, I would like to thank my supervisor, Prof. Dr. Helmut Brückner, for enabling me to work within his research group. Initially as a student assistant and later as a PhD student and scientific team member, he continuously showed support throughout my PhD thesis and scholarship application and provided motivation and encouragement to pursue my own ideas during my PhD research. I sincerely thank him for showing trust in me and for allowing me to work independently on my project. I'm grateful for his scientific supervision, financial support and continued encouragement throughout.

Besides my supervisor I would like to thank my mentors. I thank Dr. Daniel Kelterbaum for his support with my scholarship application, initializing the project and developing research ideas. Without his initiative on the Georgia project it wouldn't exist. I am grateful for his support and cooperation during the fieldwork.

Further, I would like to express my heartfelt gratitude to Dr. Simon Matthias May. His motivation, professional as well as personal support were of great comfort during difficult periods. His guidance, constructive criticism and scientific skills brought my research to higher levels.

In addition, I would like to thank Dr. Nick Marriner for supervision during my stay at the Université de Franche Comté in Besançon and for his willingness to support me over the last few years in general. In particular, with regards to language editing and scientific matters.

Thanks to Dr. Stephan Opitz for general laboratory instructions and support while writing my publications. He familiarized me with the majority of analysis methods and has proven to be a very constructive co-author.

I owe great thanks for the helpful support of Prof. Suzanne Leroy from Brunel University Uxbridge, UK (now Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environment [CEREGE], Aix-en-Provence, France) for palynological analysis as well as for her invitation to present my findings at Brunel University and for her keen interest in potential future cooperation.

Furthermore, I thank PD Dr. Martin Kehl who agreed to co-supervise this thesis and for his advice concerning analysis methods and the structure of my thesis. Also, I thank Prof. Dr. Frank Schäbitz and Dr. Simon Matthias May for being part of the commission of my PhD defence.

My dissertation project was funded by the Heinrich Böll Foundation. I am extremely thankful to them for giving me this opportunity. With such support I was able to turn my project ideas into reality. Beyond the financial support, I thank the Heinrich Böll Foundation for the mentoring and networking programme that put me in touch with so many people who are working in different disciplines and are involved in so many projects. This interdisciplinary exchange of ideas has vastly broadened by experiences.

I thank the Graduate School of Geosciences, and especially Dr. Karin Boessenkool, for the Fellowship grant that enabled me to continue with my PhD, for the travel grants, trainee programme and especially the personal support during my entire PhD. Furthermore, I would like to thank the Albertus Magnus Graduate Centre that funded my research stay at Université de Franche Comté in Besançon, France.

Many thanks to Melanie Bartz, Simon Matthias May, Nick Marriner, Maike Norpoth, Juliane Scheder, Dennis Wolf and Alan Palmer for tirelessly proof reading my thesis. Also, special thanks to Giorgi Kirkitadze and Jan Verheul for supporting me with the graphics and layout.

Our fieldwork would never have taken place, nor had been so successful without the support of our colleagues from the Ilia State University in Tbilisi, in particular Dr. Mikheil Elashvili, Giorgi Kirkitadze and Levan Navrozashvili. They provided accommodation in the Marine Research Center in Grigoleti, supported myself and my team in countless ways and endeavoured to make everything possible. At this point I would also like to thank all students who supported me during those field trips, Julian Rölkens, Jan Verheul, Arne Heisterkamp and Svenja Riedesel for their interest, patience and great company. In particular, I acknowledge the latter two for writing excellent bachelor theses within this project.

Moreover, I thank all my colleagues from the research group and my companions and friends at the Institute of Geography with whom I spent so much time with at work as well as socially. In particular, I would like to acknowledge Helge Aasen, Moritz Breul, Dominik Brill, Lisa Ehlers, Kristof Dorau, Corinna Földi, Sebastian Frank, Georgina King, Sebastian Kock, Ulrike Lussem, Matze May, Maike Norpoth, Gilles Rixhon, Jule Scheder, Friederike Stock, Jan Verheul, Dennis Wolf and many more. Special thanks to Melanie Bartz for joint field and laboratory work while working as student assistants, and for accompanying me throughout all ups and downs during our PhD theses.

Finally, I would like to thank my family, especially my grandmother and father. But above all, my mother, for universal support throughout my thesis and in my life in general. I owe you everything.

And lastly, I dedicate this thesis to my grandfather, Hans-Jürgen Schiffer. He had always been my idol and I thank him for all his kindness, generosity and understanding. He was always profoundly interested in my studies and would have loved to see this completed thesis. He passed away on the day I submitted my PhD application.

Table of Contents

List of Figures

List of Tables

Chapter 1

1 Introduction

1.1 Holocene Palaeogeography and Geoarchaeology

The disciplines of Holocene palaeogeography, a part of the Quaternary science, and geoarchaeology are comparably young research fields used to contextualize human (pre-) history. Whilst classical archaeology is able to look back on a several centuries-long tradition, research on human societies in their specific environments is rather new (Marriner & Morhange 2006). During the past two decades, archaeologists have become increasingly aware of the importance of the environment in understanding the socio-economic and natural frameworks of ancient societies (Marriner et al. 2010).

Due to their long and continuous settlement histories, the Fertile Crescent, the Mediterranean, northern Africa and Europe are regions of high interest for geoarchaeolological and palaeogeographical studies. In particular, coastal areas yield potentially rich archives. For instance, they document the different aspects of natural forcing (e.g., sea-level changes,

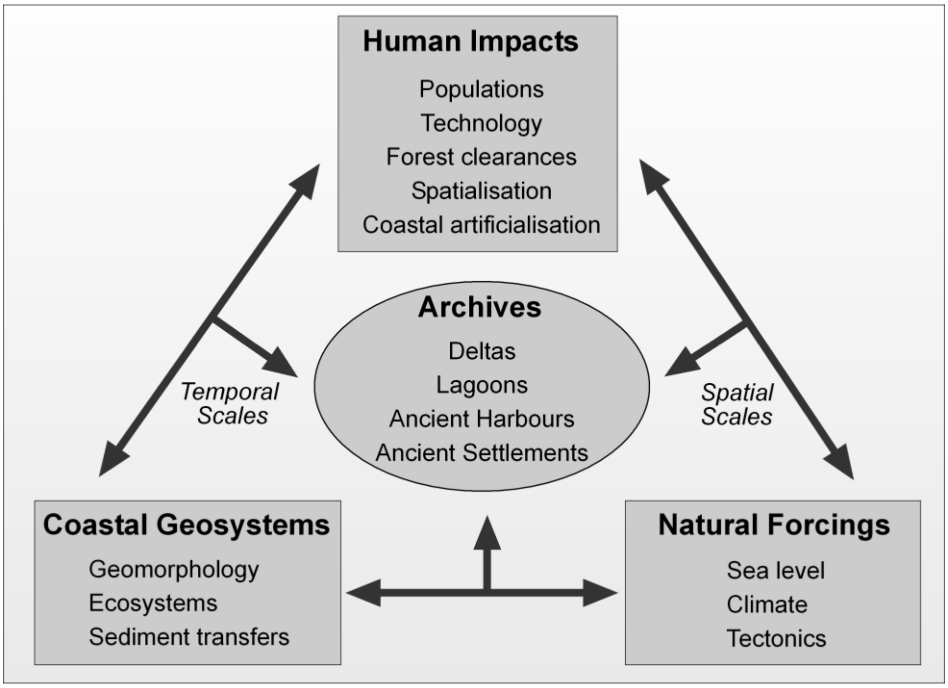

Fig. 1.1: Coastal areas as archives in geoarchaeological and palaeogeographical research (Marriner et al. 2010, modified 2017).

climate and vegetation history; Fig. 1.1; Marriner et al. 2010). This is especially true for coastal environments; however, information on their hinterland is also provided by sediment supply from fluvial systems (Haghani et al. 2015). Furthermore, their sedimentary archives may show evidence for the transition from natural to human-influenced environments (Brückner 2005).

Since the end of the postglacial transgression ~6000 years ago, coastal areas have become densely settled regions in many parts of the world, especially in the Mediterranean and the neighbouring seas. Here, the great civilizations (Greek, Roman, Phoenician etc.) left manifold anthropogenic traces – e.g. harbours, cities, fishing industries, trade economy, deforestation and agricultural land use (Marriner & Morhange 2006, 2007). Therefore, the interdisciplinary approach of geoarchaeology (Brückner & Gerlach 2011) is well suited to reconstruct natural and anthropogenic landscape-forming processes during the Holocene (see 1.4.4). This holds especially true for the Black Sea region with its specific Holocene sea-level curve and settlement history.

1.1.1 The sea-level evolution of the Black Sea

Global sea level underwent extensive changes during the Late Pleistocene and Holocene. After falling to its lowest position of ca. 120 m below today's level during the Last Glacial Maximum (LGM) around 20,000 years ago, sea level rose at an average rate of 1.5 cm/yr from ca. 14,000 BP onwards, reaching a near-present position around 6000-5500 BP (Clark & Mix 2002, Clark et al. 2009, Brückner et al. 2005, Lambeck & Purcell 2005). While this holds true for the Mediterranean the relative sea-level (RSL) evolution of the Black Sea is, according to literature, rather complex. There is in fact a great deal of confusion, in particular when looking into older publications from Russian authors.

It is assumed by many authors that during MIS 2 sea level dropped below the Bosporus sill leaving the Black Sea separated from the world ocean. If so, it must have been a giant freshwater lake (Panin & Popescu 2007), which was considerably lower than today's level. The new hypothesis to explain the great deluge, i.e. the Genesis Flood published by Ryan et al. (1997) and Pitman & Ryan (1998) started a controversial debate on the timing and mode of the Holocene reconnection of the Black Sea with the Mediterranean. These authors assume that after the separation from the Mediterranean, the Black Sea was catastrophically flooded via the Bosporus in the course of the global warming that followed the LGM since its water table had remained significantly lower. The reconnection was initially dated to ~7500 BP (Ryan et al. 1997) and later corrected to ~8400 BP (Ivanova et al. 2007, Ryan et al. 2007, Giosan et al. 2009). It is still debated, if a catastrophic flooding did indeed take place (e.g., Ryan et al. 1997, Pitman & Ryan 1998, Ballard et al. 2000, Lericolais et al. 2007, 2009) or rather a gradual or oscillating sea-level harmonization (e.g., Chepalyga 2002, Hiscott et al. 2002, Balabanov 2007) or whether the Black Sea level was always high and had a continuous waterflow into the Marmara Sea (Aksu et al. 1999, 2002).

Since the reconnection of the Black Sea with the Mediterranean via the Bosporus Strait, different RSL scenarios are assumed (Pirazzoli 1991, Martin & Yanko-Hombach 2011). Several studies proposed an oscillating curve, mainly referring to older studies (e.g., Ostrovsky et al. 1977, Voskoboinikov et al. 1982, Balabanov 1984, Chepalyga et al. 1984), spanning a wide range of scenarios that differ in the extent and number of oscillations (Pirazzoli 1991, Brückner et al. 2010). Even after the reconnection with the Mediterranean Sea, the curve differ significantly (cf. Fig. 1.2; see also Brückner et al. 2010). E.g., the position of sea level around 5000 BC shows great differences: -5 m below the current sea level (b.s.l.) (Filipova-Marinova 2007) to more than -20 to -30 m (e.g., Voskoboinikov et al. 1982, Balabanov 2007). Thereafter, they differ dramatically in the number and amplitude of oscillations ("wiggles") and variations (cf. Fig. 1.2).

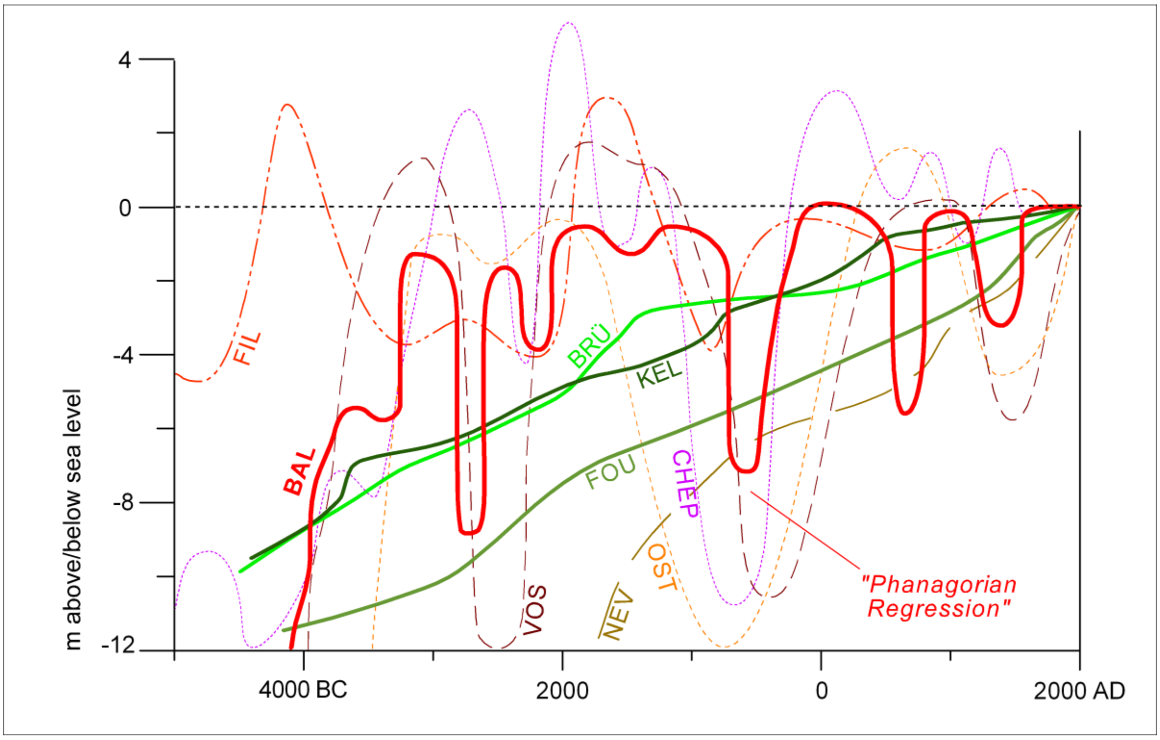

*Fig. 1.2: Compilation of different sea-level curves for the Black Sea. Older publications (e.g., **NEV** = Nevessky 1970, **OST** = Ostrovsky et al. 1977, **VOS** = Voskoboinikov et al. 1982, **CHEP** = Chepalyga et al. 1984) are summarized in the so called Balabanov curve (**BAL** = Balabanov 2007) the most prominent, but not the only modern RSL curve that propagates significant oscillations (e.g., **FIL** = Filipova-Marinova 2007). They conflict with RSL-models of Brückner et al. 2010 (**BRÜ**), Kelterbaum et al. 2011 (**KEL**) and Fouache et al.2012 (**FOU**) that indicate a continuous sea-level rise (mean values presented here). Own design 2017.*

The so-called Balabanov-curve, lastly published in 2009 (Balabanov 2009) is based on several of these former models and uses their available (uncalibrated) radiocarbon dates (Martin & Yanko-Hombach 2011). It can be seen as a summary and "consensus-curve" for the oscillating RSL. Lately, Bolikhovskaya et al. (2017) distinguish six small amplitude transgressions and seven regressive phases of different magnitudes during the last 7400 years in accordance with Martin et al. (2007) and Martin & Yanko-Hombach (2011).

The Phanagorian Regression is the best known – but also most debated – of these regressive phases. It was first proposed by Fedorov in 1963 who noted a sea-level drop of ~5-6 m in the Mid-1st millennium BC (Fouache et al. 2012). It is based on the location of archaeological remains of the Milesian Greek city of Phanagoria (and other adjacent archaeological sites); parts of these settlements lie submerged in the Gulf of Taman (Porotov 2007). Though the sea-level curves propagating an oscillating RSL rise reveal a different trend, they evoke a significant regression-transgression cycle during the 1st millennium BC (Balabanov 2009, Fouache et al. 2012).

Conversely, there are several publications (e.g., Nevessky 1970, Hiscott et al. 2002; Giosan et al. 2009, Brückner et al. 2010, Kelterbaum et al. 2011 & 2012, Fouache et al. 2012) that reject (significant) regressive cycles since the reconnection of the Mediterranean and the Black Sea via the Bosporus Strait; these authors present evidence for a continuous RSL rise instead. They point out that after the reconnection both water bodies must have reacted as a communicating system, because the glacio-eustatic effects had been the same (Brückner et al. 2010). No major Holocene regressions are known from the Mediterranean (e.g., Marriner & Morhange 2006, Morhange 2005, Vött & Brückner 2006, Brückner et al. 2006, Vött 2007, Seeliger et al. 2014) their existence must be doubted for the Black Sea as well. Even data from the western part of the Black Sea, in particular the Danube delta, hint at a more or less stable sea level (± 1.5 m) during this period (Giosan et al. 2006).

Studying the Taman Peninsula and the Kuban delta region, which includes the sites of the so-called Phanagorian regression, Brückner et al. (2010) and Fouache et al. (2012) discard the existence of major RSL fluctuations. Instead they proposed a gradual sea-level rise from 7 to 6 m below present sea level around 5000 BC to ~2 m b.s.l. around 2000 BC, and a continued slow rise until today (Brückner et al. 2010). Were there, however, minor climate-induced variations (Behre 2003, Leorri et al. 2006), eventually <2 m, as proposed for the Colchis region (Dzhanelidze 2007) and for the Thracian Black Sea coast of Turkey (between 5.4 and 3.5 ka BP; Erginal et al. 2013)? This question is still open, since these variations were as yet not found in the Aegean Sea.

1.1.2 Geoarchaeology in the coastal areas of the Black Sea region

The number of geoarchaeological studies on the Black Sea region is significantly lower than on the Mediterranean Sea. This may be explained by its peripheric position during the antiquity. The Mediterranean, the Roman *mare internum*, hosts a great number of ancient cities, such as Greek, Roman, Egyptian, Phoenician, with a huge potential for geoarchaeological research (e.g., for Rome [Portus & Ostia]: Delile et al. 2014, Goiran et al. 2014; for Alexandria: Flaux et al. 2017; for the Levant: Marriner et al. 2010; for Ephesus: Brückner 2005, Kraft et al. 2007, Stock et al. 2013, 2016, for Pergamum/Elaia: Seeliger et al. 2013, 2014, for Miletus lately Brückner et al. 2014). This also holds true for Palaeolithic to Neolithic sites as well (e.g., Zielhofer et al. 2008, Linstädter & Kehl 2012; Kehl et al. 2013). Nowadays, the Black Sea's location in the periphery of Europe, and its decade-long restricted accessibility during the Soviet Period is another reason for the few number of palaeogeographical and geoarchaeological publications. Plus, many publications were written in Russian or even in local languages.

Nevertheless, there is a certain and increasing number of palaeogeographical and geoarchaeological studies in the Black Sea region. In particular, several Milesian Greek colonies and their hinterlands in the western and northern part have been investigated in recent years. A number of studies focussed on the different progradation stages of the Danube delta and the environmental impacts for Neolithic to medieval settlements (e.g., Carozza et al. 2012, Romanescu 2013) Research on the ancient city of Histria, on the southern margin of the Danube delta, and its role as a trading town in the context of spit formation and the isolation of the harbour from the open sea can be seen as a good example (Vespremeanu-Stroe et al. 2013, Romanescu 2014, Preoteasa et al. 2017). Further examples south of the Danube delta are the diatom- and chrysophycean stomatocysts-based study of Chalcolithic to Early Bronze Age environments at Lake Durankulak (Ognjanova-Rumenova 2008) or investigations on coastal changes at the ancient Milesian colony of Appolonia Pontica, the present-day Sozopol in Bulgaria (Baralis et al. 2011, Flaux et al. 2016).

The Taman and Crimean peninsulas, which are separated by the Strait of Kerch, the ancient Cimmerian Bosporus, are another Black Sea area where several geoarchaeological studies have been carried out. Given that many of the Greek colonies were located on the peninsulas' shores (Koschelenko & Kusnetsow 1998) most geoarchaeological studies focus on their environs and the resulting interdependencies, e.g. the Dorian Greek colony of Chersonesos (Carter et al. 2000). Furthermore, Kelterbaum et al. (2011, 2012) investigated on the Kerch Peninsula, the easternmost part of Crimea and on the Taman coastline changes that separated extended embayments and inlets from the open sea. Special attention was given to the ancient Greek colony of Phanagoria due to the so-called Phanagorian Regression, which was proven to be a wrong concept (Brückner et al. 2010, Fouache et al. 2012). Beyond classical Greek sites, some Palaeolithic to Bronze Age sites were investigated under the aspect of land-use changes (Burke et al. 2008), including aspects of pedogenesis (e.g. Cordova et al. 2011, Cordova 2016).

Other than the coasts of Romania and Bulgaria – with a focus on the Danube delta – and the Crimean/Taman region, only scattered geoarchaeological investigations have been carried out in the Black Sea region. This is surprising, since there is still a great number sites of (geo-) archaeological interest. This holds especially true for the Black Sea coast of Georgia, where until a couple of years ago, very few international projects had been undertaken. Beside the Palaeolithic site of Dmanisi (e.g., Gabunia et al. 2000, Lordkipanidze et al. 2007, Messager et al. 2009, 2011) some sites in eastern Georgia were investigated (e.g., Hansen et al. 2007, von Suchodoletz et al. 2015). The political situation in Abkhazia and, until 2004, in Adjara hindered research and limited investigations on several parts of Western Georgia only. Since then, some archaeological sites, e.g. Hispani, on the southern part of the Georgian coast, have been the subject of geoarchaeological research (Connor et al. 2007, de Klerk et al. 2009, Janelidze & Tatashidze 2010).

1.2 The significance of the Colchian plain's geo-bio-archives

The Kolkheti lowlands, or Colchian plain, which equates with the historical region of Colchis, is the central part of the Georgian coast. Its topographical location differs from the other areas of the Black Sea. Between the ranges of the Greater Caucasus in the north and the Lesser Caucasus in the south it is protected against the cold winters of the steppes in the north and the Anatolian plain in the south (Eppelbaum & Keshin 2012). This situation makes the Colchian plain special for various reasons:

This topographical situation allowed <u>thermopile species to survive the glacial periods in this refuge area</u>. Hence, western Georgia is one of only three areas in western Asia where tertiary relict species survived and can be found through to today (Röhrig 1991, Connor et al. 2007). While tundra vegetation prevailed during the last glacial maximum (LGM) in most parts of Europe, it is assumed that Georgia had deciduous and mixed forests existed (Tarasov et al. 2000). Furthermore, the endemic percolation bogs, which can be found in mires southeast of Lake Paliastomi, underline the uniqueness of the region (Joosten et al. 2003, Haberl et al. 2006).

Beside its ecological importance, the Colchian plain stands out with its extraordinary long and continuous human occupation. In the adjacent Kura catchment, the oldest hominid remains outside of Africa were discovered at the site of Dmanisi (Gabunia et al. 2000). The protected location of the Colchian plain, with its mild climate, has always favoured human occupation, and allowed an early transition from hunting and gathering to farming and animal husbandry societies between 10000 and 9000 BC until the Chalcolithic (Lordkipanidze 1991, Arslanov et al. 2007).

Beyond these special characteristics of the region, the Colchian plain is also notable because of its excellent palaeoenvironmental archives. The strong long-shore drift (Korotaev et al. 2003) and meandering rivers with their high sediment supply (Berkun et al. 2015) flowing down from the adjacent foothills and the Caucasus ranges created vast lagoons and delta fans. Such water bodies, with their gradual infill of fine-grained floodplain sediments and peat growth (Chapter 2), are ideal archives for sea-level reconstructions (Haghani et al. 2015) and palaeo-environmental research (e.g., for the western Black Sea shores: Giosan et al. 2006, for the Caspian: Leroy et al. 2011, for the Aegean: Brückner 2005, Brückner et al. 2006). Furthermore, they provide the potential to document the transition from environments dominated by natural processes to strongly anthropogenic-influenced environments (Brückner 2005), whilst also covering geoarchaeological aspects too.

1.3 Objectives of the present study

As already stated (see Chapter 1.1.2), only very few geoarchaeological and palaeogeographical studies have been carried out in the coastal lowlands of Georgia, although this region is very well suited for this kind of research. The present study aims at filling the gap by investigating the evolution of the western Georgian landscape during the Holocene. It focuses on landscape formations, changes of the coastline and the environments and the vegetation history as well as the human-environment interactions during the last eight millennia. Three working hypotheses were formulated, which are subdivided into five research goals.

<u>Working hypothesis 1:</u> *Georgia's coastal areas underwent significant landscape and environmental changes during the Holocene.*

Goal 1: Reconstructing the Holocene evolution of the coastline and its hinterland in the Kolkheti lowlands.

Coastal wetlands serve as excellent geo-bio-archives to decipher palaeoenvironmental changes (e.g., Arslanov et al. 2007, Leroy et al. 2013, Seeliger et al. 2013, Stock et al. 2013, 2016, Pint et al. 2015). Against the background of sea-level rise, a significant coastline change and subsequent transformation of vast areas in the hinterland can be assumed. Therefore, this research is in particular regarding the evolution of sand spit complexes and the advance of the Rioni and Supsa deltas. By using granulometric, geochemical and other methods different environments can be identified (cf., Brückner & Gerlach 2011). Radiocarbon- and luminescence-dating littoral and aeolian sediments are tools to establish a geochronology for the palaeogeographical evolution of the Kolkheti lowlands.

<u>Working hypothesis 2:</u> *Landscape change was strongly influenced by the Holocene sea-level transgression.*

Goal 2: Establishing a Holocene sea-level curve for the Georgian Black Sea coast

The Holocene sea-level rise played an essential role in the evolution of the Black Sea, especially against the background of the reconnection between the Black Sea and the Mediterranean (e.g., Ryan at al. 1997, Ryan 2007). This is a central aspect of the Holocene landscape change. In comparison to other studies in the Ponto-Caspian region (e.g., Georgievski & Stanev 2006, Giosan et al. 2006, Brückner et al. 2010, Fouache et al. 2012, Kelterbaum et al. 2012), reliable data on the sea-level evolution of the Eastern part of the Black Sea do as yet not exis. Therefore, a Holocene sea-level curve shall be established in the framework of this PhD thesis, and compared and contrasted with other data for the Black Sea area.

Goal 3: Evaluating the scenarios for the Holocene RSL evolution for the Georgian coast: the scenario with major oscillations and the scenario of a continuously rising RSL.

While several authors continue to defend the theory of an oscillating sea-level history for the Black Sea (e.g., Balabanov 2007, 2009, Chepalyga 2007; Yanko-Hombach et al. 2007), others disproved the existence of significant historic regressions and suggest a continuous sea-level rise instead (e.g., Giosan et al. 2006; Brückner et al. 2010, Kelterbaum et al. 2012;

Fouache et al. 2012). This PhD thesis will contribute new data to this debate from the as yet unexplored Georgian coast.

Working hypothesis 3: *The palaeoenvironmental changes influenced the human settlement activities.*

Goal 4: Investigating the Colchian settlement mounds.

Based on the assumption that the territory of Georgia was continuously settled during the Holocene (Kohl 2001, Fähnrich 2010) numerous settlement mounds, locally named *Dikhagudzuba* (Lordkipanidze 1991, Gamkrelidze 2012), testify to early settlement activity. Their spatial distribution and possible dependencies on distinct landscapes shall be investigated. Furthermore, it is of great interest to understand how these settlements affected the environment (e.g., Turney et al. 2005, Oonk et al. 2009).

Goal 5: Reconstructing the chronostratigraphy of the Colchian settlement mounds.

Due to the lack of detailed archaeological investigations as well as numerical age estimates, the precise stratigraphy and age of the settlement mounds is as yet unknown. Therefore, a chronostratigraphy based on archaeological finds and radiocarbon ages shall be established to estimate the chronology of the mounds' construction and the time span of their use.

1.4 Research design and applied methodology

The palaeogeographical and geoarchaeological research conducted in this PhD thesis investigates the Holocene landscape evolution of the Colchian plain, in particular in the environs of the Supsa and Rioni deltas and the environs of the Bronze age settlement mounds close to the villages of Ergeta and Orulu. The research follows the geoarchaeological approach outlined by Brückner & Gerlach (2011). Beside geoscientific field work and laboratory work, it uses information rendered by historical sources, (historic) maps and digital image material (satellite images, areal images, photogrammetry) as well as remote sensing techniques (Fig. 1.3).

1.4.1 Field work

During this project three fieldwork campaigns were carried out. The first took place in October 2013 and focussed mainly on familiarizing ourselves with the research area, surveying and vibracoring in the areas south of the Rioni and in the Supsa area. The second phase of fieldwork in March 2014 enlarged the investigated area by the swampland and beach ridges, between the Rioni and Khobistskali, while concluding fieldwork in March 2015 expanded further north to the settlement mounds of Orulu und Ergeta.

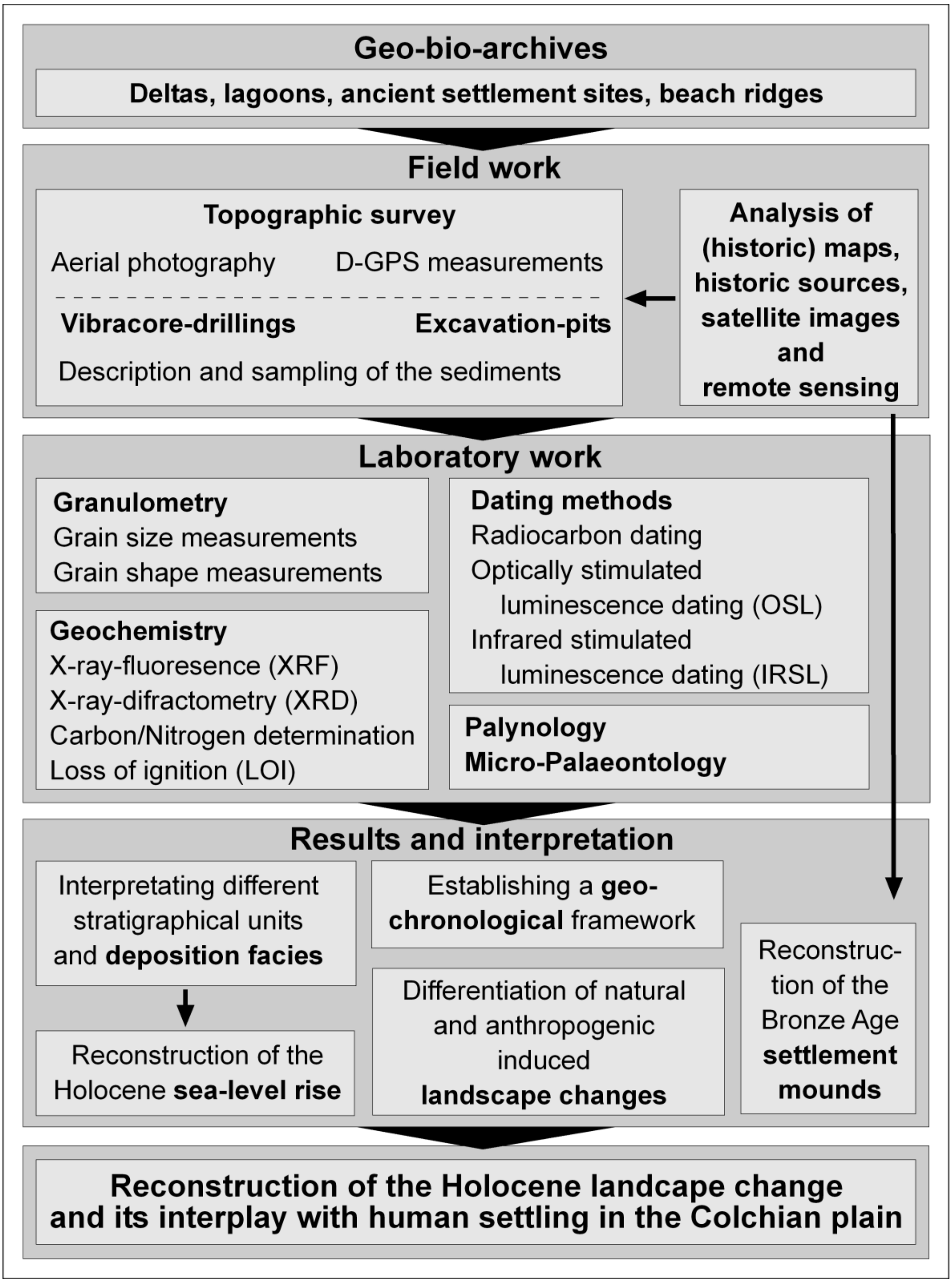

Fig. 1.3: Research design of the study (own design 2017).

The fieldwork of every campaign included on-site surveys to identify different archives and locate possible settlement locations, e.g. in the Rioni region Greek or Roman remains of the lost city of Phasis, or of settlement mounds in the northernmost part of the research area. The latter were identified in satellite images (Google Earth images, © 2014 Digital Globe) and described in archaeological sources (e.g., Lordkipanidze 1991; Tsetskhladze 1997; Gamkrelidze 2012). Unfortunately, there are no known archaeological remains that unequivocally prove the location of Phasis, but several hypotheses exist (cf., Gamkrelidze 2012, Licheli 2016).

The stratigraphic analysis and geochemical interpretation derives from sediment cores, which were taken using a Cobra TT (Atlas Copco) percussion coring device. Half-open cores of 6 and 5 cm diameters were retrieved using a hydraulic leverage device. A maximum depth of 12 m below surface (b.s.) was achieved.

In the field, the core analysis consisted first in the description of sediment texture and colour (with Munsell Soil Color Charts©). The carbonate content was tested (using hydrochloric acid [HCl], 10 %) and a preliminary distribution of the different layers established. Samples were taken from sedimentary units and special attention was given for organic material that could be used for radiocarbon dating and archaeological findings. The elevation of the sediment cores and topographical transects was measured using a Topcon Hiper V DGPS with a 3D resolution of 2 cm.

For the settlement mound *Ergeta 1* close-range aerial photogrammetric images were taken using a Nikon Coolpix camera with 16 MP 1/2.3" CMOS to create a digital surface model (DSM) and a RGB orthophoto-mosaic via the Structure-from-Motion (SfM) technique (Westoby et al. 2012).

Additionally, several sediment cores were taken in closed tubes for a high-resolution analyses in the laboratory. Furthermore, excavation pits were dug at the beach ridges north of the Rioni delta (Chapter 2) and samples for luminescence dating were taken from the opened sediment profiles in opaque plastic tubes for further treatment in the Cologne Luminescence Laboratory (CLL).

1.4.2 Sedimentology and geochemistry

In order to unravel the sediment provenance and depositional processes in the different areas of the Colchian plain, samples were analysed in the Laboratory for Physical Geography (University of Cologne). All samples were oven dried at 40 °C for 48 h, sieved using a <2 mm mesh, and gently pestled by hand for aggregate disintegration.

The analyses of the grain-size distribution were conducted using a Laser Diffraction Particle Size Analyzer (LS 13320 Beckmann Coulter$_{TM}$). To remove the organic matter the samples were pre-treated with hydrogen peroxide (H_2O_2 15 %) and subsequently with sodium pyrophosphate ($Na_4O_7P_2$, 46 g/l) to avoid coagulation. Each sample was measured three times using the optical Fraunhofer model. The data evaluation is based on Folk & Ward (1957), calculated using GRADISTAT software version 8 (Blott & Pye 2001).

Furthermore, selected samples from the sandy layers in the Supsa area were analysed for their grain-shape parameters using a Retsch CAMSIZER® P4. The <63 µm fraction was separated from the coarser material which was measured in 52 channels up to 22.4 mm to define roundness, sphericity and elongation by using the principle of dynamic image analysis (ISO 13322-2). The results were calculated using the software CAMSIZER® 4.4.1.

In addition to the granulometry, different geochemical parameters were measured. Two different methods for the estimation of organic matter were used: (i) Loss on ignition (LOI) was determined to estimate the organic matter content by oven-drying 5 g of sample material at 105 °C for 12 h and ignition in a muffle furnace (Carbolite ELF) at 550 °C for 5 h (Barsch et al. 2000; Heiri et al. 2001); (ii) C/N ratios and total organic carbon (TOC) were estimated using the method described by Meyers & Teranes (2001). The sample material was homogenized, weighed out into tin boats and subsequently determined on duplicate powdered samples using a Vario EL Cube (Elementar Analysensysteme GmbH, Hanau, Germany). In a second aliquot of each sample, $CaCO_3$ was dissolved with 10 % HCl, before TOC was determined.

Further, X-ray fluorescence (XRF) analyses were performed to estimate the element concentrations. Homogenized material was pressed into 2-mm-thick pellets, and measured with a portable XRF analyser (NITON XL3t). Each sample was measured three times in mineral mode for 160 sec to cover all possible filter options with an adequate time span. In the case of the sediment core KUL 13 XRF data was determined by using a Itrax Core Scanner (Cox Analytical Systems, Sweden; Croudace et al. 2006) to obtain a 2 mm resolution. In addition, selected samples were analysed for their mineral composition by X-ray diffraction (XRD). Therefore the homogenised samples were placed on a PVC slide and measured in a Powder X-Ray Diffractometer (Siemens D 5000) with a fixed focal distance of 0.5 mm at 5-75°

2Θ in 0.05° steps and 10 sec per degree (Cu-K-alpha radiation source, operated at 40 keV and 40 mA). The data were analysed using the DiffracPlus EVA software package (Bruker AXS, Berlin, Germany).

Magnetic Susceptibility (MagSus) measurements were performed by using a Bartington MS2B sensor.

1.4.3 Geochronology

To establish a chronostratigraphy numerical dating methods are indispensable. Therefore, organic material was extracted for radiocarbon dating. The samples were dated at the ^{14}CHRONO Centre, Queens University Belfast, Northern Ireland, UK and the Centre for Accelerator Mass Spectrometry of the University of Cologne (CologneAMS). All ages were calibrated using Calib 7.1 (calibration data set: intcal13.14c; STUIVER & REIMER 1993, REIMER et al. 2013). An age-depth model was calculated for the sediment core SUP 4 with the R-based package Bacon 2.2 (BLAAUW & CHRISTEN 2011).

To understand the chronology of the beach ridges north of the Rioni delta, samples were dated using luminescence dating techniques. Though quartz is commonly used to date Holocene deposits due to its stable signal with optically stimulated luminescence (OSL), infrared stimulated luminescence (IRSL) on potassium-feldspars were preferred here because of the inappropriately low signal intensities of the quartz. The measurements were carried out using the single aliquot regenerative dose protocol (SAR) after Murray and Wintle (2000, 2003) and Wallinga et al. (2000) and the annual dose rate was determined by laboratory high-resolution γ-spectrometry. The software DRAC v 1.1 by Durcan et al. (2015) was used to calculate final burial ages of the littoral samples.

1.4.4 Outline of the study

After a presentation of the project, the research aims, methodology and study area in this introductive Chapter 1, the single aspects of this research shall be presented.

Chapter 2 presents the palaeoenvironmental reconstruction of landscape changes that took place in the Mid- to Late Holocene in the surroundings of the Rioni delta. It focuses on the interplay between the spit system at the shoreline and the delta evolution of the Rioni in the context of the Holocene sea-level rise. During this study, different environments were classified to determine the landscape changes, in particular the silting of vast lagoons in the hinterland. To integrate these processes into a broader a chronostratigraphy, samples were

^{14}C dated; IRSL dating provided a chronological framework for aeolian landforms and processes. These results have been published in *Quaternary International* (Laermanns et al. 2017a).

Chapter 3 focuses on the geoarchaeology of the human occupation of the Colchian plain, in particular the settlement mounds (locally named *Dikhagudzuba*) which occur especially in the northern part of the study area and have not been studied from this perspective so far. Compared with other anthropogenic dwelling forms they are notable due to their rather small size and grouped occurrence. The study (to be published in *Geoarchaeology*, Laermanns et al. 2017b) provides new data on their chronostratigraphy, information on their time of foundation and occupation as well as palaeoenvironmental data.

Chapter 4 deals with the southernmost part of the Colchian plain where the morphology of the Supsa delta fan varies from the other river mouths further north. By means of geochemical and sedimentological parameters different source areas and depositional facies could be determined. Sporadic evidence for human settlement were also discovered and fit into known settlement patterns from adjacent regions (e.g., de Klerk et al. 2009). The results of these investigations were submitted to *Eiszeitalter & Gegenwart - Quaternary Science Journal*.

Chapter 5 discusses the diverse results with respect to the working hypotheses listed. Finally, Chapter 6 provides a conclusion and cumulative outlook on the results of this PhD thesis.

1.5 The study area

1.5.1 Physical setting

The research area is situated in the Colchian plain, a triangular shaped coastal plain in the west of Georgia that is located between the slopes of the Greater Caucasus in the northeast and the Lesser Caucasus in the south. While the Black Sea forms its western limit, the Likhi range that connects both the Caucasus ranges forms the easternmost border of the plain and delineates the watershed between the Rioni catchment and the Kura catchment which discharges into the Caspian Sea (Eppelbaum & Keshin 2012).

The Colchian plain is, like the whole of Georgia, located in the active convergence zone between the Arabian and Eurasian plate that is triggered by the northward drift of the former one (Dhont & Chorowicz 2006). Though the convergence on the Colchian plain is, in contrast to the eastern parts, rather small, it still persists along the Adjara-Trialeti Thrust Belt

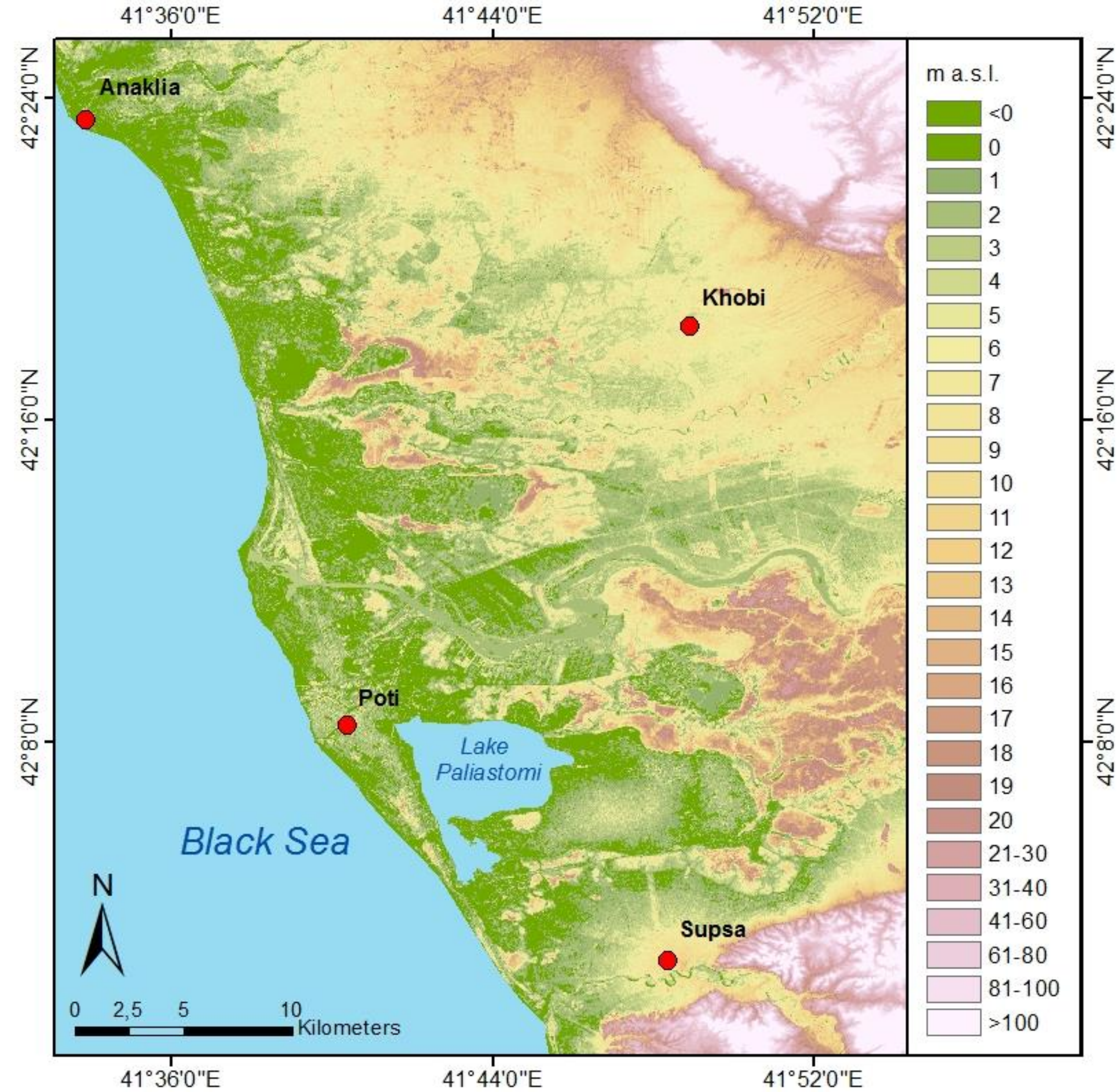

Fig. 1.4: Digital Elevation Model (DEM) of the research area (based on ALOS World 3D with 30 m resolution [AW3D30]). Large parts of the plain are situated only on low height above the sea level. The elevations standing out in red colour east of Lake Paliastomi are caused by the woodland since this DEM doesn't exclude the region's vegetation (design: Laermanns & Verheul 2017).

(ATTB) in the south and the Chaladidi-Tsaishi Thrust (CTT) in the north (Adamia et al. 2008, 2011, Forte et al. 2014) with ca. 2 mm per year (Avdeev & Niemi 2011, Yılmaz et al. 2013). Though it is a collision zone, the Colchian plain is influenced by tectonic subsidence. However, subsidence rates of 2-4 mm/a for the central Colchian plain and 5-6 mm/a for the area around Poti, near the outlet of the Rioni, as proposed by Gamkrelidze (1998) appear to be overestimated (Chapter 2).

The geology of the Colchian plain differs from the Caucasus mountains. While the Greater Caucasus is a polycyclic, folded-nappe formation (Okrostsvaridze et al. 2016) and consists of a Pre-Alpine crystalline basement complex and a younger cover of Mesozoic to Neogene ophiolithes, (marine) sedimentary and volcanic rocks, the Lesser Caucasus inherits additional andesitic pyroclastica and effusiva (Mitchell & Westaway 1999) and granites and gneiss intrusions (Yılmaz et al. 2013). In contrast, the Colchian plain is primarily covered by Cretaceous and Palaeogene sediments and volcanoclastics (Bazhenov & Burtman 2002). On top, Quaternary molasses and river terraces of eroded material from the surrounding mountains and their foothills have been deposited (Adamia et al. 2011).

The topography of the Colchian plain is dominated by these fluvial deposits that formed flat areas full of vast swamps, peat bogs, shallow lakes, open reed areas and forests. The soils evolved on the alluvial substrate are mainly semi-terrestrial soils, e.g. gleys while on the foothills fertile krasnozems and leached podzols are found (Connor et al. 2007).

Today, four major rivers, the Enguri, Khobistsqali, Rioni and Supsa (North to South), contribute most of the water and sediment supply to this system. While the former three draw their source in the Greater Caucasus, the latter originates from the Lesser Caucasus. Of all the Georgian rivers that discharge into the Black Sea (total discharge: 45.7 km^3/a), the Rioni represents the largest catchment, draining an area of around 13400 km^2 with a water discharge of 13.38 km^3/a (Berkun et al. 2015). Even though the suspended sediment load has been impeded by the construction of hydroelectric power stations and reservoirs since 1933, the Rioni still transports 6.02 x 10^6 t/a to the Black Sea, providing 8 % of its total sediment input (Berkun et al. 2015). In contrast, the far smaller second biggest Supsa River covers a catchment area of ca. 1100 km^2 and discharges a sediment load of 0.246 x 10^6 t/a into the Black Sea (Berkun et al. 2015).

In combination with high annual precipitation (>2000 mm/a in the south and 1500 mm/a in the north) and average annual temperatures of 14°C without regular winter frosts (Box et al. 2000, Denk et al. 2000, de Klerk et al. 2009) extensive wetlands formed on the Colchian plain. The vegetation is characterized by a great diversity, including over 50 arboreal species and more than 450 endemics, i.e. several Tertiary-relict plants and endemic peat evolution (Denk et al. 2001, Connor et al. 2007). The percolation peat bogs that occur east of Lake Paliastomi are mainly formed of *Sphagnum imbricatum, S. papillosum, S. palustre, S. rubellum* and moor-grass. They rise slightly above their surroundings and are of even surface indicating the absence of surficial lateral water flow (Joosten et al. 2003, Couwenberg & Joosten 2005). The mixed forests are characterized by evergreen understoreys, i.a. *Buxus colchica, Laurocerasus officinalis, Ruscus aculeatus, R. hypophyllum, Ilex colchica,* etc. (Nakhutsrishvili 1999, Denk et al. 2001, Connor et al. 2007) and dominate the neighbouring foothills as well (Box et al. 2008).

The anthropogenic impact on the region's topography and ecology is clearly visible. In particular, the course of the Rioni has been artificially reshaped since the beginning of the 20th century. The river mouth has shifted away from Poti to the north where it has built the recent delta (Figs. 1.4, 1.7 & 2.1B). Due to the increasing silting of the city's harbour, an additional smaller river branch was relocated to the south to maintain the harbour's function. While several tributaries of the Rioni still run in braided beds (e.g., Tekhuri River) the main course

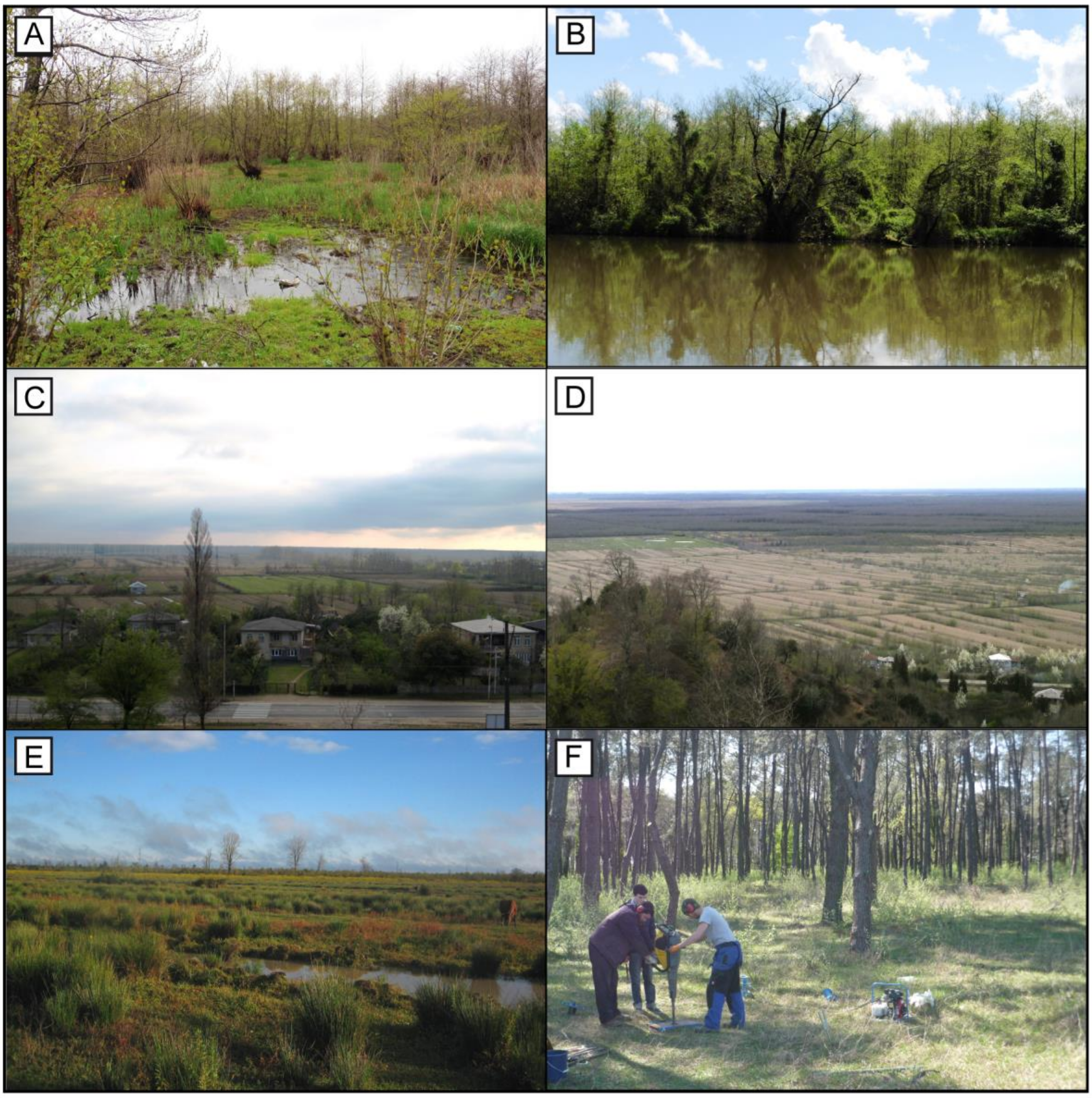

Fig. 1.5: Photos of the research area: The original landscape is characterized by open forests and swamp forests, e.g., in Area 2 at the site of sediment core KUL 12 (A) that forms in some parts like the Pichora River in Area 3, an impenetrable brush (B). Nowadays horticulture and agriculture cover the region to a great extent as seen from the foothills close to the town of Khobi in area 1 (C) and the town of Supsa in area 3 (D). Especially there, on the Supsa fan the extensive ridge-and-furrow drainage system dominates the landscape (D & E). In contrast, large parts of the beach ridge on the coastline are covered by planted pine forests (F). (Photos: Laermanns & Kelterbaum, 2013-2015).

is dyked or a parallel navigation channel has been constructed. Furthermore, great tracts of the plain have been drained and cultivated. Particularly along the rivers, and in front of the southern foothills, natural swamp areas with reed or open forests were replaced by farmland and horticulture (Connor et al. 2007, de Klerk et al. 2009) characterized by drainage ditches and ridge-and-furrow fields (Nikolaishvili et al. 2015). Still, there are great parts, in particular east of Lake Paliastomi and between the Rioni and Khobistskali Rivers that have remained almost untouched. In large parts, these areas are protected because they fall within the Kolkheti National Park (Nikolaishvili et al. 2015).

However, an increasing problem is the environmental pollution of the rivers and the adjacent areas. Both, the Rioni and Supsa delta regions are the most polluted areas of the Georgian Black Sea coast (Soligo & Myers Jaffe 2002, Janelidze & Tatashidze 2010). Regarding the Rioni, this is caused by the important harbour of Poti (recently a free trade zone under construction) and by industry and household wastes within the Rioni catchment, particularly the city of Poti. Furthermore, agriculture and mining in the hinterland of both rivers has caused severe pollution and, finally, the oil terminal of the Baku-Supsa pipeline close to the Supsa River mouth is one of the main sources of this pollution (Soligo & Myers Jaffe 2002, Kvinikadze et al. 2014).

1.5.2 Archaeological background

Due to its protected location between the Caucasus ridges and the resulting mild climate conditions, western Georgia has witnessed a very long and continuous occupation. These favourable circumstances were conducive to an early transition from a society based on hunting and gathering to farming and animal husbandry taking place from early Neolithization between 10000 and 9000 BC until the Chalcolithic (Lordkipanidze 1991, Arslanov et al. 2007, Fähnrich 2010). While in eastern Georgia, the oldest settlement date at least to the 6th millennium BC (Hansen et al. 2007), the oldest known sites in the Kolkheti lowlands are slightly younger resulting from the continuing sea-level rise and the limitation of habitable areas. Some early occupation sites might also be buried under the alluvions, which is frequently the case in deltaic systems e.g., studied in the Nile delta (Hassan 1986, 2010), Greece (Soter & Katsonopoulou 2011) or the Danube delta (Carozza et al. 2011). The two oldest known settlements, Ispani, close to the town of Kobuleti (Connor et al. 2007, de Klerk et al. 2009, Papuashvili & Papuashvili 2014), and Ontskoshia, close to Anaklia (Janelidze & Tatashidze 2010) date back to the transition between the Chalcolithic and the Early Bronze Age in the mid-3rd millennium BC (Lordkipanidze 1991) and are located 1-2 km from the present shoreline.

During the Early Bronze Age, the area witnessed a cultural diversification. Meanwhile in eastern Georgia, several cultures superseded each other, e.g., Mtkwari-Araxes or Kura-Araxes culture, Trialeti culture and in the Iron Age the Iberian culture (Greppin 1991, Kohl 2001), the Chalcolithic culture of western Georgia persisted and evolved into the Colchian culture without any sudden changes. Its territory covered the Kolkheti lowlands and the adjacent foothills. There, villages occurred along the coast and rivers as well as grouped settlement mounds with wooden housings in swampy areas in between (Lordkipanidze 1991, Tsetskhladze 1997, Sens 2009, Fähnrich 2010).

The Colchian culture formed a stable state at least since the 8th century BC and enjoyed its acme between the 6th-4th century BC (Fig. 1.6). According to Xenophon (*Anabasis*, V, VI, 37) it was ruled by the Aeëtides' dynasty, that referred themselves to the mythological king Aeëtes (Braund 1994). Though the region had been known since Mycenaean Greeks' sporadic explorations in the late 2nd to early 1st millennium BC, intensive trade contact with the ancient Greek world did not evolve until Milesian Greeks founded several colonies from the 8th century BC onwards along the Colchian coast. The most famous of these are Dioscurias

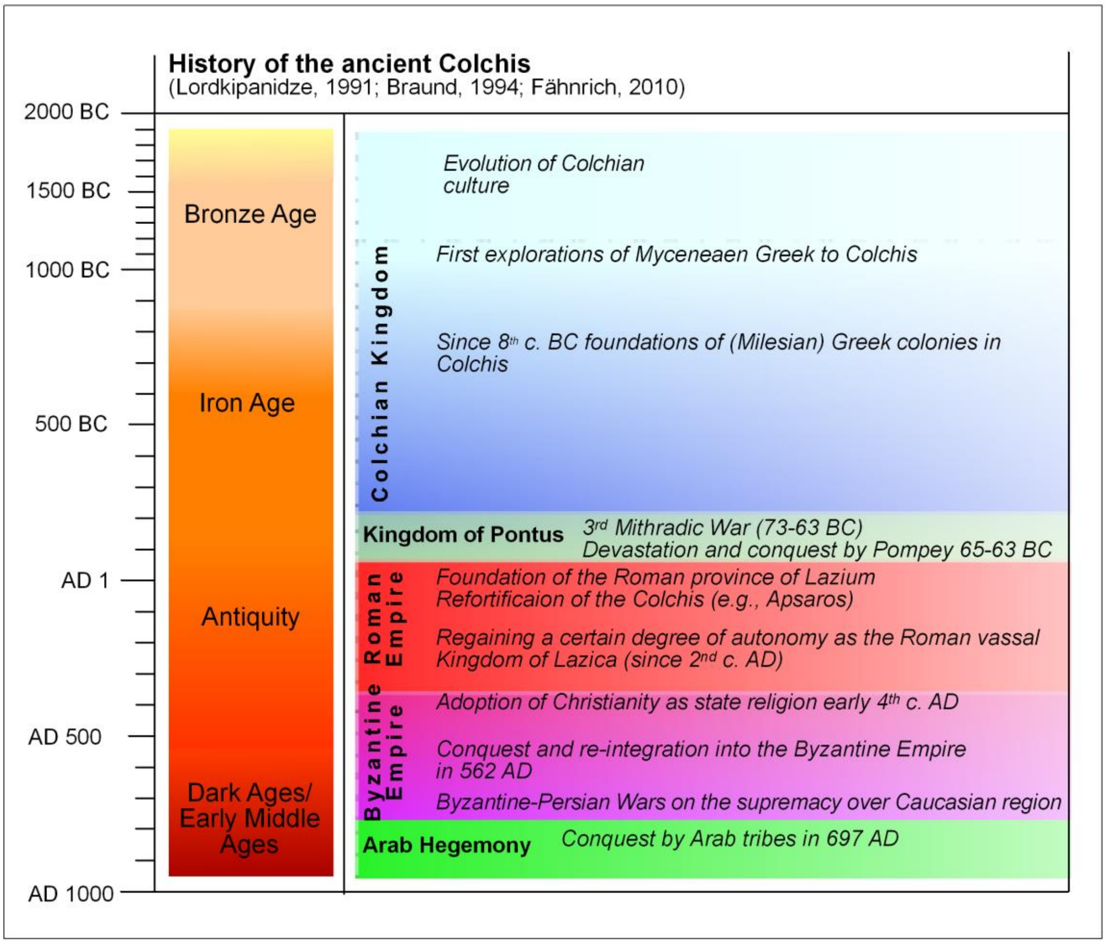

Fig. 1.6: Overview of the history of ancient Colchis (own design 2017).

(referred to the recent Sukhumi in the separatist Republic of Abkhazia) and Phasis (referred to the Rioni delta region and the city of Poti; Lordkipanidze 1991, Sens 2009).

The first contacts of Mycenaean Greeks are reflected in the myth of the Argonauts. On this mythical and adventurous journey of the Greek hero Jason and his companions, the Argonauts, named after their ship *Argo,* embark for the Kingdom of Colchis on their quest to find the "Golden Fleece". Though the oldest sources of this extremely popular and famous literary subject is Homer's "*Odyssey*" (XII, 70; 8th-7th century BC) the epic poem "*Argonautica*" (Greek: Ἀργοναυτικά) by Apollonius Rhodius in the 3rd century BC is seen as the most important version of this myth (Okrostsvaridze et al. 2016). Furthermore, the saga was re-told by Gaius Valerius Flaccus in the 1st century AD and its continuation focussing on Jason and his Colchian bride Medea is the subject of Euripides' 5th century BC tragedy "*Medea*" (Okrostsvaridze et al. 2016). The interpretation of the Golden Fleece, the central subject of the Argonauts' desire remains disputed. While some link it to sheep skins which were used for the extraction of gold, as described by Strabo, book XIII, Pliny the Elder and Appian of Alexandria, praising the gold and silver richness of the Colchian rivers (Okrostsvaridze et al. 2016), others see it rather as a symbol for the wealth of the Colchis in general (Braund 1994).

From this era of Colchian Kingdom manifold archaeological evidence document the development of its culture and the intensive trade contact with the Greek world. Though there are more than 30 settlement mounds known in Colchis, the number of bigger discovered settlement remains is rather small. Instead, many fine metal works contesting the great Colchian artistry were preserved in graves (for the research area e.g., in Ergeta [Area A] and Ureki [Area C]; Miron & Orthmann 1995). Within the research area, several archaeological sites are known as well. Whole 4th to 3rd century BC amphorae and fragments from Heraclea Pontica and Sinope were found between the village Maltakva and the Supsa River mouth as well as slightly younger Colchian amphorae (2nd to 1st century BC) (Sadzradze 1999). A huge variety of fine Bronze works from axes to horse figures were found in Ergeta (Area A) and Ureki (Area C) (Miron & Orthmann 1995, Gamkrelidze 2012). On the northern edge, the early Bronze age settlement of Ontskoshia is known through excavation (Janelidze & Tatashidze 2010). However, the location of the most celebrated site, that of Phasis, remains unknown despite numerous theories and surveys (e.g., Lordkipanidze 2000, Gamkrelidze 2012, Licheli 2016). A Roman fort (smaller but probably comparable to the well preserved fort of Apsaros in Gonio, close to the Turkish border; cf. Plontke-Lüning 2007, Mamumladze et al. 2014) is still often discussed as a possible location for ancient Phasis. The ruins were located between the Rioni and Lake Paliastomi (Area B) fulfilling the location description of various authors such as Pliny the Elder etc. (Dubois de Montpéreux 1842, Lordkipanidze

2000, Licheli 2016) that existed until the 1960s. It was stripped down in course of the construction of the airport that closed down in the 1990s and today there is no evidence of any construction.

During the late 2nd to early 1st century BC the Kingdom of Colchis came under the increasing influence of the Kingdom of Pontus. In 65 BC, Colchis was devastated by Pompey in the course of his Georgian campaign during the 3rd Mithridatic War. After the defeat of the Pontic king Mithridates VI Eupator in 63 BC it was integrated into the Roman Empire, at first as a client state and later turned into the province *Lazica* (Lordkipanidze 1991, Rayfield 2013). It remained under Roman/ Byzantine rule despite several Persian invasions until the conquest by Arab tribes in the 7th century AD (Braund 1994, Fig. 1.6) and was (perambulated and) described by several Greek and Roman authors such as Herodot and Hippocrates (both 5th century BC), Pseudo-Scylax (4th century BC), Pseudo-Scymnos (probably 2nd/1st century BC), Strabo (1st century BC/AD), Arrian and Pliny the Elder (both 1st century AD) etc. (Gamkrelidze 1992, 2012, Jouanna 1996, Lordkipanidze 2000, Korenjak 2003, Dan 2014, 2016).

1.5.3 Geography of the study area: research sites and situation

The study area comprises three subunits in the central part of the Colchian plain. They string along the Black Sea coast from the Enguri River in the north, that builds the demarcation line to the separatist Republic of Abkhazia, to the point where foothills of the Lesser Caucasus reach close to the shore in the south (Fig. 1.7).

The northernmost Area A southeast of the town Anaklia covers mostly agri- and horticultural areas in the surroundings of the two villages Ergeta and Orulu, where several settlement mounds were localized (Chapter 3, Fig. 3.1). The area is characterized by small-scaled (provide some spatial dimensions in metres) fields and gardens that are subdivided by a close-meshed drainage system. Furthermore, it is comparably densely settled and the villages consist of scattered farms, so it is not easy to delimit them.

Area B is limited to the north and to south by the two rivers Khobistskali and Rioni (with one exception being the sediment core SHAV 2, close to the village of Shavreli on the southern bank of the Rioni). The western limitation forms the Black Sea shore while the easternmost point is marked by the sediment core KUL 11, close to the road that leads from Tchaladidi north to Kulevi and Khobi (Chapter 2, Fig. 2.1B). Within Area B there are only few settlements around Tchaladidi and on the southern bank of the Rioni. Apart from the areas close to the main roads and rivers there are hardly any drainage constructions except for the visible larger channels dug through the swamp. In large parts, it consists of natural swamp areas dominated by reed and scattered forests. The coastal strip is formed by a sequence of beach ridges that rise some meters above the flat swamp of the hinterland. It is overgrown with (planted) pine trees and scrubs turning into scattered marram grass towards the beach.

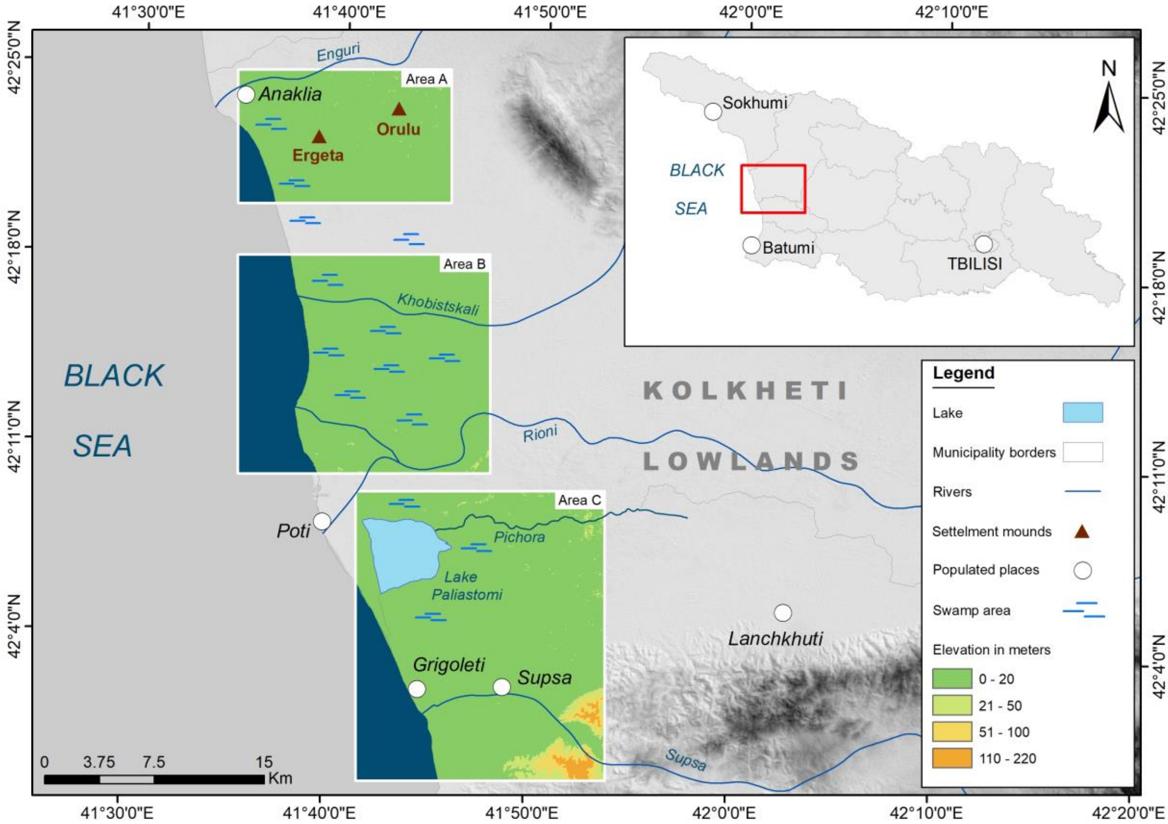

Fig. 1.7: Study area. Three areas can be subdivided. Area A contains about two dozens of settlements mounds where of three were investigated (Chapter 3). Area B covers the swamp lands between the Khobistskali and Rioni Rivers (Chapter 2). Area C is located south of Lake Paliastomi (Chapter 4). Figure based on: ASTER Digital Elevation Model, Shaded Model, design: Laermanns & Krikitadze 2017.

The third area (Area C) is located at the southern edge of the research area from the sea shore around the Supsa River mouth in the west to the eastern edges of the Supsa fan (Chapter 4). With the foothills of the Lesser Caucasus as the southern limitation, the elevated Supsa fan with its drained farmland and the Pichora River as the northern outlier it contains the most diverse topography and vegetation of all the research areas (Fig. 4.1). The banks of the Pichora, that discharges into Lake Paliastomi, are almost untouched and overgrown by dense evergreen subtropical forest. In contrast, the small town of Supsa is more densely arranged than the other settlements further north and the surrounding fields and meadows are used more intensely.

Chapter 2

2 Mid- to Late Holocene landscape changes in the Rioni delta area (Kolkheti lowlands, W Georgia)

Hannes Laermanns[1], Daniel Kelterbaum[1], Simon Matthias May[1], Mikheil Elashvili[2], Stephan Opitz[1], Daniela Hülle[3], Julian Rölkens[1], Jan Verheul[1], Svenja Riedesel[1], Helmut Brückner[1]

[1] Institute of Geography, University of Cologne, Germany

[2] School of Natural Sciences and Engineering, Ilia State University, Georgia

[3] Institute of Geology and Mineralogy, University of Cologne, Germany

Abstract

The Kolkheti lowlands (Colchis, Colchian plain) form the central part of the extensive coastal lowlands along the Black Sea coast of Georgia. Situated between the Greater and the Lesser Caucasus, favourable climatic conditions resulted in a constant human occupation of the region during the Holocene. However, due to continued deltaic sedimentation and alluviation of the river Rioni, the configuration and the environmental conditions of the coast and its hinterland have changed considerably; this was related to sea-level fluctuations of the Black Sea and variation of the sediment supply. This study presents new data on the Holocene coastal evolution of Western Georgia. Based on the geochemical and sedimentological analysis of sediment cores and trenches from the northern part of the Kolkheti lowlands, between the Black Sea and the rivers Rioni and Khobistsqali, and a robust chronology (^{14}C and IRSL dating), our goals are (i) to document the chronostratigraphy along two coring transects; (ii) to decipher geographical and environmental changes along Georgia's Black Sea coast; and (iii) to trace the sea-level evolution of the study area. Based on the succession of eight facies, representing different depositional environments, our results suggest that significant environmental changes took place throughout the last eight millennia. At least since 5000 cal BC, the sedimentary record indicates the widespread existence of shallow lagoons. Floodplain-related fine-grained alluvium accumulated on top of the lagoonal stratum. The progradation of the delta plain between 3500 and 1500 cal BC was accompanied by the evolution of extensive swamps with peat formation. The data indicate a gradual and moderate sea-level rise since ~6000 BC. Ultimately, this and follow-up studies may provide a valuable background for the understanding of the palaeogeographical context of ancient settlements in the area.

Keywords

Rioni, Black Sea, sea-level rise, Colchis, IRSL, beach ridges

Published 2018 in *Quaternary International* 465, 85-98.

DOI:10.1016/j.quaint.2016.12.037

2.1 Introduction

With an area of ca. 412,000 km^2 and a maximum depth of 2212 m the Black Sea is the largest anoxic water basin in the world (Degens and Ross, 1972). It is connected to the Mediterranean via narrow and shallow straits (Bosporus, Dardanelles). Over the last millennia, the Black Sea has been subject to substantial environmental changes. In effect, from a giant freshwater lake during the Last Glacial Maximum (Panin and Popescu, 2007) it evolved to its present state of salinity and sea level. While some authors have evoked for remarkable oscillations of the postglacial sea-level rise (e.g. Ryan et al., 1997, 2003; Chepalyga, 2007; Yanko-Hombach et al., 2007; Balabanov, 2007), a number of follow-up studies reasonably challenged this interpretation by presenting new data on the Holocene sea-level evolution (cf. Brückner et al., 2010; Fouache et al., 2012; Kelterbaum et al., 2012). Recent studies have particularly focused on the northern and western parts of the Pontic region (e.g. Panin and Popescu, 2007; Carozza et al., 2012; Cordova et al., 2011). In contrast, the eastern Pontic region has been neglected so far, although extensive lowlands exist, for instance along the Black Sea coast of Georgia. Here, protected between the Greater and the Lesser Caucasus, human occupation is evidenced in the so-called Colchian plain (Colchis) at least since the Late Chalcolithic and Early Bronze Age (Lordkipanidze, 1991; Papuashvili, 2002). In addition, as part of ancient Colchis, the famous Greek colony of Phasis is assumed to be located in the area of the present Rioni delta (Gamkrelidze, 1992, 2012; Lordkipanidze, 2000; Korenjak, 2003), although remnants of the city have hitherto not been discovered, and its exact position is unknown (Lordkipanidze, 1991; Gamkrelidze, 2012). The lack of studies focusing on coastal evolution, sea-level and environmental changes, particularly against the background of the continuous occupational history in Western Georgia (Gamkrelidze, 2012), demands an intensification of research activities in this area.

This paper contributes to fill knowledge gaps by adding new information on Holocene environmental changes in the Kolkheti lowlands, which constitute the central part of the Colchian plain. Based on eleven sediment cores, two sediment trenches, detailed sedimentological and geochemical analyses, as well as radiocarbon and infrared stimulated luminescence (IRSL) dating, our study presents the first systematic geoscientific investigation of the said coastal lowlands. More specifically, we aim at (i) documenting the chronostratigraphy between the Rioni and Khobistsqali rivers along two coring transects; (ii) deciphering palaeogeographical and palaeoenvironmental changes along the Georgian Black Sea coast and its hinterland; and (iii) reconstructing the sea-level evolution for the study area, and comparing it to other regional studies. Finally, this study represents a valuable background for the interpretation of (future) local to regional archaeological studies, e.g. on the identification of appropriate locations for the 'lost city' of Phasis.

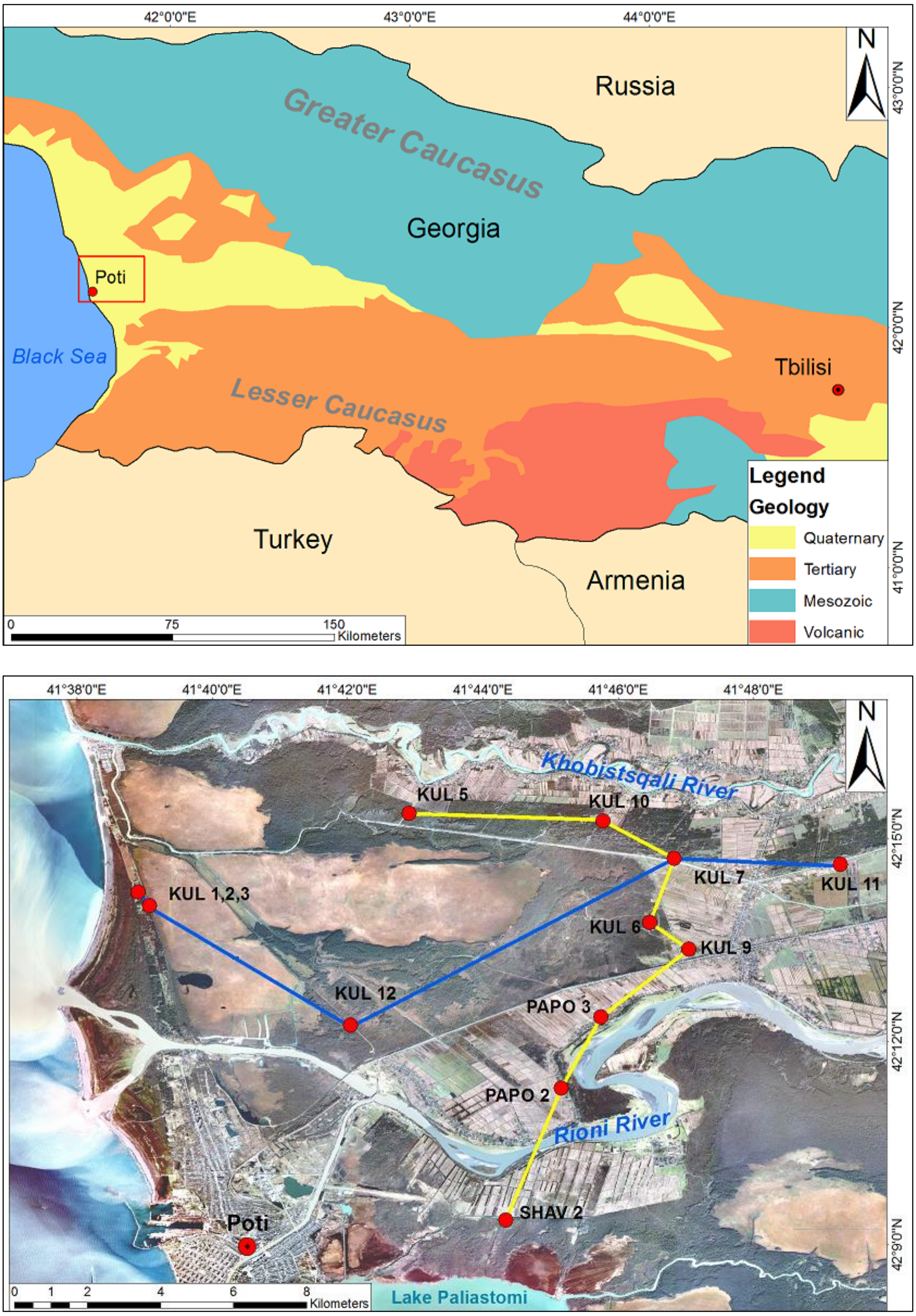

Fig. 2.1: Overview of the research area with location of coring sites and trenches. They are arranged in transects A (blue line) and B (yellow line). Prominent features are the areas of agricultural use on the levees of the rivers Rioni and Khobistsqali. They are in great contrast to the open grasslands, peat bogs and swamp forests. Figure based on Esri basemap and www.naturalearthdata.com.

2.2 Regional setting

2.2.1 Geological and geomorphological framework

The triangle-shaped Colchian plain (Fig. 2.1) is framed by the Black Sea in the west, the Greater Caucasus in the north and the Lesser Caucasus in the south. Both mountain ranges formed during the Alpine orogeny as a consequence of continent-continent-collision starting in the middle Pliocene (e.g. Adamia et al., 2011). They consist of Mesozoic to Neogene igneous and sedimentary rocks and, especially in the Lesser Caucasus, of Miocene to Quaternary volcanic rocks. In the east, where both mountain ranges meet, the Surami range (or Likhi range) separates the Colchian plain from the Kura basin, which drains into the Caspian Sea. The geologic basement of the Colchian plain mainly consists of Cretaceous and Palaeogene sediments and volcanoclastics (Bazhenov and Burtman, 2002). These strata are overlain by Quaternary strata, which were deposited by fluvial and marine processes (Adamia et al., 2011). The Colchian plain is influenced by tectonic subsidence. Gamkrelidze (1998) estimates subsidence rates of 2-4 mm/a for the central Colchian plain and 5-6 mm/a for the area around Poti near the outlet of the Rioni.

While foothills of both mountain ranges reach the Black Sea coast south of Kobuleti and north of Ochamchire, respectively, the floodplain of the Rioni dominates the Kolkheti lowlands. With a catchment area of 13,400 km^2 it is the largest river of Western Georgia. Most of its tributaries originate in the Greater Caucasus and dissect extensive foothills before entering the coastal lowlands. Here, expanded wetlands with peat bogs, ponds, open reed areas and low forests dominate; agricultural activities are impeded by the high water-table position. However, drainage measures and ridge and furrow-systems enable agriculture between and along the two rivers (Nikolaishvili et al., 2015).

At the coast, the Rioni has formed a wave-dominated delta (Fig. 2.1), where longshore drift rapidly redistributes the mostly sandy sediments along the graded shoreline. The flat and wide beaches are backed by beach-foredune ridges, which are occasionally covered by pine forests. The main estuary of the Rioni, formerly debouching into the sea directly in Poti, was relocated to its present position during the Soviet era.

2.2.2 Palaeoenvironmental changes and sea-level fluctuations

Even though a number of studies on the Holocene landscape evolution exist from the second half of the 20th century (e.g. Janelidze, 1980), most data from the Soviet era is difficult to access. During the last 25 years only a few publications provide valuable information on

Holocene environmental development, with main focus on the vegetation history of Georgia's Black Sea coast since the mid-Holocene (e.g. Connor et al., 2007; de Klerk et al., 2009; Shatilova et al., 2010). Palynological records document a coastal plain vegetation and generally outline warm and humid conditions; however, while Connor et al. (2007) describe a gradual evolution from chestnut-dominated open woods in the mid-Holocene followed by shrubby marshy landscapes and, caused by groundwater fluctuations due to coastal subsidence and sea-level changes, recent beach-hornbeam conditions, de Klerk et al. (2009) highlight a relatively constant vegetation history with only minor effects of anthropogenic land use change. Other studies investigated the degree of anthropogenic landscape changes, e.g. deforestation (Nikolaishvili et al., 2011), human-induced landslides (Nikolaeva et al., 2014; Vezolli et al., 2014), and soil contamination (Narimanidze and Brückner, 1999; Svanidze et al., 2008). Several geoarchaeological projects have been carried out concerning the environs of archaeological sites – e.g. the anthropologically famous Dmanisi (Messager et al., 2009, 2011); Bronze age settlements on the Bedeni Plateau (Kvavadze et al., 2015) – as well as the analysis of fluvial archives (von Suchodoletz et al., 2015).

The Holocene reconnection of the Black Sea with the Mediterranean Sea occurred around ~7400-6400 cal BC (Ryan, 2007; Giosan et al., 2009; Lericolais et al., 2009; in a previous publication a date of ~5500 cal BC had been suggested by Ryan et al., 1997). Several studies were dedicated to the subsequent sea-level rise, for which both a steadily rising (Hiscott et al., 2002; Giosan et al., 2009) and an oscillating (Balabanov, 2007; Chepalyga, 2007; Yanko-Hombach et al., 2007) curve were proposed. Based on his evaluation of ~400 radiocarbon ages from Black Sea coasts, Balabanov (2007) suggested several major regression-transgression cycles for the Holocene period. This interpretation was strongly opposed. Brückner et al. (2010) presented evidence for a gradual sea-level rise; they attributed the assumed regression-transgression wiggles of the Balabanov curve to local neotectonics and a misinterpretation of the data set (see also Kelterbaum et al., 2012). Especially the concept of the so-called Phanagorian Regression, which was postulated for the time span ~800 BC to ~500 BC, i.e. for the time when the Greek settlers had founded many coastal colonies in the Black Sea region, was rejected (Fouache et al., 2012).

For the Kuban delta plain (Taman Peninsula, Russia), Brückner et al. (2010) proposed a gradual sea-level rise from 7 to 6 m below present sea level at 5000 BC to ~2 m below sea level at 2000 BC, and a subsequent decelerated rise until today. For the Danube delta region, Giosan et al. (2006) assume a stable (±1.5 m) sea level over the last 5000 years, based on morphodynamic and palaeogeographic data. As in other study areas, the local sea-level evolution is assumed to have influenced both sedimentation patterns and settling activities in Western Georgia as well.

2.2.3 Human occupation and archaeological background

In the Colchian plain, findings of Lower Palaeolithic (~12,000 BC) tools indicate a long occupation history of the Kolkheti lowlands (Fähnrich, 2010). Although the transition from hunter-gatherer communities to a pastoral and agricultural sedentism is supposed to have taken place in the Neolithic (8th to 5th millennium BC) only few of these sites are known to date. Increasing numbers of settlements are known from the Late Chalcolithic and Early Bronze Age, the latter beginning in the first half of the 3rd millennium BC (Lordkipanidze, 1991; Fähnrich, 2010). Henceforth, settlement mounds occur in the northern part of the Kolkheti lowlands, which represent typical dwelling places of the Bronze Age society in Western Georgia (Jibladze, 2007; Fähnrich, 2010; Gamkrelidze, 2012). In the first half of the 2nd millennium BC, the Colchian culture was formed, which was accompanied by an advance of technical innovations. It merged into the Kingdom of Colchis with a cultural heyday in the 8th century BC (Lordkipanidze, 1991). At the same time, ancient Greek merchants reached the Black Sea area and founded several colonies along the Colchian coast. Early cultural exchange (supposedly originating from Mycenaean time) is likely reflected in the saga of the Argonauts, in which the Colchis is praised for its metal (particularly gold; 'Golden Fleece') works and its prosperous society (Lordkipanidze, 1991).

The city of Phasis represents the most important ancient Greek colonial foundation in the Colchian territory. It was described by various ancient authors such as Strabo, Pliny the Elder, Pseudo-Scymnos, Pseudo-Scylax and Hippocrates. It was probably situated in the Rioni delta close to Lake Paliastomi (Fig. 2.1) (Gamkrelidze, 1992, 2012; Lordkipanidze, 2000; Korenjak, 2003). However, while the location of ancient Phasis has been related to ruins of a Roman fort (Dubois de Montpéreux, 1842) which existed until the construction of the former airport of Poti, remnants of the city hitherto have not been discovered, and its exact position remains unclear.

2.3 Methods

2.3.1 Field work

Our research is based on eleven sediment cores and two trenches, organized in two transects (transect A: general direction W – E; Figs. 2.1-2.3, 2.5; transect B: general direction N – S; Figs.2.1, 2.3, 2.4 and 2.6). Corings were done with the Cobra TT (Atlas Copco) percussion coring device. The sediment cores reached a maximum depth of 12 m below surface (b.s.), while core diameters were 6 and 5 cm, respectively. The trenches reached 2 m b.s. Field documentation included the description of sediment texture, colour, and the $CaCO_3$ test (with HCl, 10%). Samples were taken from the different sedimentary units, and at regular spacing intervals of 30-50 cm.

Three master cores which are representative of the study area were analysed in detail: Core KUL 3 (Fig. 2.2) represents the sand-dominated stratigraphy close to the recent shoreline and is situated in the direct vicinity of trench KUL 2 in the slope of the easternmost beach-foredune ridge facing the swampy hinterland. Cores KUL 7 and PAPO 2 represent the typical depositional sequence of the coastal hinterland. KUL 7 (Fig. 2.3) is situated in the eastern central part of the swamp, ca. 100 m north of the Tsiva river, an artificial drainage channel which crosses the swampy lowlands from southeast to northwest. Core PAPO 2 (Fig. 2.4) is located close to the Rioni, some 7 km south of KUL 7. From the three master cores, plant fragments and charcoal remains were taken for radiocarbon dating. The two trenches, KUL 1 and KUL 2 (Fig. 2.5), were dug on top of the most landward lying beach-foredune ridges just north of the Rioni river mouth.

The elevation of cores and trenches was measured by using a Topcon Hiper V DGPS with a spatial resolution of 2 cm. Soviet topographic maps (1:25,000 scale, approx. 1960s; 1:50,000 scale, approx. 1970s) served for supplementary information on surface changes over the last decades.

2.3.2 Geochemical and sedimentological analyses

They were conducted at the Geo-Laboratory of the Institute of Geography, University of Cologne. All samples were dried at 40 °C for 48 h, sieved to <2 mm, and gently pestled by hand for aggregate disintegration. Granulometric analyses were conducted for the fine grained fraction (<2 mm) of all samples using a Laser Diffraction Particle Size Analyzer (LS 13320 Beckmann CoulterTM). Samples were pre-treated with hydrogen peroxide (H_2O_2 15%) to remove the organic matter, and sodium pyrophosphate ($Na_4O_7P_2$, 46 g/l) was added as a dispersant to avoid coagulation. Each sample was measured three times using the optical Fraunhofer model. Grain-size parameters based on Folk and Ward (1957) were calculated using GRADISTAT software version 8 (Blott and Pye, 2001).

Loss on ignition (LOI) was determined by oven-drying of 5 g sample material at 105 °C for 12 h and ignition in a muffle furnace (Carbolite ELF) at 550 °C for 5 h. Although possible uncertainties may result from the combustion of clay minerals and/or carbonates, LOI was used for estimating organic carbon contents in the sediments (Barsch et al., 2000; Heiri et al., 2001).

Furthermore, the samples of core KUL 7 were analysed for their C/N ratio using the method described by Meyers and Teranes (2001). Total organic carbon (TOC), total carbon (TC), and nitrogen (N) were determined on duplicate powdered samples using a Vario EL Cube (Elementar Analysensysteme GmbH, Hanau, Germany). Before measurement the material was homogenized and weighed out into tin boats. In a second aliquot of each sample $CaCO_3$ was dissolved with 10% HCl, before TOC was determined.

In addition, selected samples were analysed for their mineral composition by X-ray diffraction (XRD; cores KUL 3 and 7; Fig. 2.7C) and for their element contents by X-ray fluorescence (XRF; cores PAPO 2, KUL 3 and 7). The material was homogenized using an automatic ball grinder (Retsch MM 400), pressed into 2 mm thick pellets, and measured with a portable XRF analyzer (NITON XL3t). Each sample was measured three times in mineral mode for 160 sec to cover all possible filter options with an adequate time span. In case of the elements K, Ca, Fe, Mn errors were below 1%, in case of S below 4%. For XRD analysis, the homogenized powder was placed on a PVC slide and measured in a Powder X-Ray Diffractometer (Siemens D 5000) with a fixed focal distance of 0.5 mm. All samples were measured at 5-75° 2Θ in 0.05° steps and 10 sec per degree (Cu-K-alpha radiation source, operated at 40 keV and 40 mA). The data were analysed using the DiffracPlus EVA software package (Bruker AXS, Berlin, Germany).

To distinguish the different facies two forms of visualisation were chosen. For the principal component analysis (PCA; Fig. 2.7A) the PAST software (version 3.1.1) was applied (Hammer et al., 2001). The values were standardized and standard deviation was calculated. Altogether eight components (contents of K, Ca, Fe, Mn, LOI, clay and sand, and sorting) were used. The spatial distribution bases on the principle components 1 and 2. The ternary plot (see Brumsack, 1989; Dellwig et al., 2000, Fig. 2.7B) was evaluated with the Grapher 9 software and predicates on the standardized values of mean grain size, sorting and Ca/K ratio.

Finally, six samples of core KUL 12 were analysed for their microfaunal content. Samples were sieved into fractions of >100 µm and 63-100 µm after adding sodium pyrophosphate ($Na_4O_7P_2$, 46 g/l) to avoid coagulation. Species determination was carried out under a light stereo microscope.

2.3.3 Dating techniques

Thirteen samples (plant remains and charcoal) taken from cores KUL 3, KUL 7 and PAPO 2, were radiocarbon-dated in the CologneAMS Laboratory, University of Cologne (Table

2.1). All ages were calibrated with the Calib 7.1 program (Reimer et al., 2013). The age-depth-model was calculated with the OxCal version 4.2.4 (Bronk Ramsey and Lee, 2013), restricted to the deposition models for chronological records of Bronk Ramsey (2008).

In order to gain chronological information on the generation and last activation of the beach-foredune ridges north of the Rioni river mouth, infrared stimulated luminescence (IRSL) dating was carried out on four samples from trenches KUL 1 and 2. The luminescence samples were taken by pushing steel tubes of 5 cm diameter into the cleaned vertical sections. The tubes were closed with plastic lids to avoid light contamination. For further information on sample preparation see Chapter 2.9.1 (Apendix).

2.4 Results

2.4.1 The beach-foredune ridges and the adjacent hinterland (KUL 1 – KUL 3)

KUL 1 and 2 were trenched down to a depth of ca. 2 m below surface (b.s.). They comprise of homogeneous coarse to medium sand layers, with a few roots. Only the upper ~30 cm

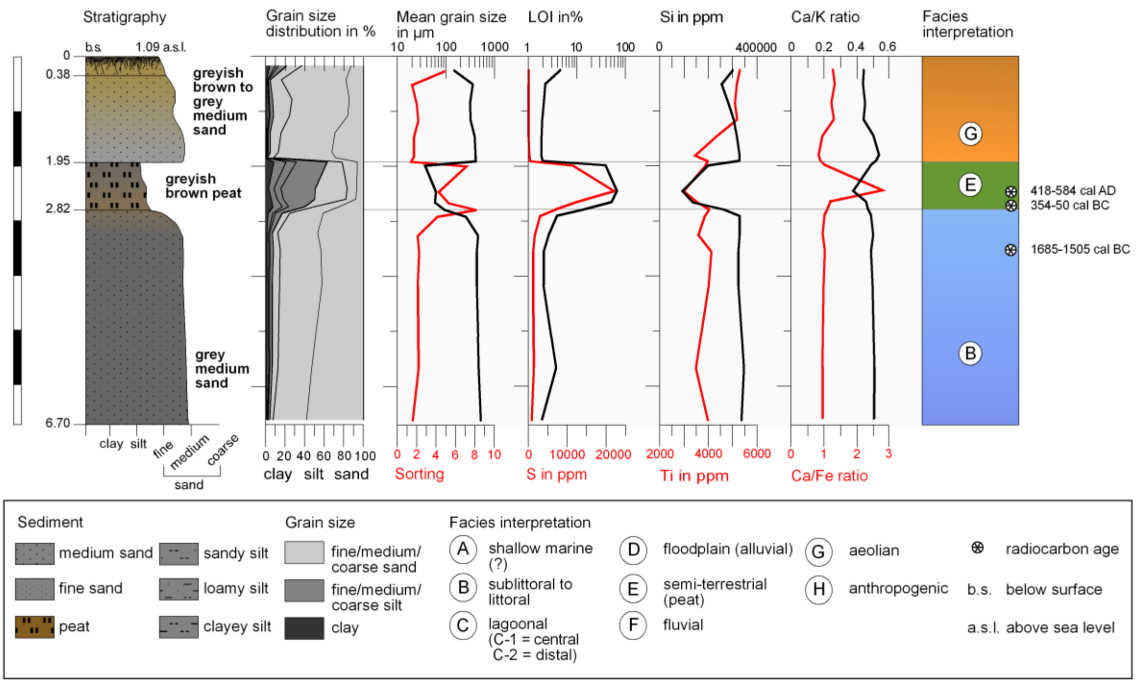

Fig. 2.2: Facies interpretation, granulometry, geochemistry and ^{14}C age estimates of the sediment core KUL 3. It represents the stratigraphy of the landward part of the coastal barrier complex, consisting of a (sub-) littoral base, semi-terrestrial back-barrier facies, and aeolian cover sands (deposits of the foredune ridges).

reveal a slightly finer grain size and an increased content of organic matter. Sediment core KUL 3 (Fig. 2.2) is composed of well-sorted medium sand (mean grain size between 522 and 455 µm) with organic matter of <4% (6.70-2.82 m b.s.) at its base. Subsequently, the overlying peat unit (2.82-1.95 m b.s.) shows grain size values of 254-237 µm and high LOI (15-67%). Above, relatively homogeneous sand occurs. The uppermost part (0.38-0m) is characterised by decreasing mean grain size and increased LOI.

2.4.2 The Kolkheti wetlands – master cores KUL 7 and PAPO 2

2.4.2.1 Sediment core KUL 7

The lowermost stratigraphical unit (12-11.68 m b.s.) is composed of grey homogeneous silt which is characterised by high Ca contents, also reflected in the Ca/Fe and Ca/Ka ratios (Fig. 2.3). The mineral composition of this layer differs from the subsequent layers; calcite was detected only in sample KUL7/44. The overlying stratum (11.68-11.55 m b.s.) consists of an intensely weathered dark-brown peat with high LOI values (up to 37%) and TOC/N ratios, and low Ca/K and Ca/Fe ratios. At 11.55 m b.s. the peat gradually changes into dark grey clayey silt (mean grain size <10 µm) with few shell fragments and elevated contents of organic matter, particularly between 11.31 and 11.28 m b.s. At 11.00 m b.s., LOI reaches a constant level below 5%, while Ca remains high and TOC/N decreases. The clayey silt dominates until 7.71 m b.s., although it is intercalated by a dark brown peat at 9.56-9.40 m b.s. (LOI up to 23%). Subsequently, the sand content increases considerably, and fine sand-dominated layers alternate with silt-dominated layers until 5.27 m b.s. While LOI and TOC/N remain relatively low, Ca/Fe and Ca/K show constantly decreasing values above 6.43 m b.s. In general, elevated Si and Ti values characterise the strata between 9.40 and 5.27 m b.s., compared to the sediments below.

Above, the sedimentary succession is characterised by two distinct peats (5.27 and 2.49 m b.s.), intercalated by a light grey silt layer (3.89-3.59 m b.s.). The peat units are indicated by increased S and TOC/N values; they are mainly composed of a clay- and silt-dominated matrix (mean grain size <9 µm) with high LOI values (10-34%) and only few macroscopic plant remains. Subsequently, the peat layer gradually changes to clayey silt which prevails until 0.45 m b.s. Above the ground water table, the sediments have a reddish brown colour, contain root fragments and show signs of redox characteristics. The uppermost layer is the plough horizon.

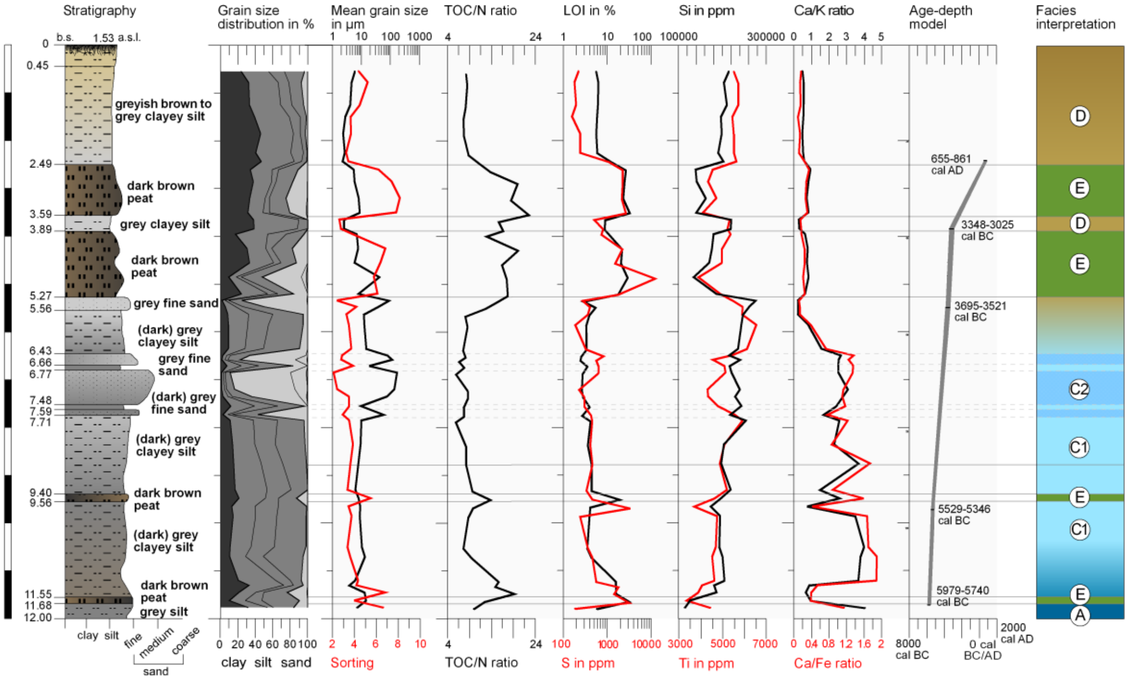

Fig. 2.3: Facies interpretation, granulometry, geochemistry and age-depth model of the sediment core KUL 7 (caption see Fig. 2.2). It represents the stratigraphy of the central coastal lowlands, and comprises the entire range of facies: possibly shallow marine deposits at the base (see discussion in chapter 2.5.1), followed by an interdigitating of lagoonal, semi-terrestrial and alluvial strata.

2.4.2.2 Sediment core PAPO 2

From 10 to 9.78 m b.s. sandy silt with low LOI occurs. It is covered by silty sand with large plant remains, high LOI, Ca/K and Ca/Fe, and low Si and Ti values (Figs. 2.1 and 2.4). Then follows a peat (LOI 41-79 %, 8.59-8.03 m b.s.) with very low Ca/K and Ca/Fe ratios. It gradually changes to grey homogeneous (8.03-~6.00 m b.s.) and laminated (~6.00-3.36 m b.s.) clayey silt, which is characterised by low LOI, but high values of Si, Ti, Ca/K and Ca/Fe. Sandy intercalations are found, e.g. between 6.39 and 6.03 m b.s. Then peat layers with macroscopic plant remains occur between 3.36 and 2.76 m b.s., and from 2.22 to 1.41 m b.s.; they are characterised by increased organic contents and reduced Ca/K and Ca/Fe ratios. The peats are separated by grey clayey silt (2.76-2.22 m b.s.). Red-brown silt with low LOI occurs in the uppermost ~1.4 m of the core.

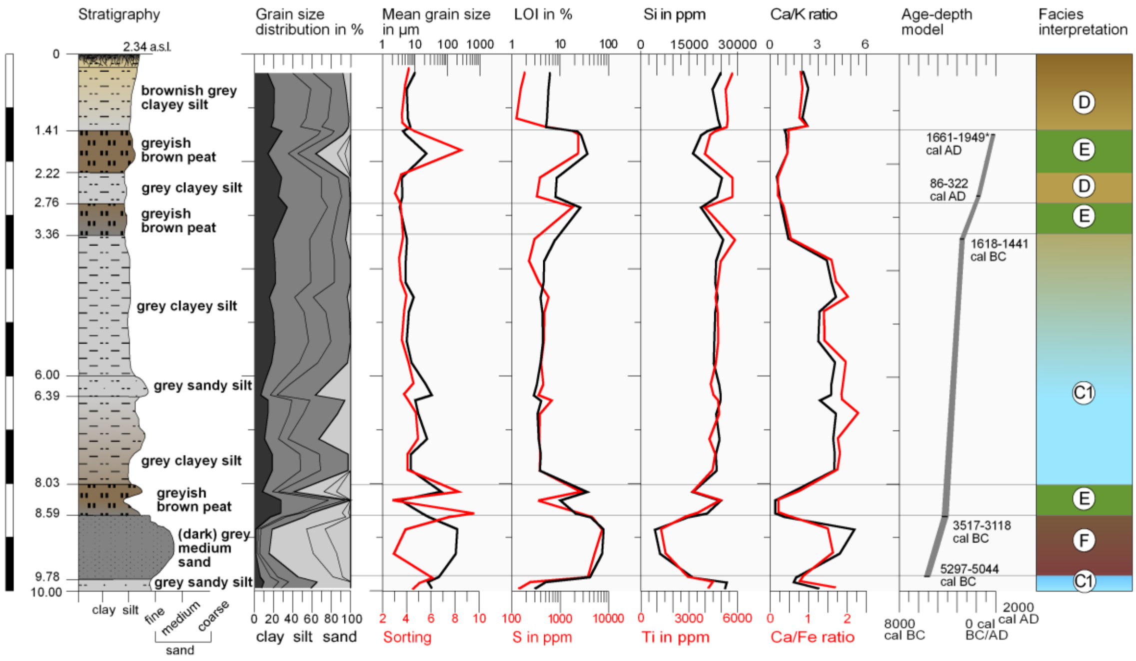

Fig. 2.4: Facies interpretation, granulometry, geochemistry and age-depth model of the sediment core PAPO 2 (caption see Fig. 2.2). The stratigraphy, which is typical for the three southernmost cores, shows river sediments covered by lagoonal deposits. According to the age-depth model, the siltation of the lagoon took place ~2000 years later than at the site of KUL 7.

2.4.3 Additional stratigraphic information along the coring transects A and B

Compared to master cores KUL 7 and PAPO 2, a number of similarities can be found in the sedimentary succession of all other cores along the two coring transects (Figs. 2.5 and 6). All cores are predominantly composed of fine-grained (silt-dominated) and often laminated sedimentary units with macroscopic plant remains. However, depending on the location of each core along the coring transects, differences exist regarding the presence of basal sand layers as well as the position of sand and peat intercalations.

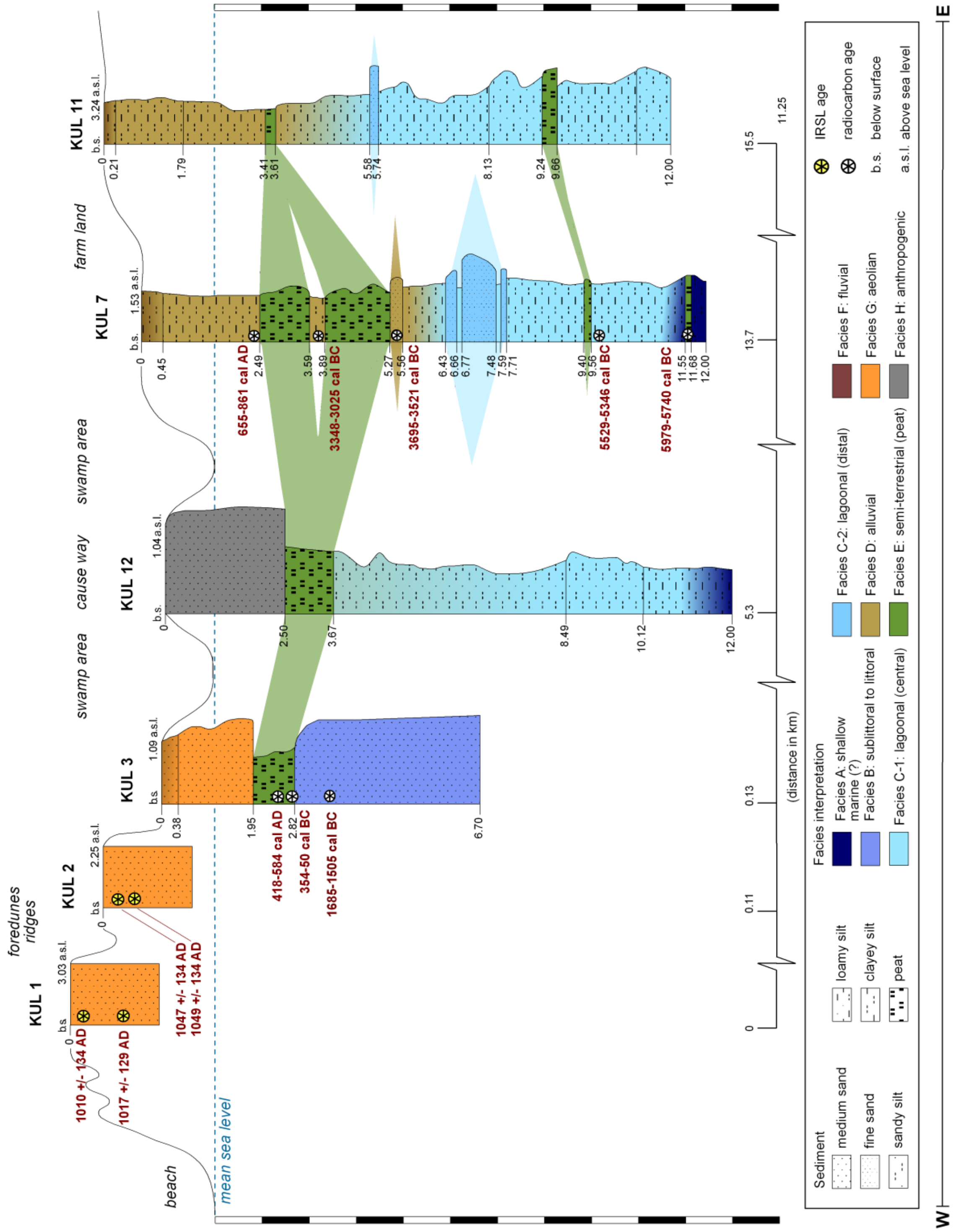

Fig. 2.5: Transect A crossing the research area from W to E (position in Fig. 2.1). While KUL 1, 2 and 3 belong to core group 1 representing the evolution of the coastal barrier complex, KUL 12 belongs to core group 3, which represents the evolution in the centre of the swamps. Cores KUL 7 and KUL 11 are part of core group 4 (see text for further explanations).

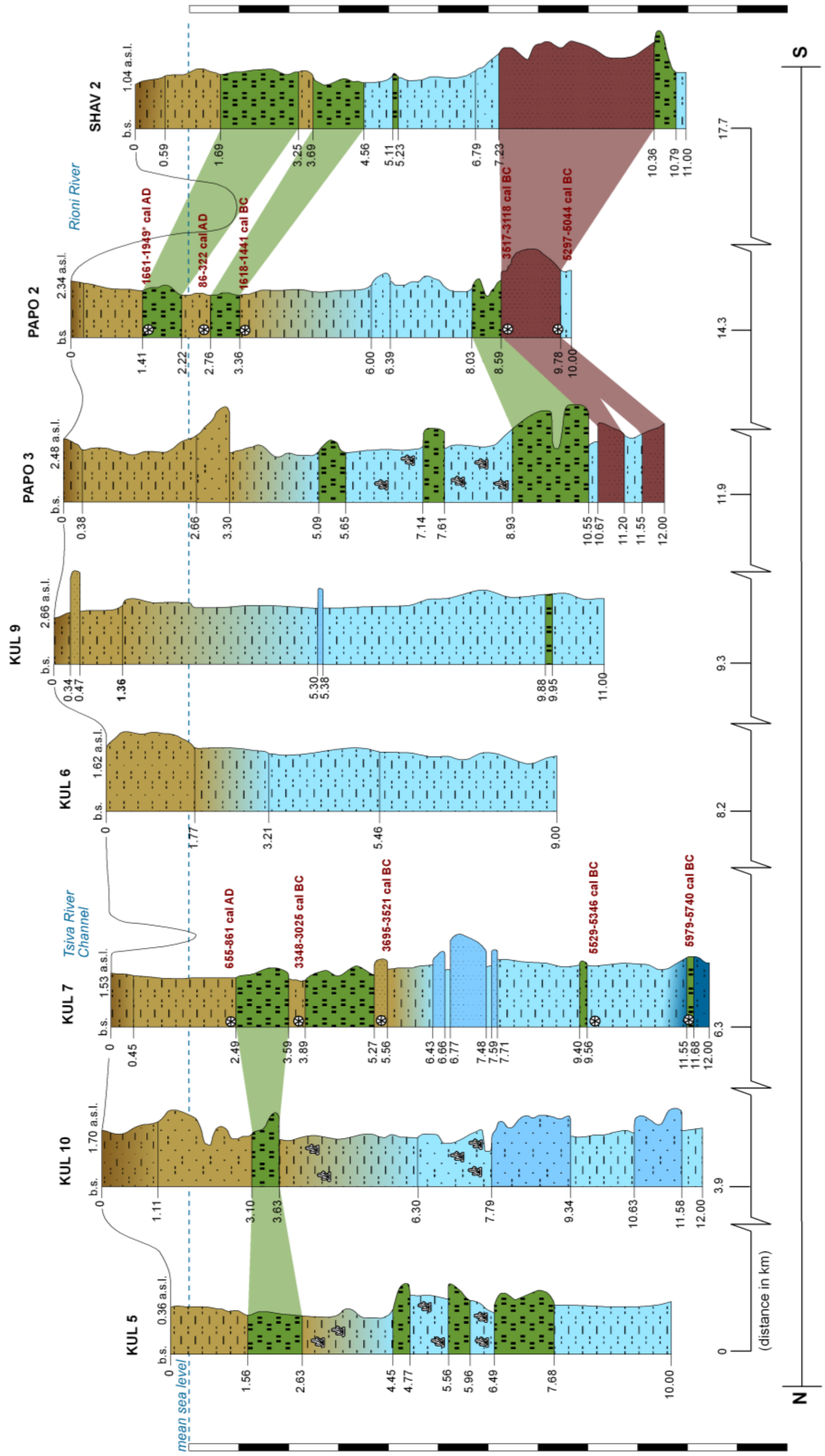

Fig. 2.6: Transect B crosses the research area in S-N direction (position in Fig. 2.1; legend in Fig. 2.5). The southernmost cores (SHAV 2, PAPO 3, PAPO 2) belong to core group 1; they are characterized by strong fluvial influence in the lower parts. KUL 9 and KUL 6 represent the evolution in the central part of the swamps, dominated by fine-grained lagoonal mud without intercalation of sand or peat. KUL 7, 10 and 5 belong to group 4 which contains several peat layers, but no major fluvial of alluvial input.

In the southern section of coring transects A and B, the lower parts (below 5.5 m b.s.l.) of cores SHAV 2 and PAPO 3 (Fig. 2.6) comprise fine sand-dominated and poorly sorted layers with varying silt contents (mean grain size ~30-200 µm), which is similar to the section between 9.78 and 8.59 m b.s. in master core PAPO 2. In case of SHAV 2, this unit reaches a thickness of almost 3 m. In contrast, units of (silty) sand are better sorted and more homogeneous, which is expressed by reduced fluctuations of the mean grain size in cores KUL 7, 9, 10 and 11. Finally, medium sand with parts of coarse sand (~250-520 µm) are found in core KUL 3, in sediment profiles of trenches KUL 1 and 2, and in the uppermost 2.5 m of core KUL 12. Here, sand units are well-sorted (in general σ < 2), homogeneous and void of macroscopic plant remains.

The distribution and thickness of peats reveal a certain pattern as well. Except for KUL 6, all cores contain at least one distinct peat layer. The peats generally occur in the upper parts of the cores, predominantly in a sequence of 2-3 layers, which are separated by thin clay- and silt-dominated strata. In the lower core sections, peats were found in only 7 cores.

Six samples of core KUL 12 were analysed for their microfaunal content, with only two of them revealing scattered findings: At 11.74 m b.s. a few indeterminable remains of foraminifera occur; at 9.49 m b.s. a sample contains two indeterminable foraminifera specimens.

2.4.4 Radiocarbon and IRSL dating results

Table 2.1 gives the details of the radiocarbon dating results, including specifications of the dated material, sample numbers and depths. The ^{14}C ages (2 σ) are noted in the figures of the profiles at the position of the sampled depths (see Figs. 2.2-2.6).

The fading-corrected IRSL dating of samples from trench KUL 1 resulted in ages of 1010 ± 134 a (KUL 1/2) and 1017 ± 129 a (KUL 1/4). The IRSL ages from trench KUL 2 are only insignificantly younger (KUL 2/1: 1047 ± 134 a; KUL 2/2: 1049 ± 134 a) (Table 2.2).

Tab. 2.1: Radiocarbon data sheet. Calibration with Calib 7.1 software (following Stuiver and Reimer, 1993). Dating was carried at the Centre for Accelerator Mass Spectrometry of the University of Cologne (CologneAMS).

Sample ID	**Lab code**	**Depth below surface**	**Material**	**$\delta^{13}C$ (‰)**	**Conventional ^{14}C-age BP**	**Calibrated ^{14}C-age (cal BC/cal AD), 2 sigma**
KUL 3/9	COL 3180.1.1	2.45	Plant/wood	-27.1	1553±37	AD 418-584
KUL 3/10	COL 3181.1.1	2.65	Plant/wood	-25.5	2135±38	354-250 BC
KUL 3/14	COL 3182.1.1	3.55	Plant/wood	-26.9	3313±39	1685-1505 BC
KUL 7/7	COL3183.1.1	2.43	Plant/wood	-30.3	1286±39	AD 655-861
KUL 7/13	COL3184.1.1	3.84	Plant/wood	-27.0	4479±41	3348-3025 BC
KUL 7/20	COL3185.1.1	5.47	Plant/wood	-24.9	4821±42	3695-3521 BC
KUL 7/37	COL3186.1.1	9.65	charcoal	-29.5	6483±44	5529-5346 BC
KUL 7/44	COL3187.1.1	11.62	Plant/wood	-29.8	6967±47	5979-5740 BC
PAPO 2/6	COL3188.1.1	1.5	Plant/wood	-29.9	165±36	AD 1661-1949
PAPO2/9	COL3189.1.1	2.65	Plant/wood	-27.9	1823±37	AD 86-322
PAPO2/11	COL3190.1.1	3.45	Plant/wood	-28.6	3252±40	1618-1441 BC
PAPO2/28	COL3192.1.1	8.62	Plant/wood	-28.1	4602±41	3517-3118 BC
PAPO2/31	COL3193.1.1	9.74	Plant/wood	-28.8	6201±43	5297-5044 BC

Tab. 2.2: Luminescence age estimates of the beach ridges of Kulevi. Feldspar, coarse grain, SAR protocol after Murray and Wintle, 2000, central age model (CAM) after Galbraith et al., 1999.

Sample ID	Lab-code	Grain size (µm)	Depth (m b.s.)	n_a/n_m	H_2O (%)	Radionuclide concentration			Total dose rate (Gy/ka)	Dose distribution		De values (Gy)	Age estimation (a)	g-value (%/ decade)	Fading corrected age (a)
						U (ppm)	Th (ppm)	K (%)		RSD (%)	OD (%)	CAM	CAM		
KUL1/2	C-L3663	100-200	0.3 m	10/47	10 ± 5	1.88 ± 0.1	9.17 ± 0.51	1.31 ± 0.02	2.764 ± 0.213	39.9	31.9 6 ± 4.07	2.17 ± 0.22	785 ± 100	1.9	1010 ± 134
KUL1/4	C-L3664	100-200	1.1 m	25/41	10 ± 5	1.79 ± 0.09	8.39 ± 0.48	1.44 ± 0.03	2.714 ± 0.214	16.1	14.98 ± 0.85	2.21 ± 0.072	814 ± 69	1.9	1017 ± 129
KUL2/1	C-L3665	100-200	0.3 m	40/44	10 ± 5	2.00 ± 0.12	10.86 ± 0.7	1.31 ± 0.02	2.871 ±0.218	27.3	24.19 ± 1.36	2.70 ± 0.001	940 ± 72	1.3	1047 ± 134
KUL2/2	C-L3666	100-200	0.9 m	47/47	10 ± 5	1.94 ± 0.1	10.07 ± 0.51	1.44 ± 0.03	2.843±0.218	25.8	23.58 ± 1.2	2.72 ± 0.09	957 ± 80	1.3	1049 ± 134

2.5 Discussion

2.5.1 Facies interpretation

Based on the samples taken from the master cores, eight facies were distinguished, which were adopted for the further cores of coring transects A and B. The facies represent depositional environments that differ in terms of grain size, sorting, organic content and elemental composition (Fig. 2.7A, B, C).

2.5.1.1 Facies A: shallow marine (?)

Facies A was only found in the basal section of KUL 7 (Fig. 2.3). From 12 m b.s. to the peat layer at 11.68 m b.s., the sediment shows low S values and the presence of (magnesium-) calcite (Fig. 2.7C), which is manifested in high Ca contents. Samples from this section contain few undetermined shell fragments and few foraminifera. This facies differs from facies D (alluvial, semi-terrestrial deposits) and facies C (lagoonal mud) in terms of lower Si, Ti and S contents. The slightly increased TOC/N ratio is a possible indicator for both shallow marine and terrestrial conditions (Meyers and Teranes, 2001). The PCA and the standardized ternary plot (Fig. 2.7A and B) both reveal no distinct differentiation of this sample to facies C and D. Therefore, a lagoonal or semi-terrestrial origin, e.g. related to a standing water body on the evolving delta floodplain, comparable to facies C1 or C2, cannot be excluded. In this case a continuous sea-level rise and drowning of the study area would have provoked the growth of a transgressive peat (KUL 7, 11.68-11.55 m b.s.).

2.5.1.2 Facies B: sublittoral to littoral

Relatively well-sorted medium to coarse sand between 6.70 and 2.82mb.s. at KUL 3 (Fig. 2.2) points to hydrodynamic conditions with rather high sediment transport capacities, typical of wave- dominated sublittoral to littoral conditions (Dingler, 2005; Aagaard and Hughes, 2013). Sediments from facies B are coarser and better sorted than sediments from facies F (fluvial deposits). Based on Folk and Ward (1957), beach sands are characterised by good sorting and tend to unimodal distributions, even if they are located close to river mouths (Tucker, 1996; Hesp, 2002). In the ternary plot this facies is congruent to facies G due to the coarse grain size, but it is distinguishable from the other remaining facies (Fig. 2.7B). A slightly better differentiation is revealed by the PCA (Fig. 2.7A), although two samples from facies G plot similar to the samples of facies B as well.

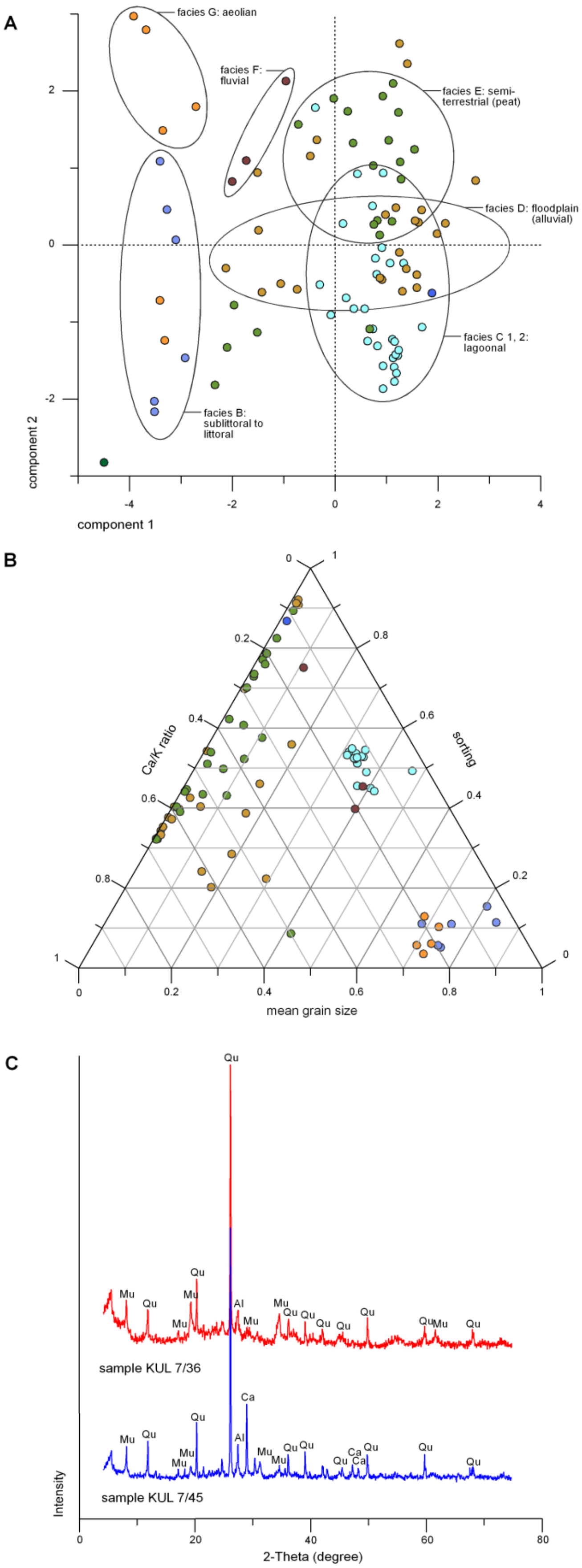

Fig. 2.7A: Principal component analysis (PCA) of the samples taken from the master cores KUL 3, 7 and PAPO 2. Eight PCs were estimated. The spatial distribution is based on components 1 and 2 with a variance of 36.9 and 19.8% (further variances: PC 3: 14.3%, PC 4: 10.5, PC 5: 8.4%, PC 6: 6%, PC 7: 0%). For the colour code of the samples see Fig. 2.5.

2.7B: Ternary plot of mean grain size, sorting and Ca/K ratio, plotted for all samples of the three master cores. For the colour code of the samples see Fig. 2.5.

2.7C: Mineralogical compositions of the samples KUL7/36 and KUL 7/45. Qu = quartz, Mu = muscovite, Al = albite, Ca = magnesium-calcite. The obvious difference is that KUL 7/45 contains magnesium-calcite.

2.5.1.3 Facies C: lagoonal

Sediments from facies C have a grey colour and tend to be indicated by low contents of organic matter. The lagoonal sediments differ from the semi-terrestrial and shallow marine deposits in terms of higher Ca/Fe and Ca/K ratios and low Si and Ti contents (Figs. 2.3, 2.4 and 2.7B). Furthermore, the low TOC/N ratios point to a predominance of algae and low terrestrial input of vascular plant material (Meyers and Teranes, 2001) which supports the differentiation between those two facies.

Nevertheless, several samples from the lagoonal strata reveal a coarser grain size. Although strong storms are known from the Black Sea, neither the absence of microfauna, nor geochemical or sedimentological features typically related to storm deposition (e.g. lamination, fining upward sequences) were found. Therefore a deposition by wave events is unlikely (Morton et al., 2007). However, geochemical parameters are consistent with still water conditions as well. Therefore, facies C can be divided into two subunits: Facies C-1, which consists of the predominating fine-grained mud of the central lagoonal areas, and Facies C-2, which is formed by the coarser deposits of the lagoon areas close to the river

mouths. This explains the similar composition between some lagoonal and alluvial samples in the PCA (Fig. 2.7A). The standardized ternary plot reveals a well-defined distinction of all other facies, except for two fluvial samples which may be explained by the fluvial origin of both facies C-2 and facies F (Fig. 2.7B).

2.5.1.4 Facies D: alluvial (overbank deposits)

As typical for alluvial sediments, facies D is characterised by silty to clayey deposits. The high TOC/N ratio is an effect of the increased content of vascular or even cellulosic plant material of terrestrial origin (Meyers and Teranes, 2001). Extensive inundation of lowlying delta areas and oxbow lakes during flood events typically induce the accumulation of fine sediments from slack waters as overbank deposits (overbank fines), when the stream overtops its banks (Blair and McPherson, 1994). In any case, major floods of the lower sections of the rivers Rioni and Khobistsqali can also provoke crevasse splays by breaching of levees, most commonly leading to sand deposition on the floodplain (e.g., North and Davidson, 2012). However, crevasse splay deposition typically goes along with basal erosional unconformities, and no such erosional surface was found in the presented cores. Core sections with varying fine sand contents and Ca/Fe and Ca/K values thus reflect the fluctuating hydrodynamic conditions on the delta plain which are predominantly characterised by the deposition of overbank fines (Boggs, 2006). These coarser layers have similar granulometric characteristics compared to facies C-2, but can be distinguished by differences in the geochemistry. Due to high LOI, many samples resemble those of facies E (Fig. 2.7A and B).

2.5.1.5 Facies E: semi-terrestrial (peat)

Facies E is represented by peat with numerous macroscopic plant remains and considerably elevated LOI and K values. Preservation of plants points to anoxic conditions (Turney et al., 2005). High TOC/N ratios are typical of peat bogs (Joosten et al., 2003; Haberl et al., 2006) and indicate a dominance of cellulosic plants (Meyers and Teranes, 2001). The most remarkable difference is revealed in elevated LOI and S values. The connection with the surrounding strata is reflected in the scattered distribution in the PCA and ternary plot (Fig. 2.7A, B), e.g. adjacent to facies B, C-1 and C-2.

2.5.1.6 Facies F: fluvial

A fluvial origin is assumed for some sections of cores PAPO 2, PAPO 3 and SHAV 2 and refers primarily to sediment input by distributary channels of the two rivers in the delta. These sediments show coarser grain size, moderate to poor sorting (Sun et al., 2002), and are void of macro- and microfauna. Elevated Fe and K values point to increased input of terrestrial material (Arz et al., 1998; Meyers and Teranes, 2001; Kujau et al., 2010). The varying grain size and sporadically occurring fining-upward sequences (e.g. PAPO 2) can for instance be explained by river avulsion and temporary lateral channel migration, deposition during larger floods in areas close to distributary channels, and/or – in contrast to facies D – crevasse splay deposition (Boggs, 2006). There are certain similarities with facies C-2 (Fig. 2.7B), but facies F reveals coarser mean grain size and elevated LOI, Si and Ti values. A better separation is revealed in Fig. 2.7A, where the plots of facies F and C-2 are disjoint.

2.5.1.7 Facies G: aeolian

Facies G is restricted to sediment profiles of trenches KUL 1 and 2, and the upper part of KUL 3. The elevation of these sediments with respect to sea level (2.50-3.00 m a.s.l.), the high degree of sorting and the dominance of medium sand (mean grain size 310-410 µm) suggest an aeolian origin. The location on the landward slope of the shore-parallel foredune ridges confirms this assumption (Hesp, 2002). The high degree of similarity to littoral sediments (facies B; Fig. 2.7A and B) can be explained by the shared source area and the short transport distance. This is reflected by slightly increased fine sand and reduced coarse sand contents (Fig. 2.2).

2.5.1.8 Facies H: anthropogenic

This facies reveals the same characteristics as facies B (sublittoral to littoral environments). The sediment was intentionally deposited at the site of KUL 12 in order to build a causeway.

2.5.2 Chronostratigraphic interpretation of sediment cores

2.5.2.1 Trenches KUL 1 and 2, core KUL 3

In KUL 3 the coastal evolution north of the present Rioni mouth is documented for the last 3500 years (Fig. 2.2). Due to the circulation pattern of the offshore currents (Korotaev et al., 2003), the Rioni is the main sediment source for the littoral deposits along the graded shoreline. Relatively well-sorted medium to coarse sands between 6.70 and 2.82 m b.s. point to relatively high transport capacities. Sublittoral to littoral conditions (facies B) at site KUL 3 established before ~1500 cal BC and ceased some time before ~350-50 cal BC, when decreasing mean grain size (3.25 m and 2.82 m b.s.; facies B and C) and a subsequent peat layer (2.82-1.95 m b.s.; facies E) indicate a back-barrier milieu with beach aggradation and/or delta progradation. These conditions continued at least until ~500 cal AD. Elevated S values and well-preserved plant remains suggest an anoxic milieu in the back-barrier swamp.

After ~500 AD, well-sorted medium sand was accumulated at site KUL 3, which is similar to the sediment in the upper 2 m of the adjacent foredune ridges (KUL 1 and 2, facies G) and therefore of aeolian origin. Based on the IRSL ages taken from the trenches, sand deposition on top of the foredunes was still active or was reactivated around AD ~830-1150 (1049 ± 134 a and 1010 ± 134 a, Table 2.2), before the eastern part of the ridges was finally stabilized. This is roughly in accordance with the uppermost radiocarbon age of KUL 3: ~500 cal AD is a *terminus post quem* for the deposition of the well-sorted medium sand.

However, several uncertainties may be related to the IRSL ages. Due to the low temperature of the preheat plateau not all narrow electron traps may have been emptied, which could lead to age overestimation (Auclair et al., 2003). Furthermore, the feldspar aliquots show a significant scatter of equivalent doses. Since the samples were taken from the upper section of the foredune ridges and likely experienced aeolian transport, sediments are assumed to be rather well-bleached. Therefore, post-depositional mixing may be a reason for the large scatter. The reforestation of the area with pine trees during the 20th century (de Klerk et al., 2009) and resulting root penetration could be a possible explanation. Thus, the IRSL ages should be treated as maximum ages for the last period of foredune activity.

2.5.2.2 Master cores KUL 7 and PAPO 2

The development of the central part of the swampy hinterland between the rivers Khobistsqali and the Rioni is documented by master cores KUL 7 (Fig. 2.3) and PAPO 2 (Fig. 2.4). For the lowermost section of core KUL 7 (12-11.68mb.s.), two different scenarios may be considered: assuming a shallow marine environment of the basal unit, the following peat documents the establishment of semi-terrestrial conditions, e.g. in the form of a floodplain swamp (facies D), pointing to a westward shift of the coastal environments. Assuming that the basal unit of KUL 7 represents lagoonal to semiterrestrial conditions, a western position of the coastline must be assumed, and back-barrier conditions existed at KUL 7 already before ~6000 cal BC.

However, as documented by the peat layer, back-barrier conditions dominate the entire study area, except for site KUL 3, at least since 5979-5740 cal BC (Table 2.1). Subsequently, peat growth could not keep pace with the, at that time, still considerably rising sea level (Giosan et al., 2006; Brückner et al., 2010). The establishment of open lagoonal conditions (facies C) is inferred from the following ~4 m thick unit of clayey silt, although the mineralogical composition (i.e. absence of calcite) of these sediments and the absence of micro- and macrofossils point to conditions inappropriate for the development of faunal assemblages. Depositional conditions remained stable for the following centuries, and, despite the development of a thin intercalated peat, were most likely characterised by a lagoonal back-barrier situation. While no microfauna was found to determine salinity conditions, the geochemical parameters are the most reliable indicators for this facies determination. High depositional rates are inferred from the ^{14}C age of plant fragments taken from the uppermost part of the silt layer: with an age between 5529 and 5346 cal BC (Table 2.1) it is only slightly younger than the sample taken from the peat below.

In the following units we assume an increasing significance of alluvial processes, e.g. overbank deposition during major floods of the lower sections of the rivers Rioni and

Khobistsqali. The increased alluvial deposition marks the transition to subsequently evolving semi-terrestrial conditions (facies D), which were likely related to the gradual evolution of the Rioni-Khobistsqali floodplain, i.e. the Kolkheti lowlands, established around 3600 cal BC. Subsequently, the stratigraphy is dominated by thick peat units (facies E). Peat formation at KUL 7 dominated at least until ~900 cal AD; sporadic sand input on the floodplain is inferred from the sand fraction in the peat layers.

Additionally, different rates of peat accretion may be inferred from the radiocarbon ages. While 1.50 m of peat accumulated between 3695 and 3521 cal BC and 3348-3025 cal BC (5.27-3.89 m b.s.) (Table 2.1), reduced rates of peat formation must be assumed for the section between 3.59 and 2.49 m b.s., where 1.10 m of peat formed during a period of 4000 years (3348-3025 cal BC to 655-861 cal AD). If it is not a dating error, this might be explained by different rates of groundwater level changes. However, the development of paralic peats is dependent on the local sea-level evolution (Fouache et al., 2012), and a sea-level rise of only 1.1 m in ~4000 years is problematic. Thus, possible uncertainties have to be considered, e.g. dating of different material, a possible hiatus within the sequence and floating peat (Haberl et al., 2006; Vött et al., 2007). Finally, the peat is covered by fine-grained alluvial deposits and 0.45 m of anthropogenic infill.

The stratigraphy recorded in core PAPO 2 reflects a similar evolution. It starts with lagoonal deposits (facies C). The following sandy stratum of fluvial origin (facies F) was deposited between 5297 and 5044 cal BC and 3517-3118 cal BC. When the riverine input declined, peat (facies D) formed, indicating semi-terrestrial conditions and the establishment of a lagoonal environment, still affected by episodic flooding. The end of input of coarser-grained sediments may reflect an avulsion of the Rioni. After 1618-1441 cal BC, peat growth indicates the end of the lagoonal conditions (3.36-2.76 m b.s.). Related to the extending delta floodplain of the Rioni, alluvial sediments (facies E) had been deposited at the site at least since 86-322 cal AD.

2.5.3 The evolution of the Kolkheti lowlands

The evolution of the Kolkheti lowlands can be deduced from coring transects A and B (Figs. 2.5 and 2.6). The facies of the three master cores were adopted to the cores along the coring transects. In addition, the cores were classified into four groups based on their site-specific sedimentary succession.

Group 1 consists of core KUL 3 and trenches KUL 1 and 2. It is dominated by sublittoral to littoral (KUL 3) and aeolian sands (upper part of KUL 3, KUL 1 and 2). Similar deposits are absent in the other parts of the coring transects.

Cores SHAV 2, PAPO 2 and PAPO 3 comprise **group 2**, which is restricted to the southern part of the research area. In these cores, the lowermost sections (below ~6 m b.s.l.) show lagoonal environments (facies C), which were episodically affected by sediment input from the Rioni river (facies F). Especially in the case of SHAV 2, a 3 m thick layer of fluvial sand occurs, which can be related to similar sand intercalations at PAPO 2 and PAPO 3. Due to ^{14}C-dated plant material in PAPO 2 (Table 2.1, sample PAPO2/31), the distinct sand layers was accumulated after ~5300 cal BC. It is assumed that by then the course of the Rioni was located at a similar position as today. When lagoonal conditions (facies C) were established in the area after ~3000 BC, major sand intercalations are absent. Instead, intercalated peats indicate recurrent siltation and shoreline shift of a shallow lagoon. In the southern part of transect B, the transformation from lagoonal (facies C) to semi-terrestrial and later terrestrial depositional environments (facies D and E) occurred after ~1500 BC.

Further north, cores KUL 6, 9 and 12 (Fig. 2.1) comprise **group 3**. The cores represent the central part of the Kulevi swamps between the rivers Rioni and Khobistsqali. They almost entirely consist of clayey silt, which is interpreted to represent lagoonal (facies C) and, subsequently, alluvial strata (facies E). Alluvial and fluvial deposition was reduced wherefore intercalations of coarser material are missing. It seems that these core sites had been located in the centre of the former lagoon. Only a thin sand layer suggests flood-related deposition at KUL 9. The sand layer in the upper 2.5 m of KUL 12 is artificial infill (facies G; Figs. 2.5 and 2.7) since the coring site is located in close proximity to the road.

Group 4 comprises cores KUL 5, 7, 10 and 11 and exhibits parallels with group 2. KUL 7 is the deepest core and reaches ~10.50 m b.s.l. It is the only core where shallow marine conditions (facies A) are inferred at the base. However, the subsequent strata are dominated by fine-grained sediments of the lagoonal facies (facies C-1), with sand intercalations indicating episodic alluvial sediment input (facies C-2) particularly at sites KUL 7 and 10 which are located close to the river mouth. While peat layers are almost absent in the lower core sections, thick peat units are present in the upper part of the cores from this group. We have not yet resolved whether alluvial deposition is related to the Rioni or the Khobistsqali.

In summary, the presented findings allow to sketch a general scenario for the evolution of the Kolkheti lowlands over the last eight millennia.

Around 6000 cal BC, a shallow marine environment may be inferred from the base of two cores (KUL 7 and 12); these sediments show slightly different characteristics compared to all other strata. However, samples from this unit cannot be unambiguously separated from the lagoonal and semi-terrestrial samples based on the sedimentological and geochemical characteristics (Fig. 2.7). It thus remains open whether the Holocene transgression is reflected in the form of shallow marine deposits, or in the form of landward migrating back-barrier conditions.

Around 5900 cal BC, the coastline was located west of coring transect B, most likely between KUL 12 and 3 (cf. transect A and Fig. 2.1). In all cores, a thick sequence of fine grained sediments points to standing water bodies and quiescent depositional conditions, evidencing the existence of a coastal barrier. As suggested by peat intercalations and input from the rivers, recurrent siltation and re-establishing open water bodies characterised this back-barrier environment.

Since ~3500 cal BC (at KUL 7), the delta plain is assumed to have reached the eastern to northeastern part of the coring transects. The final transition from lagoonal to semi-terrestrial environments is represented by the development of peat. In other parts of the lowlands, this change took place significantly later, e.g. ~1500 cal BC at site PAPO 2. Further west, at KUL 3, the siltation was connected to the subsequent westward shift in the shoreline. North of the present Rioni mouth it took place sometime before ~350 cal BC.

This scenario is in agreement with the results presented by Connor et al. (2007) and de Klerk et al. (2009), who suggested an interaction of sea-level rise and fluvial infill causing fluctuating groundwater conditions in peat bogs at the site of Ispani (ca. 30 km south of the research area). Furthermore, the establishment of a floodplain with peat bogs is indirectly corroborated by historical sources from Antiquity: although uncertainties remain regarding the locations and landscape descriptions given by Hippocrates (ca. 460 - ca. 370 BC) and Strabo (64/63 BC - ca. AD 24), both describe the surroundings of Phasis and the Rioni as marshy forests and swamps (cf. Gamkrelidze, 2012).

2.5.4 Implications for the local relative sea-level evolution

Although the reconstruction of a relative sea-level curve for the research area remains challenging due to the lack of unambiguous sea-level index points, the relationship of each dated sample to the respective past sea level allows for an approximation of the relative sea-level position for each data point (Fig. 2.8). Based on the facies succession inferred for the cores, the peat in the lower part of core KUL 7 (sample KUL 7/44) is assumed to represent a paralic peat layer. Since paralic peats are directly related to the back-barrier groundwater table, and, thus, to the local relative sea level (Pirazzoli, 1991; Vött, 2007), we defined a vertical error range of ~±0.5 m (Pirazzoli, 1996; Behre, 2003) for this and for similar (KUL 3/9, KUL 3/10; back-barrier position) samples. The local relative sea level thus was ca. -9 m around 6000 BC.

The three ages of KUL7/37, PAPO2/31 and PAPO2/28 derive from plant remains taken from lagoonal mud (facies C). Since the material was deposited below the former local sea level, these samples represent minimum values for the sea level position at ~5450 BC (-8 m), ~5200 BC (-7.4 m) and ~3300 BC (-6.3 m). Rather shallow lagoonal conditions and a deposition close to the lagoonal water table is most likely, since subsequently peat evolved (KUL7/37, PAPO2/31).

In contrast, samples taken from an alluvial facies (facies D), i.e. related to the deposition of overbank fines, derive from elevations above the former local sea level. At present, the dry floodplain with episodic overbank deposition shows maximum elevations of ~3 m a.s.l. Therefore, samples KUL 7/20, KUL 7/13, PAPO2/11, PAPO 2/9 and KUL 7/7 indicate maximum values for the respective sea-level position. However, while KUL 7/20, KUL 7/13, PAPO2/11 give valuable information about the maximum sea-level position for the time span between ~3500 and ~1500 BC, the latter two samples (PAPO 2/9, KUL 7/7) may be neglected since samples KUL3/10 and KUL 3/9 (paralic peat in back-barrier position) represent more reliable sea-level index points for this time period, with a rather narrow error range. For KUL3/14, representing sublittoral to littoral facies (facies B), an error range of several metres must be assigned as well. Finally, the peat sample PAPO2/6 derives from a core section dominated by alluvial sediments, indicating an oxbow peat, which only gives a maximum estimate for the position of the local sea level.

Altogether, our data points (Fig. 2.8) indicate an estimated relative sea level at ~ -9 m ~6000 cal BC, and a subsequent sea-level rise until 2000-1500 cal BC, when a sea level of ~3-2 m below present level was reached. Afterwards sea-level rise decelerated until it reached today's level.

Compared with the local sea-level curves for the Taman Peninsula in SW Russia, our curve shows a rather similar trend, in particular when compared to the RSL curves of the former two sites which point to a relatively slow sea-level rise throughout the last ~4000 years as well as to other RSLs of the Eastern Mediterranean (Vött, 2007; Brückner et al., 2010). However, the data presented here point to an even slower local relative sea-level rise in the Rioni delta. The differences can be explained by the different tectonic settings of the central Georgian coast and the Taman Peninsula. Sites on Taman Peninsula are related to subsidence due to tectonic activity or compaction (Fouache et al., 2012). This may also be the case for the study area as a back-arc marginal extensional basin between the Caucasus

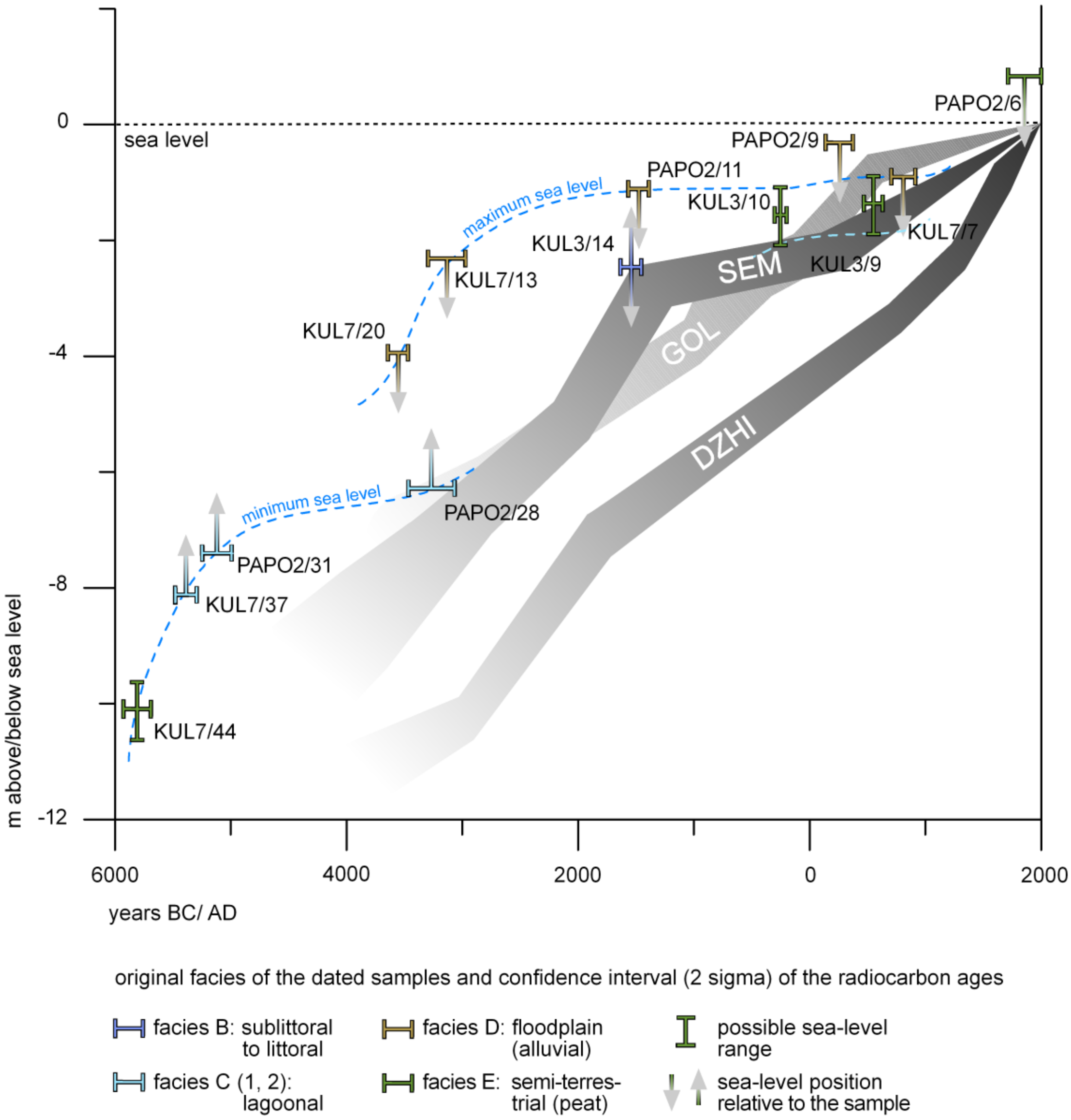

Fig. 2.8: Compilation of ^{14}C-dated samples from the Kolkheti lowlands and their relative position to the local sea level. Horizontal bar shows ^{14}C dating result (2 sigma). The arrows pointing up/down indicate that sea level was higher/lower than the dated sample. In case of paralic peat (facies E; KUL 7/44, KUL 3/10, KUL 3/9), the sea-level range was narrowed to ±0.5 m (see text for further explanations). The data set is compared to sea-level curves from the Taman Peninsula in SW Russia, with the sites of SEM = Semebratnee (Brückner et al., 2010), GOL = Golobitskaya (Kelterbaum et al., 2011), and DZHI = Dschiginka (Fouache et al., 2012). The differences are due to different tectonic settings. For the study area, a continued and rather moderate rise in sea level for the last eight millennia is assumed.

ridges (Yılmaz et al., 2013), though at a more moderate pace. Based on the findings presented here, the high subsidence rates suggested by Gamkrelidze (1998) for the study area of 2-6 mm/a may be questioned.

Finally, as already suggested by Giosan et al. (2006), Brückner et al. (2010), Kelterbaum et al. (2011, 2012), and Fouache et al. (2012), no remarkable wiggles of the curve, representing regression-transgression cycles, can be inferred, which further challenges older sea-level curves of the Black Sea, and especially the so-called Phanagorian Regression (e.g. Balabanov, 2007).

2.6 Conclusion

Based on a total of eleven vibracores and two sediment trenches, this study presents, for the first time, detailed information on the chronostratigraphy of the Kolkheti lowlands (Colchis) in Georgia. Using a combination of sedimentological and geochemical parameters, we identified different facies, the succession of which reflects the palaeoenvironmental evolution of these coastal lowlands. Radiocarbon and IRSL ages show that the sedimentary record presented here covers the last ~8000 years.

During this period, the area of research was subject to considerable landscape changes. While a shallow marine origin for the very basal part of cores KUL 7 and KUL 12 remains ambiguous, the rapid establishment of lagoonal conditions, sometime before ~5000 cal BC, can be demonstrated based on sedimentological indicators. The lagoon was separated from the Black Sea by a barrier. Its sedimentation was influenced by the discharge of the rivers Rioni and Khobistsqali. Subsequently, alluviation transformed the lagoon into a delta plain with wetland-dominated sections, characterised by peat bogs, and sections with fine-grained alluvium. Depending on the location within the delta area, this transformation took place between 3500 and 1500 cal BC. Today, a substantial part of the area is still occupied by wetlands with peat bogs and forests, while other parts remain open waters or have been transformed into farmland.

As for the sea-level evolution, no evidence for significant oscillations of the local relative sea level was found, in particular no regression-transgression cycles as suggested by Balabanov (2007). Instead, our results point to a progressively and moderately rising sea level, with decelerated speed since 3000-2000 BC. This evolution resembles sea-level curves inferred for the Taman Peninsula (Brückner et al., 2010; Kelterbaum et al., 2011; Fouache et al., 2012). Differences between the curves may potentially reflect different tectonic settings.

Against the background of the early establishment of a permanently changing delta plain, it remains difficult to draw conclusions about the possible location for the, as yet, undiscovered location of the ancient city of Phasis. Due to the persistence of extended peat bogs and open water bodies, a location close to the Rioni, for example on a palaeo-levee of the river, seems likely. However, ancient reports locate Phasis south of the Rioni (Gamkrelidze, 1992, 2012; Lordkipanidze, 2000; Korenjak, 2003). Further investigations, including geophysical surveying techniques to detect subsurface palaeochannels of the Rioni, are needed to find the lost city of Phasis.

Based on this study, future research will reveal more details about Georgia's sea-level curve, thereby making an important contribution to the ongoing debate on the sea-level evolution of the Black Sea throughout the Holocene. Plus, the peat bogs to the north of the Rioni and the Lake Paliastomi are promising archives for palynological studies and will add new information on Georgia's Holocene vegetation history.

2.7 Acknowledgements

H. L. gratefully acknowledges the funding of his PhD project by the Heinrich Böll Foundation, Berlin (P106171). The Graduate School of Geosciences (GSGS) of the University of Cologne financially supported H. L. to attend the IGCP 610 conference in Baku, Azerbaijan, in 2015. Radiocarbon dating was carried out by Janet Rethemeyer, Alfred Dewald and Stefan Heinze and their teams at the CologneAMS Centre at the University of Cologne. Several colleagues from Georgia rendered administrative and logistic help during field work. Accommodation was provided by the Marine Research Centre of the Ilia State University in Grigoleti. Nick Marriner (CNRS Besançon) is thanked for language editing of an earlier version of this manuscript.

2.8 References

Aagaard, T., Hughes, M., 2013. Sediment transport. In: Schroder, J.F., Sherman, D.J. (Eds.), Treatise on Geomorphology, Coastal Geomorphology, vol. 10. Elsevier, Amsterdam, pp. 74-105.

Adamia, S., Zakariadze, G., Chkhotua, T., Sadradze, N., Tsereteli, N., Chabukiani, A., Gventsadze, A., 2011. Geology of the Caucasus: a review. Turkish J. Earth Sci. 20, 489-544.

Auclair, M., Lamothe, M., Huot, S., 2003. Measurement of anomalous fading for feldspar IRSL using SAR. Radiat. Meas. 37, 487-492.

Arz, H.W., Pätzold, J., Wefer, G., 1998. Correlated millennial-scale changes in surface hydrography and terrigenous sediment yield inferred from last-glacial marine deposits off Brazil. Quat. Res. 50, 157-166.

Balabanov, I.P., 2007. Holocene sea-level changes of the Black sea. In: Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Eds.), The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement. Springer, Dordrecht, pp. 711-730.

Barsch, H., Billwitz, K., Bork, H., 2000. Arbeitsmethoden in der Physiogeographie und Geoökologie. Klett-Perthes, Gotha.

Bazhenov, M.L., Burtman, V.S., 2002. Eocene paleomagnetism of the Caucasus (southwest Georgia): oroclinal bedding in the Arabian syntaxis. Tectonophysics 344, 247-259.

Behre, K.-E., 2003. Eine neue Meeresspiegelkurve für die südliche Nordsee. Transgressionen und Regressionen in den letzten 10.000 Jahren. Probl. Küstenforsch. im südlichen Nord. 28, 9-63.

Blair, T.C., McPherson, J.G., 1994. Alluvial fans and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes, and facies assemblages. J. Sediment. Res. A64, 450-489.

Blott, S.J., Pye, K., 2001. Technical communication, GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surf. Process. Landforms 26, 1237-1248.

Boggs, S., 2006. Principles of Sedimentology and Stratigraphy. Pearson Prentice Hall, New Jersey.

Bronk Ramsey, C., 2008. Deposition models for chronological records. Quat. Sci. Rev. 27, 42-60.

Bronk Ramsey, C., Lee, S., 2013. Recent and planned developments of the program Oxcal. Radiocarbon 55, 720-730.

Brückner, H., Kelterbaum, D., Marunchak, O., Porotov, A., Vött, A., 2010. The Holocene sea level story since 7500 BP e lessons from the eastern Mediterranean, the Black and the Azov seas. Quat. Int. 225, 160-179.

Brumsack, H.-J., 1989. Geochemistry of recent TOC-rich sediments from the Gulf of California and the Black sea. Geol. Rundsch. 78, 851-882.

Carozza, J.-M., Micu, C., Mihail, F., Carozza, L., 2012. Landscape change and archaeological settlements in the lower Danube valley and delta from early Neolithic to Chalcolithic time: a review. Quat. Int. 261, 21-31.

Chepalyga, A.L., 2007. The late glacial great flood in the Ponto-Caspian basin. In: Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Eds.), The Black Sea Flood Question. Springer, Dordrecht, pp. 119-148.

Connor, S., Thomas, I., Kvavadze, E., 2007. A 5600-yr history of changing vegetation, sea levels and human impacts from the Black Sea coast of Georgia. Holocene 17, 25-37.

Cordova, C., Gerasimenko, N., Lehman, P., Kliukin, A., 2011. Late Pleistocene and Holocene paleoenvironments of Crimea: pollen, soils, geomorphology, and geoarchaeology. GSA Spec. Pap. 473, 133-164.

de Klerk, P., Haberl, A., Kaffke, A., Krebs, M., Matchutadze, I., Minke, M., Schulz, J., Joosten, H., 2009. Vegetation history and environmental development since ca. 6000 cal yr BP in and around Ispani 2 (Kolkheti lowlands, Georgia). Quat. Sci. Rev. 28, 890-910.

Degens, E.T., Ross, D.A., 1972. Chronology of the Black Sea over the last 25000 yrs. Chem. Geol. 10, 1-16.

Dellwig, O., Hinrichs, J., Hild, H., Brumsack, H.-J., 2000. Changing sedimentation in tidal flat sediments of the southern North Sea from the Holocene to present: a geochemical approach. J. Sea Res. 44, 195-208.

Dingler, J.R., 2005. Beach processes. In: Schwartz, M.L. (Ed.), Encyclopedia of Coastal Sciences. Springer, Dordrecht, pp. 161-168.

Dubois de Montpéreux, F., 1842. Reise um den Kaucasus, zu den Tscherkessen, Abchasen, nach Kolchis, Georgien, Armenien und in die Krim, Band 1, Darmstadt.

Fähnrich, H., 2010. Geschichte Georgiens. Handbuch der Orientalistik, Bd. 21. Koninklijke Brill NV, Leiden.

Folk, R.L., Ward,W.C., 1957. Brazos river bar: a study in the significance of grain size parameters. J. Sediment. Pet. 27, 3-26.

Fouache, E., Kelterbaum, D., Brückner, H., Lericolais, G., Porotov, A., Dikarev, V., 2012. The Late Holocene evolution of the Black Sea e a critical view on the so-called Phanagorian regression. Quat. Int. 266, 162-174.

Galbraith, R., Roberts, R., Laslett, G., Yoshida, H., Olley, J., 1999. Optical dating of single and multiple grains of quartz from Jinmium Rock Shelter, Northern Australia: Part I, Experimental design and statistical models. Archaeometry 41, 339-364.

Gamkrelidze, G., 1992. Hydroarchaeology in the Georgian Republic (the Colchian littoral). Int. J. Naut. Archaeol. 21, 101-109.

Gamkrelidze, G., 1998. Stress vector orientations and movement of the Earth's crust of the territory of Georgia and the neotectonic stage. Bull. Georgian Acad. Sci. 158, 284-287.

Gamkrelidze, G., 2012. Researches in Iberia-Colchology (History and Archaeology of Ancient Georgia). Georgian National Museum, Tbilisi.

Giosan, L., Donnelly, J.P., Filip, F., Ovejanu, I., Vespremeanu-Stroe, A., Vespremeanu, E., Duller, G.A.T., 2006. Young Danube delta documents stable Black Sea level since the middle Holocene: morphodynamic, paleogeographic, and archaeological implications. Geology 34, 757-760.

Giosan, L., Filip, F., Constantinescu, S., 2009. Was the Black Sea catastrophically flooded in the early Holocene? Quat. Sci. Rev. 28, 1-6.

Haberl, A., Kahrmann, M., Krebs, M., Matchutadze, I., Joosten, H., 2006. The imnati mire in the Kolkheti lowland in Georgia. Peatl. Int. 1, 35-38.

Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: paleontological statistics software package for education and data analysis. Palaeontol. Electron. 4, 9-11.

Heiri, O., Lotter, A., Lemcke, G., 2001. Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. J. Paleolimnol. 25, 101-110.

Hesp, P., 2002. Foredunes and blowouts: initiation, geomorphology and dynamics. Geomorphology 48, 245-268.

Hiscott, R.N., Aksu, A.E., Yas¸ ar, D., Kaminski, M.A., Mudie, P.J., Kostylev, V.E., MacDonald, J.C., Isler, F.I., Lord, A.R., 2002. Deltas south of the Bosphorus strait record persistent Black sea outflow to the Marmara Sea since 10 ka. Mar. Geol. 190, 95-118.

Janelidze, C.P., 1980. Paleogeography of Georgia in the Holocene. Metsniereba (in Russian).

Jibladze, L., 2007. II-I Millennium BC Settlements of Kolkheti Lowland, Tbilisi (in Georgian).

Joosten, H., Kaffke, A., Matchutadze, I., 2003. The Mires of the Kolkheti Lowlands (Georgia). IMCG Newsletter 2003/3, pp. 19-23.

Kelterbaum, D., Brückner, H., Porotov, A., Schlotzhauer, U., Zhuravlev, D., 2011. Geoarchaeology of Taman Peninsula (SW Russia) e the example of the ancient Greek settlement of Golubit-skaya 2. Die Erde 142, 235-258.

Kelterbaum, D., Brückner, H., Dikarev, V., Gerhard, S., Pint, A., Porotov, A., Zin'ko, V., 2012. Pal-aeogeographic changes at Lake Chokrak on the Kerch Peninsula, Ukraine, during the Mid- and Late-Holocene. Geoarchaeology 27, 206-219.

Korenjak, M., 2003. Die Welt-Rundreise eines anonymen griechischen Autors ("Pseudo-Skymnos"). Georg Olms Verlag, Hildesheim.

Korotaev, G., Oguz, T., Nikiforov, A., Koblinksy, C., 2003. Seasonal, internannual, and mesoscale variability of the Black Sea upper layer circulation derived from altimeter data. J. Geophys. Res. 108, 1-15.

Kujau, A., Nürnberg, D., Zielhofer, C., Bahr, A., Röhl, U., 2010. Mississippi River discharge over the last ~ 560,000 years indications from X-ray fluorescence core-scanning. Palaeogeogr. Palae-oclimatol. Palaeoecol. 298, 311-318.

Kvavadze, E., Sagona, A., Martkoplishvili, I., Chichinadze, M., Jalabadze, M., Koridz, I., 2015. The hidden side of ritual: new palynological data from early Bronze age Georgia, the southern Caucasus. J. Archaeol. Sci. Rep. 2, 235-245.

Lericolais, G., Bulois, C., Gillet, H., Guichard, F., 2009. High frequency sea-level fluctuations recorded in the Black Sea since the LGM. Glob. Planet. Change 66, 65-75.

Lordkipanidze, O., 1991. Archäologie in Georgien: Von der Altsteinzeit zum Mittelalter. VCH Verlagsgesellschaft mbH, Weinheim.

Lordkipanidze, O., 2000. Phasis: the River and City in Colchis. Geographica Historica, vol. 15. Steiner, Stuttgart.

Messager, E., Lordkipanidze, D., Kvavadze, E., Ferring, C.R., Voinchet, P., 2009. Palaeoenvironmental reconstruction of Dmanisi site (Georgia) based on palaeobotanical data. Quat. Int. 223e224, 20-27.

Messager, E., Lebreton, V., Marquer, L., Russo-Ermolli, E., Orain, R., Renault-Miskovsky, J., Lordkipanidze, D., Despriée, J., Peretto, C., Arzarello, M., 2011. Palaeoenvironments of early hominins in temperate and Mediterranean Eurasia: new palaeobotanical data from Palaeolithic key-sites and synchronous natural sequences. Quat. Sci. Rev. 30, 1439-1447.

Meyers, P.A., Teranes, J.L., 2001. Sediment organic matter. In: Last, W.M., Smol, J.P. (Eds.), Tracking Environmental Change Using Lake Sediments 2. Kluver Academic Publishers, Dordrecht, pp. 239-269.

Morton, R., Gelfenbaum, G., Jaffe, B., 2007. Physical criteria for distinguishing sandy tsunami and storm deposits using modern examples. Sediment. Geol. 200, 184-207.

Murray, A.S., Wintle, A.G., 2000. Luminescence dating of quartz using an improved single aliquot regenerative-dose protocol. Radiat. Meas. 32, 57-73.

Narimanidze, E., Brückner, H., 1999. Survey on metal contamination of agricultural soils in Georgia. Land Degrad. Dev. 10, 467-488.

Nikolaishvili, D.A., Elizarbarashvili, N., Meladze, G.G., 2011. Evaluation of degree of landscape's anthropogenic transformation (landscapes of Georgia). Proced. Soc. Behav. Sci. 19, 547-555.

Nikolaishvili, D., Salukvadze, E., Bolashvili, N., Chikhradze, N.G., Matchavariani, L., 2015. Anthropogenic transformation of landscapes of Colchis lowland and surrounding foothills. Earth Sci. 4, 68-72.

Nikolaeva, E., Walter, T.R., Shirzaei, M., Zschau, J., 2014. Landslide observation and volume estimation in central Georgia based on L-band InSAR. Nat. Hazards Earth Syst. Sci. 14, 675-688.

North, C.P., Davidson, S.K., 2012. Unconfined alluvial flow processes: recognition and interpretation of their deposits, and the significance for palaeogeographic reconstruction. Earth Sci. Rev. 111, 199-223.

Panin, N., Popescu, I., 2007. The northwestern Black Sea: climatic and sea-level changes in the Upper Quaternary. In: Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Eds.), The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement. Springer, New York, pp. 387-404.

Papuashvili, R., 2002. Settlement below peat layer in Ontskoshia, Dziebani. J. Centre Archaeol. Res. Georgian Acad. Sci. 10, 35-38 (in Georgian).

Pirazzoli, P.A., 1991. World Atlas of Holocene Sea-level Changes. Elsevier Oceanogr, Ser. 58, Amsterdam, London, New York, Tokyo.

Pirazzoli, P.A., 1996. Sea-level Changes. The Last 20,000 Years. Wiley and Sons, Chichester.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Turney, C., van der Plicht, J., 2013. InterCal13 and Marine 13 radiocarbon age calibration curves 0-50,000 years cal BP. Radiocarbon 55, 1869-1887.

Ryan, W.B.F., 2007. Status of the Black sea flood hypothesis. In: Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Eds.), The Black Sea Flood Question. Springer, Dordrecht, pp. 63-88.

Ryan, W.B.F., Pitman, W.C., Major, C.O., Shimkus, K., Moskalenko, V., Jones, G.A., Dimitrov, P., Görür, N., Sakınç, M., Seyir, H.I., Yüce, H., 1997. An abrupt drowning of the Black Sea shelf. Mar. Geol. 138, 119-126.

Ryan, W.B.F., Major, C.O., Lericolais, G., Goldstein, S.L., 2003. Catastrophic flooding of the Black Sea. Annu. Rev. Earth Plant. Sci. 31, 525-554.

Shatilova, I., Rukhadze, L., Mchedlishvili, N., 2010. The stages of development of vegetation climate of Western Georgia during the Middle and Late Pleistocene. In: Proceedings of the Natural and Prehistoric Section 2, Georgian National Museum, Tbilisi, Georgia, pp. 75-81.

Stuiver, M., Reimer, P., 1993. Extended 14C data base and revised calib 3.0 ^{14}C age calibration program. Radiocarbon 35, 215-230.

Svanidze, Z., Gogichaishvili, B., Turkadze, G., Alpaidze, V., 2008. Dynamics of heavy metal distribution in soils and natural waters of mining and metallurgical regions. In: Ecocity World Summit 2008 Proceedings, San Francisco, CA, USA, pp. 1-12.

Suchodoletz, H. von, Menz, M., Kühn, P., Sukhushvili, L., Faust, D., 2015. Fluvial sediments of the Algeti River in southeastern Georgia e an archive of Late Quaternary landscape activity and stability in the Transcaucasian region. Catena 130, 95-107.

Sun, D., Bloemenda, J., Rea, D.K., Vandenberghe, J., Jiang, F., An, Z., Su, R., 2002. Grain-size distribution function of polymodal sediments in hydraulic and aeolian environments, and numerical partitioning of the sedimentary components. Sediment. Geol. 152, 263-277.

Tucker, M., 1996. Methoden der Sedimentologie. Ferdinand Enke, Stuttgart.

Turney, C., Canti, M., Branch, N., Clark, P., 2005. Environmental Archaeology: Theoretical and Practical Approaches. Routledge, London.

Vezolli, G., Garzanti, E., Vincent, S., And_o, S., Carter, A., Resentini, A., 2014. Tracking sediment provenance and erosional evolution of the western Greater Caucasus. Earth Surf. Process. Landforms 39, 1101-1114.

Vött, A., 2007. Relative sea level changes and regional tectonic evolution of seven coastal areas in NWGreece since the mid-Holocene. Quat. Sci. Rev. 26, 894-919.

Vött, A., Schriever, A., Handl, M., Brückner, H., 2007. Holocene palaeogeographies of the central Acheloos River delta (NW Greece) in the vicinity of the ancient seaport Oiniadai. Geodin. Acta 20, 241-256.

Yanko-Hombach, V., Gilbert, A.S., Dolukhanov, P., 2007. Controversy over the great flood hypotheses in the Black Sea in light of geological, paleontological, and archaeological evidence. Quat. Int. 167-168, 91-113.

Yılmaz, A., Adamia, S., Yılmaz, H., 2013. Comparisons of the suture zones along a geotraverse from the Scythian platform to the Arabian platform. Geosci. Front. 5 (6), 855-875.

2.9 Appendix – Sublementary data.

2.9.1 Sample preparation for luminescence (IRSL) dating

The following sample preparation and luminescence measurements were carried out in the Cologne Luminescence Lab (CLL) under subdued red light. After HCl, H_2O_2 and $Na_4O_7P_2$ treatments to remove carbonates, organics and clay contents, gravity separation was carried out using heavy liquid solutions (sodium polytungstate; ρ_1 = 2.68 g/cm^3, ρ_2 = 2.62 g/cm^3, ρ_3 = 2.58 g/cm^3) in order to separate coarse-grained (100-200 µm) quartz and feldspar. All measurements were carried out on an automated Risø TL/OSL DA 20 reader equipped with a ^{90}Sr/^{90}Y beta source delivering 0.08 Gy/sec.

Quartz is commonly used to date Holocene deposits due to its ubiquity and a generally stable signal for dating young deposits. However, in this study, potassium-rich feldspars were preferred for dating because of inappropriate luminescence properties of the quartz (e.g. low signal intensities). Nonetheless, feldspar can exhibit anomalous fading, which is defined as a signal loss due to leakage of electrons at room temperature. This can cause an age underestimation (see Wintle, 1973; Lamothe and Auclair, 1999; Balescu et al., 2001; Huntley and Lamothe, 2001). To include the effect of anomalous fading in the age calculation, several sub-samples were tested and measured to observe a possible decrease in the IRSL response over time, following Auclair et al. (2003). Indeed, a signal loss was detected in all sub-samples. The g-values (1.9 and 1.3 %/decade) were calculated for the samples KUL 1/4 and KUL 2/2. Thus, the fading was corrected by using the procedure proposed by

Huntley and Lamothe (2001), as the equivalent dose was derived using linear parts of the growth curve. The resulting ages are given both with uncorrected and fading corrected values. The fading correction for sample KUL 1/2 refers to the g-value of KUL 1/4, and the fading correction for sample KUL 2/1 was conducted using the g-value of KUL 2/2 (Tab. 2.2).

For the feldspar measurements an infrared stimulation (880 ± 80 nm) and an interference filter (410 nm) were used. All measurements were carried out following the single aliquot regenerative dose protocol (SAR) after Murray and Wintle (2000, 2003) and Wallinga et al. (2000). Due to the preheat plateau test, which indicated no plateau building at higher temperatures, a preheat temperature of 180 °C was chosen. Each aliquot was thus preheated at 180 °C (according to combined preheat-plateau-dose-recovery-tests) for 10 sec and then measured for 300 sec at 50 °C (IRSL 50 protocol after Wallinga, 2000).

To calculate the annual dose rate derived from the decay of lithogenic radionuclides in the sediments, the concentrations of uranium, thorium and potassium were determined by laboratory high-resolution γ-spectrometry using the software DRAC by Durcan et al. (2015). The conversion factors of Adamiec and Aitken (1998), and α- and ß- attenuation factors of Bell (1979) and Mejdahl (1979) were applied. Following the approach of Prescott and Hutton (1994) the cosmic dose rate was calculated. An internal radiation of 12.5 ± 0.5 % potassium (Huntley and Baril, 1997) and an α-efficiency factor of 0.07 ± 0.02 (Preusser et al., 2005) were assumed for feldspars.

2.9.2 References

Adamiec, G., Aitken, M., 1998. Dose rate conversion factors: update. Ancient TL16, 37-50.

Auclair, M., Lamothe, M., Huot, S., 2003. Measurement of anomalous fading for feldspar IRSL using SAR. Radiation Measurements 37, 487-492.

Balescu, S., Lamothe, M., Auclair, M., Shilts, W.W., 2001. IRSL dating of Middle Pleistocene interglacial sediments form southern Quebec (Canada) using multiple and single grain aliquots. Quaternary Science Reviews 20, 821-824.

Bell, W.T., 1979. Attenuation factors for the absorbed radiation dose in quartz inclusions for thermoluminescence dating. Ancient TL 8, 2-13.

Bøtter-Jensen, L., McKeever, S.W.S., Wintle, A.G., 2003. Optically Stimulated Luminescence Dosimetry. Elsevier, Amsterdam.

Durcan, J.A., King G.E., Duller G.A.T., 2015. DRAC: Dose rate and age calculator for trapped charge dating. Quaternary Geochronology 28, 54-61.

Huntley, D.J., Baril, M.R., 1997. The K content of the K-feldspars being measured in optical dating or in thermoluminescence dating. Ancient TL 15, 11-13.

Huntley, D.J., Lamothe, M., 2001. Ubiquity of anomalous fading in K-feldspars and the measurement and correction for it in optical dating. Canadian Journal of Earth Sciences 38, 1093-1106.

Lamothe, M., Auclair, M., 1999. A solution to anomalous fading and age shortfalls in optical dating of feldspar minerals. Earth and Planetary Science Letters 171, 319-323.

Mejdahl, V., 1979. Thermoluminescence Dating: Beta-dose attenuation in quartz grains. Archaeometry 21, 61-72.

Murray, A.S., Wintle, A.G., 2000. Luminescence dating of quartz using an improved single aliquot regenerative-dose protocol. Radiation Measurements 32, 57-73.

Murray, A.S., Wintle, A.G., 2003. The single aliquot regenerative dose protocol: potential for improvements in reliability, Radiation Measurements 37, 377-381.

Prescott, J.R., Hutton, J.T., 1994. Cosmic ray contributions to dose rates for luminescence and ESR dating: Large depths and long-term time variations. Radiation Measurements 23, 497-500.

Preusser, F., Andersen, B., Denton, G.H., Schlüchter, C., 2005. Luminescence chronology of Late Pleistocene glacial deposits in North Westland, New Zealand. Quaternary Science Reviews 24, 2207-2227.

Wallinga, J., Murray A., Wintle A., 2000. The single-aliquot regenerative-dose (SAR) protocol applied to coarse-grain feldspar. Radiation Measurements 32, 529-533.

Wintle, A.G., 1973. Anomalous Fading of Thermo-luminescence in Mineral Samples. Nature 245, 143-144.

Chapter 3

3 Bronze Age settlement mounds on the Colchian plain at the Black Sea coast of Georgia – a geoarchaeological perspective

Hannes Laermanns[1], Giorgi Kirkitadze[2], Simon Matthias May[1], Daniel Kelterbaum[1], Stephan Opitz[1], Arne Heisterkamp[1], Giorgi Basilaia[2], Mikheil Elashvili[2], Helmut Brückner[1]

[1] Institute of Geography, University of Cologne, Germany

[2] School of Natural Sciences and Engineering, Ilia State University, Georgia

Abstract

Situated between the rivers Enguri in the north and Khobistskali in the south, more than 30 settlement mounds (locally named *Dikhagudzuba*) provide evidence for a relatively densely populated landscape in the coastal lowlands of Western Georgia during the Bronze Age. Compared to older mounds in Eastern Georgia and other regions, these mounds differ not only in age but also in their average size and spatial distribution. Based on the interpretation of 9 sediment cores, drone survey and Structure-from-Motion photogrammetry techniques, our study aims at (i) establishing a chronostratigraphic framework for the mounds based on ^{14}C datings; (ii) reconstructing possible phases and gaps in human occupation; (iii) determining potential source areas of the mounds' construction material; and (iv) identifying the environmental conditions at the time of their use. The three investigated mounds are similar in dimension and stratigraphy. Anthropogenic layers could clearly be identified and separated from the natural alluvial deposits below. According to the ^{14}C age estimates, the mounds date to the first half of the 2nd millennium BC; this confirms the archaeological interpretation of their Bronze Age origin. While only one construction phase is assumed for two of the mounds, stratigraphic findings suggest a successive enlargement of a third mound over at least 470 years. The palaeoenvironmental conditions in the vicinity of the mounds were dominated by swampy, fluvial (channel) to alluvial (overbank) processes, as attested by river-bank deposits and flood-plain alluvium.

Keywords

Bronze Age, Colchis, Georgia, multielement analysis, settlement mound

Published 2018 in *Geoarchaeology* 33 (4), 453-469.

DOI:10.1002/gea.21670

3.1 Introduction

Settlement mounds are dwelling forms consisting of mud-based and typically cone-shaped anthropogenic accumulations, which represent prehistoric and early historic settlements (Menze, Ur, & Sherratt, 2006). While the term *tell* refers to a settlement mound which develops passively by the gradual accumulation of occupation debris (Darvill, 2008; Menze, Ur, & Sherratt, 2006), the term *settlement mound* also summarises forms such as terps, warfts or platform mounds, which were intentionally built for various reasons (Lindauer & Blitz, 1997; Ervynck et al., 2012). Most settlement mounds have a Neolithic to Chalcolithic age (Steadman, 2000); however, the Tell es-Sultan at Jericho, probably the oldest known settlement mound worldwide, dates back to approximately 11000 BC (Rosenstock, 2010). From the beginning of the Pre-Pottery-Neolithic to the beginning of the Bronze Age, settlement mounds in their different forms spread from the Fertile Crescent throughout the Eastern Mediterranean, the entire Near East and different parts of Europe (Lubos et al., 2011). While many sites in Anatolia, Thessaly and the Balkan region have been investigated in the last years (Parkinson & Gyucha, 2012), relatively few studies have been undertaken in the regions north and east of the Fertile Crescent (Hansen, Mirtskhulava, & Bastert-Lamprichs, 2007).

However, a number of settlement mounds are known from the Caucasus region as well. They provide insights into the early human occupation of Georgia. The protected location between the Greater and Lesser Caucasus and the mild climate have always favoured human occupation and allowed an early transition from hunting and gathering cultures to farming and animal husbandry (Lordkipanidze, 1991). While in the eastern part of Georgia settlement mounds are of similar (i.e., Neolithic/Chalcolithic) age compared to sites from Anatolia or the Balkan region (Hansen, Mirtskhulava, & Bastert-Lamprichs, 2007), the mound constructions of the Colchis region in the west of Georgia (local name *Dikhagudzuba*) are reported to have a younger age, and differ also in their smaller size and their dense distribution. Archaeological surveys identified more than 30 mounds in the area between the rivers Enguri in the north and Khobistskali in the south (Figure 3.1). The existing chronology of the known settlement mounds is only based on archaeological findings, which point to a Bronze Age origin (Fähnrich, 2010). However, only limited information on their internal structure and their palaeoenvironmental context is available, and a detailed chronostratigraphy is still lacking (Lordkipanidze, 1991). Therefore, there is no information whether these mounds were intentionally constructed or not, whether they accumulated during multiple occupation phases, or whether they can be compared to known sites from Eastern Georgia, Anatolia or the Balkan region.

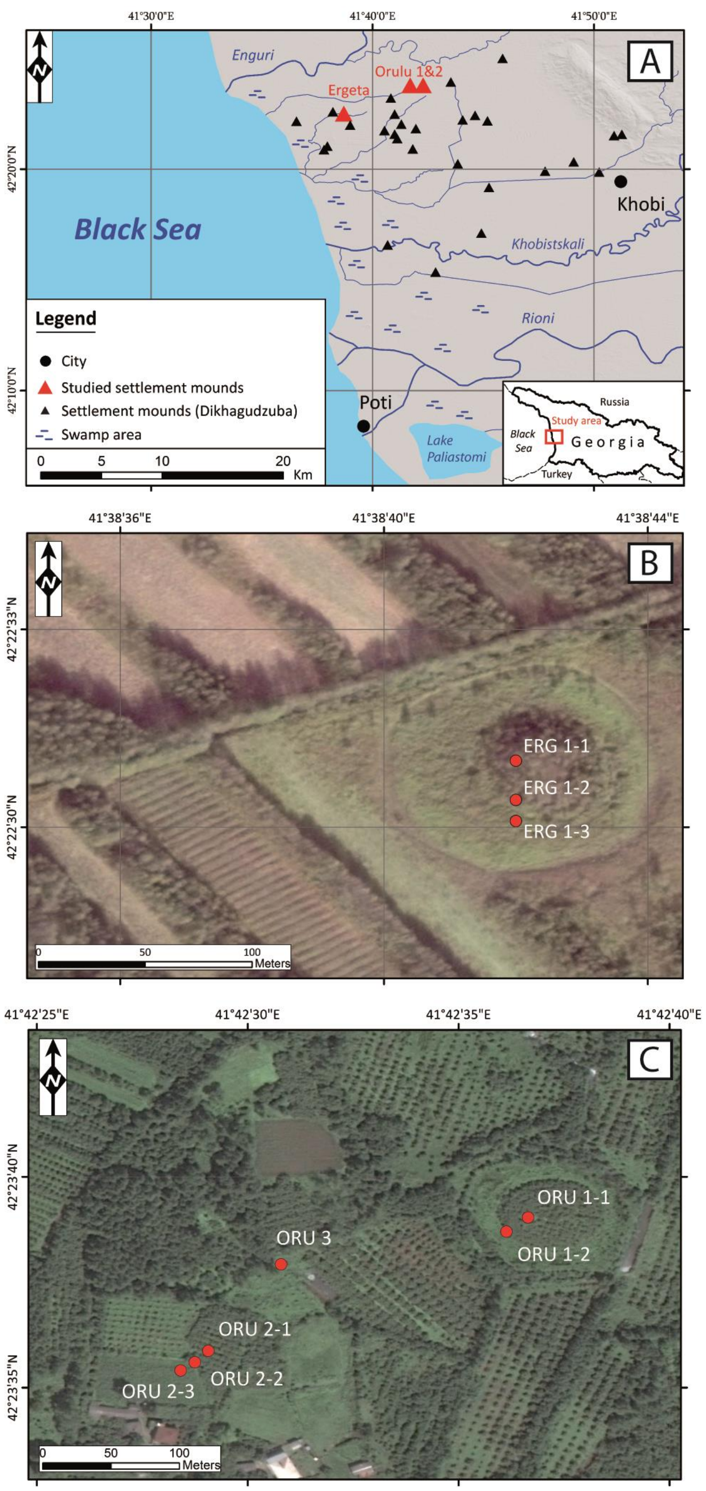

Figure 3.1A: Overview of the occurrence of settlement mounds in the Colchian plain (Colchis) in Western Georgia. The map is based on Aster digital shaded model – from Aster global digital elevation model 30 m (NASA) – and was created in Esri ArcGIS 10.2.2.

Figure 3.1B: Overview of the research area of the settlement mound Ergeta 1 and the sites where sediment core drillings were conducted (indicated by red dots). The circular ditch that was dug by the recent landowner and encompasses the mound is clearly visible. (Google Earth Image © 2016 Digital Globe. Map created in Esri ArcGIS 10.2.2).

Figure 3.1C: Overview of the research area with locations of the two neighbouring settlement mounds Orulu 1 and Orulu 2 and sites of core drillings (red dots). The circular swamp belt around the mound Orulu 1 is well visible due to the absence of trees. (Google Earth Image © 2016 Digital Globe. Map created in Esri ArcGIS 10.2.2).

Against this background, this paper investigates three of the most representative settlement mounds and their surroundings, located close to the villages of Ergeta and Orulu (Figure 3.1). Based on vibracores taken from the top, slopes and the direct vicinity of the studied mounds, geochemical and sedimentological analyses were conducted to determine element concentrations (XRF), granulometry, and organic contents (C/N) of the different stratigraphic layers. Furthermore, we used drone survey and Structure-from-Motion photogrammetry techniques in order to calculate the mounds' dimensions and the sediment volumes needed for the formation of these anthropogenic features. Our investigations aimed at (i) establishing a chronostratigraphic framework for the mounds based on ^{14}C dating; (ii) identifying the time of initial construction and possible phases and gaps in human occupation; (iii) identifying the spatial extent of the mounds and potential source areas of the construction material; and (iv) reconstructing the environmental conditions at the time of their occupation.

3.2 Regional Setting

3.2.1 Physical Setting

The Colchian plain is a coastal lowland region bordered by the slopes of the Greater Caucasus in the northeast and the Lesser Caucasus in the southeast. To the west, the Black Sea coast extends from north to south. In the east, the Likhi range forms the easternmost limit of the plain (Eppelbaum & Keshin, 2012).

The Colchian plain is a back-arc marginal extensional basin, which is located in a continent-continent-collision zone, triggered by the northward drift of the Arabian plate (Yılmaz, Adamia, & Yılmaz, 2013). It forms a part of the complex of the Alpine-Himalayan collision belt system, and the mountains' uplift can be dated to Middle Pliocene Alpine orogeny (Adamia et al., 2011). The Caucasus consists mainly of Mesozoic to Neogene sedimentary rocks of marine origin, ophiolithes and, especially in case of the Lesser Caucasus, additional andesitic pyroclastica and effusiva (Mitchell & Westaway, 1999) as well as gneiss and granite intrusions (Yılmaz, Adamia, & Yılmaz, 2013). In contrast, the geologic basement of the Colchian plain primarily comprises of Cretaceous and Paleogene sediments and volcanoclastics (Bazhenov & Burtman, 2002), overlain by Quaternary molasses and river terraces (Adamia et al., 2011) which were finally shaped during the LGM (Gobejishvili, Lomidze, & Tielidze, 2011).

As a part of the Black Sea coast of Georgia, the Colchian plain has undergone significant morphological changes induced by large-scale sea level rise and considerable accumulation of fluvial and alluvial sediments during the Holocene. In particular, since the reconnection of the Black Sea with the Mediterranean Sea ~7400-6400 BC (Ryan, 2007; Giosan, Filip, & Constantinescu, 2009; Lericolais et al., 2009), the water table rose significantly until it nearly reached its current position around 3000 BC (Giosan et al., 2006; Kelterbaum et al., 2012; Fouache et al., 2012). In coastal Georgia, extensive back-barrier areas were mainly silted up by fluvial sediments; they changed between 3000 and 1500 BC from open lagoons to swampland and peat formations (Laermanns et al., 2017).

Today, the natural landscape of the coastal plain is dominated by extensive wetlands consisting of numerous rivers of different size, shallow lakes, swamps, peat bogs, open reed areas and low forests. The region's climate is characterized by high precipitation (more than 2000 mm/a) and mild temperatures including the absence of regular winter frosts (Denk, Frotzler, & Davitashvili, 2000). The natural wetland areas have been reduced by centuries of deforestation and drainage activity (de Klerk et al., 2009). Although extensive wetland areas remain under protection, e.g. in the Kolkheti National Park in the central part of the Colchian plain, large areas north of the Khobistskali river have been cultivated. Due to the high groundwater, agriculture depends on an extensive drainage system of ditches and ridge-and-furrow fields (Nikolaishvili, Elizarbarashvili, & Meladze, 2011). Due to the severe agricultural overprint, the natural landscape with its numerous small river courses is heavily converted in these parts of the plain.

3.2.2 Human Occupation and Archaeological Background

Settlement mounds have their origins in the Fertile Crescent and are closely associated with the Neolithic Revolution, when hunter-gatherer communities adopted farming and animal husbandry (Parkinson & Gyucha, 2012). The most important reasons for a continuous settlement site may have been the increasing dependence on domestic plants and animals and the related reduction in the communities' mobility (Parkinson & Gyucha, 2012). During the Pre-Pottery Neolithic in the 8^{th} to 7^{th} millennium BC, settlement mounds spread from the core area in the Fertile Crescent throughout several parts of the Old World, especially from the Near and Middle East to the Balkan region and Central Europe (Hansen, Mirtskhulava, & Bastert-Lamprichs, 2007; Rosenstock, 2010; Lubos et al., 2011; Parkinson & Gyucha, 2012). Depending on the environmental and societal contexts, the settlement mounds present regional disparities not only in terms of intentional or non-intentional formation. Notably, they can differ in size, spatial and historical occurrence, their proximity (isolated or grouped) and phases of occupation, with continuously occupied sites, e.g. in Thessaly (Parkinson & Gyucha, 2012), or temporary or reoccupied sites with significant phases of abandonment, e.g. in the Great Hungarian Plain (Raczky & Anders, 2008).

The oldest known settlement mound north of the Fertile Crescent, the tell of Çatalhöyük, is located in Anatolia close to Konya and dates back approximately to the mid-8^{th} millennium

BC (Hodder, 2005). Further settlement mounds in Middle and West Anatolia occur at a similar time, between the early 7th and the early 6th millennium BC (Çilingiroğlu, Çevik, & Çilingiroğlu, 2012). Other famous associated sites of comparable age are Ulucak Höyük ca. 20 km east of Izmir (Çilingiroğlu, Çevik, & Çilingiroğlu, 2012), Çukuriçi Höyük and Arvalya Höyük near Selçuk/Ephesos (Horejs, 2012; Stock et al., 2015) and Barcın Höyük (Groenhuijzen et al., 2015). All of these mounds are located in fertile plains in proximity to the coast and a mountainous hinterland, and are thus located in a strategically important position.

For the territory of Georgia, Neolithization began between 10000 and 9000 BC (Arslanov, Dolukhanov, & Gei, 2007). It is assumed that the transition from hunting and gathering to farming and animal husbandry took place in a fluid transition, which persisted until the Chalcolithic (Fähnrich, 2010). Even though metallurgy was known, tools of flint, obsidian and bone remained predominant. While settlements in Eastern Georgia date at least to the 6th millennium BC, e.g. the settlement mound of Aruchlo (Hansen, Mirtskhulava, & Bastert-Lamprichs, 2007), the oldest settlements in Western Georgia are much younger: The two oldest settlements – the site of *Ispani* (Connor, Thomas, & Kvavadze, 2007; de Klerk et al., 2009; Papuahsvili, & Papuashvili, 2014), located close to the town of Kobuleti, and the site of *Ontskoshia* (Janelidze & Tatashidze, 2010) in the vicinity of the town of Anaklia at the river mouth of the Enguri (Figure 3.1A) – are both located in the Colchian plain (also known as Colchis) ca. 1-2 km east of the coastline. They were radiocarbon-dated to the mid-3rd millennium BC, i.e. the transition between the Chalcolithic and the Early Bronze Age in this region (Lordkipanidze, 1991).

With the beginning of the Bronze Age in the 3rd millennium BC, different cultural expressions emerged (Greppin, 1991). While in Eastern Georgia the so-called Mtkwari-Araxes (also known as the Kura-Araxes) culture spread to further areas of Transcaucasia, the Chalcolithic culture in the coastal areas of the west continued. In both East and West Georgia, settlement mounds of that time were discovered and associated with the transition to farming and animal husbandry (Lordkipanidze, 1991; Fähnrich, 2010). In eastern Georgia, nomad tribes superseded the Mtkwari-Araxes culture and were later replaced by the Trialeti culture, the predecessor of the Iron Age Iberian culture. Due to these multiple and sudden changes (Kohl, 2001), many sites, such as the settlement mound Aruchlo I reveal several population gaps between initial and later occupation, which are often superimposed on older layers (Hansen, Mirtskhulava, & Bastert-Lamprichs, 2007).

In contrast, the settlement mounds and areas in the western parts of Georgia are reported to remain populated, without any known hiatus or sudden change in Bronze and Iron Age. There, settlement mounds occurred in groups and contained wooden housings with a round ground plan (Lordkipanidze, 1991; Tsetskhladze, 1997; Sens, 2009; Fähnrich, 2010). Often the artificial mound formed the centre of a bigger settlement system, surrounded by one or two moats and wooden fortifications. These are attested from the 5th century BC onwards in Hippocrates' treaty *On the Airs, Waters, and Places* (§15, Jouanna, 1996), as well as in the *Anabasis* of Xenophon. On his way back to Greece through northern Anatolia, Xenophon met the people of the Mosynoikoi, i.e. "those living in wooden towers", *mosynes* (*Anabasis* 5.4.31-34; cf. also Diodorus Siculus 14.30.6-7; see Dan 2014, 2016). The dwelling form of wooden constructions on hill-site positions continued while Colchis came under the increasing influence of Mithridates VI Eupator (late 2nd to early 1st century BC), and subsequently, from 63 BC, of the Roman Empire, until the end of the Byzantine occupation of Lazica, and even further on (Braund, 1994). Most of the identified mounds are located between the rivers Enguri and Khobistskali (Figure 3.1). However, some further mounds were discovered on the middle course of the Rioni, close to the town of Partskhanaqanevi. During the Soviet era, some of these sites were excavated, e.g. the site of *Dikhagudzuba* (*Ergeta 1*), which is eponymous for the local name of Colchian settlement mounds in general (Gamkrelidze, 2012).

3.2.3 Research Area

The investigations presented in this study focus on three settlement mounds located in the central part of the research area (Figures 3.1 & 3.2), between the rivers Enguri and Khobistskali. They were chosen based on their representative morphology, location and accessibility for fieldwork. The recent use of some mounds, e.g. as construction ground or (modern) cemetery, limited the possible sites for investigation including vibracoring.

Mound *Ergeta 1* (Figure 3.1B) is located in a meadow ca. 1.5 km west of the centre of the small village of Ergeta (Figures 3.1, 3.2, 3.4; coordinates: E 41.645059, N 42.375279, peak altitude: 9.72 m above sea level (a.s.l.), diameter: ca. 40 m, construction height: ca. 5.75 m). It is covered by grass, open scrub and scattered hazel. *Ergeta 1* is surrounded by a ditch of several decimetres depth, which runs for a distance of ca. 25 to 45 m around the mound.

The two mounds *Orulu 1* and *Orulu 2* (Figure 3.1C) are located 2.5 km east-northeast of *Ergeta 1* in the village of Orulu. Mound *Orulu 1* (coordinates: E 41.710186, N 42.394191, peak altitude: 15.39 m a.s.l., diameter: ca. 40 m, construction height: ca. 4.3 m) is covered by a hazel plantation and reveals traces of a former excavation. It is surrounded by a ca. 10

to 15 m wide circular swamp which adjoins directly to the hill foot. Mound *Orulu 2* (coordinates: E 41.708131, N 42.393303, peak altitude: 13.19 m a.s.l., diameter: ca. 35 m, construction height: ca. 2.85 m) is also used as a hazel plantation. It is surrounded by a small ditch (depth <40 cm), located directly in front of the hill foot and reaching a maximum width of 1.5 m. The distance between the two mounds (measured from top to top) amounts to approximately 240 m.

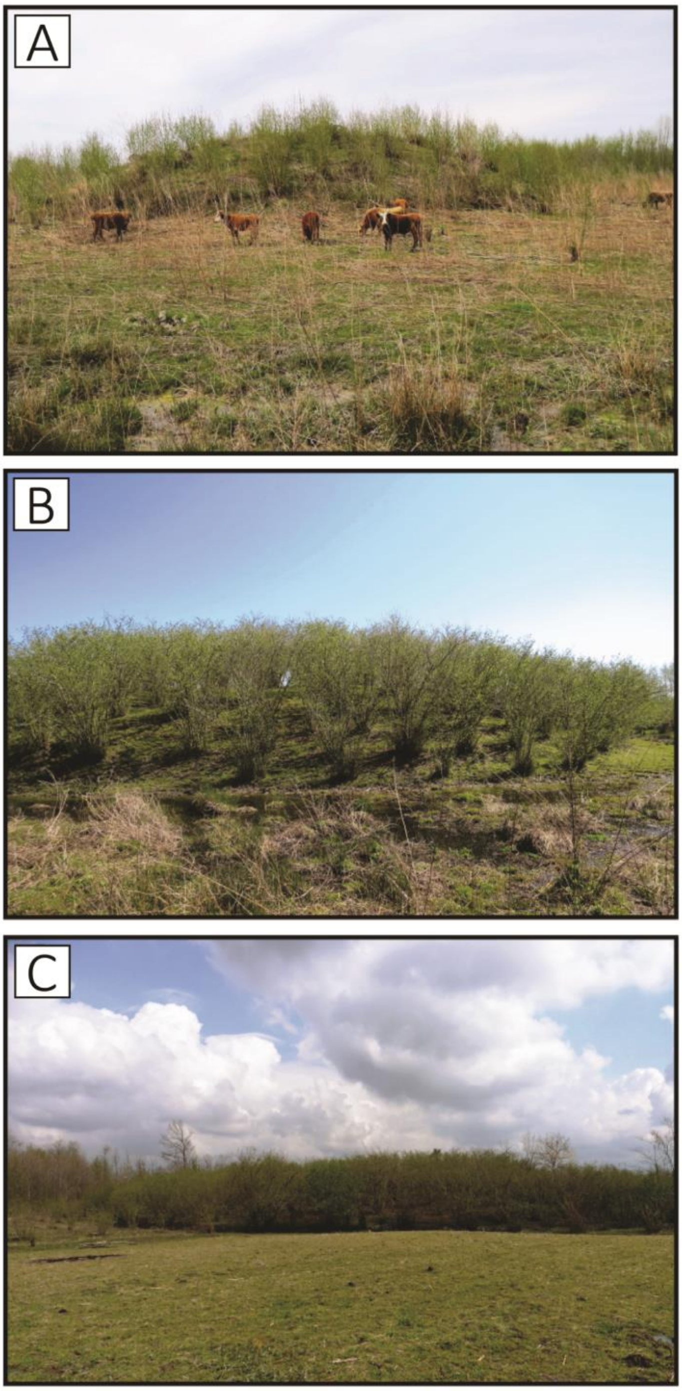

Figure 3.2: Photos of the mounds (A) Ergeta 1, (B) Orulu 1, and (C) Orulu 2. (Photos: Kelterbaum and Laermanns 2015). Orulu 1 (B) is surrounded by a wide swampy moat. The mounds Ourlu 1 and Orulu 2 (B & C) are used for hazel plantation. Due to the elevated location the dry ground benefits the cultivation in the otherwise swampy surrounding.

3.3 Methods

3.3.1 Fieldwork

Fieldwork included on-site surveys to locate settlement mounds identified in satellite images (Google Earth images, © 2014 Digital Globe) and described in archaeological sources (e.g. Lordkipanidze, 1991; Tsetskhladze, 1997; Gamkrelidze, 2012). The stratigraphic analysis and geochemical interpretation is based on sediment cores, which were taken using a Cobra TT (Atlas Copco) percussion coring device (Figure 3.3A). Half-open cores had diameters of 6 and 5 cm (Figure 3.3B), and were retrieved using a hydraulic pulling device. A maximum depth of 12 m below surface (b.s.) was achieved. Core analysis consisted of the description of sediment texture, colour (with Munsell Soil Color Charts©), and $CaCO_3$ test (with HCl, 10 %) of the different layers. Samples were taken from sedimentary units vertically every 10 to 20 cm throughout the settlement layers and every 20 to 40 cm for the other parts of the core.

At each of the three mounds, one drilling was performed on the top of the mound. The sediment cores will be presented in detail in the following chapters (ERG1-1, ORU1-1, ORU2-1; Figures 3.1, 3.4 to 3.6). Furthermore, a core was taken from the slope of each mound (ERG1-2, ORU1-2, ORU2-2; Figures 3.1 & 3.10), and in the case of mounds *Ergeta 1* and *Orulu 2*, a third core close to the foothill was drilled (ERG1-3, ORU2-3; Figures 3.1, 3.10). A supplementary core (ORU3) was taken from the farmland between *Orulu 1* and *Orulu 2* (Figures 3.1, 3.7, 3.10). The elevation of cores and topographical transects was measured using a Topcon Hiper V DGPS with a 3D resolution of 2 cm.

3.3.2 Geochemical and Sedimentological Analyses

All laboratory analyses were conducted at the Geoscience Laboratory of the Institute of Geography, University of Cologne. The samples were dried at 40 °C in a drying chamber for 48 h. Subsequently they were sieved <2 mm and crushed gently with a mortar to disintegrate the aggregates.

For the fine-grained fraction (<2 mm) of all samples, granulometric analyses were performed in 116 channels from 0.04 to 2000 μm with a Laser Diffraction Particle Size Analyzer (LS 13320 Beckmann Coulter$_{TM}$). Before measurement, organic matter was removed by hydrogen peroxide (H_2O_2, 15 %).The samples were pre-treated with sodium pyrophosphate ($Na_4P_2O_7$, 46 g/l) to avoid coagulation, and shaken for at least 12 hours in an overhead shaker. Each sample was measured three times using the optical Fraunhofer model.

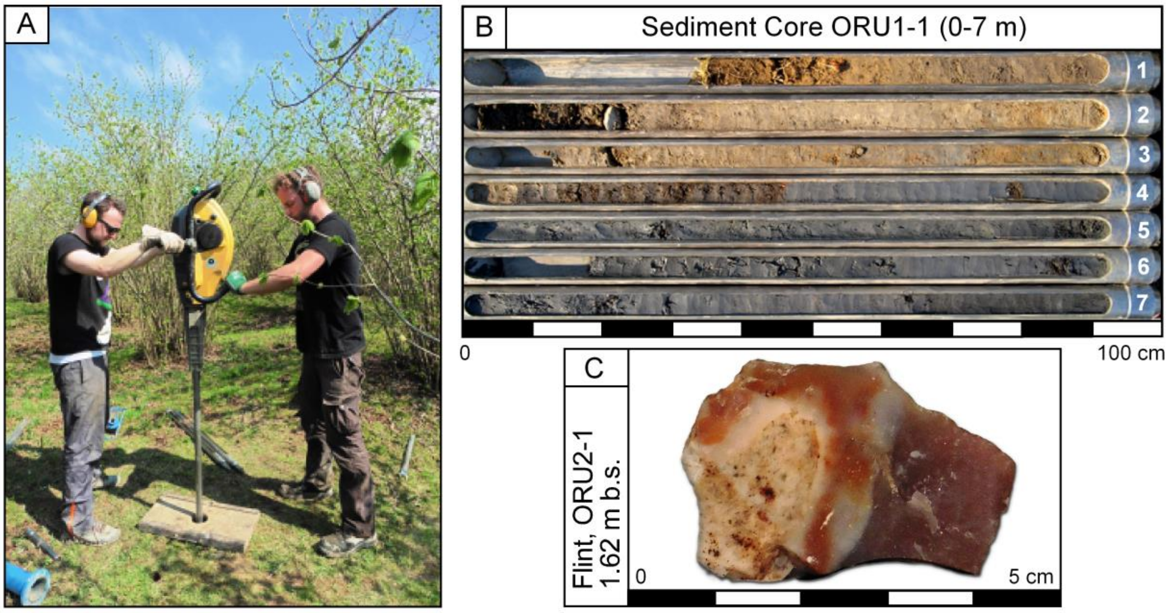

Figure 3.3A: Drilling procedure with the Atlas Copco Cobra at the site of sediment core ORU1-1 on the top of the settlement mound Orulu 1 (Photo: Heisterkamp 2015). B: Sediment core ORU1-1 in the half-open m long tubes from the surface (left side of the uppermost tube No. 1) to the maximum depth (right side of the lowermost tube No 7). Due to its poriferous and organic rich texture the topsoil was compacted during the drilling process (Photo: Laermanns 2015). C: Flint flake taken from sediment core ORU2-1 (settlement mound Orulu 2) at a depth of 1.62 m b.s. (Photo: Laermanns 2015).

Grain-size parameters are based on Folk & Ward (1957) and were calculated by GRADISTAT software version 8 (Blott & Pye, 2001).

Contents of total carbon (TC), total organic carbon (TOC), and nitrogen (N) were determined using a Vario EL Cube (Elementar Analysensysteme GmbH, Hanau, Germany). Before measurement the sample material was ground and homogenized using an automatic ball grinder (Retsch MM 400). Total inorganic carbon content was dissolved using 10 % HCl in a second aliquot of each sample, before TOC was determined. The ratios of the TOC and N contents were determined following the method of Meyers & Teranes (2001) and will be specified in the following text and figures under the conventional labelling "C/N ratio".

To estimate the element concentrations, X-ray fluorescence (XRF) analysis was performed. The ground and homogenized material was pressed into 2-mm-thick pellets, and measured with a portable XRF analyser (NITON XL3t). Each sample was measured three times in mineral mode for 160 sec to cover all possible filter options.

Principal Component Analysis (PCA) was applied using the PAST software (version 3.1.1; Hammer, Harper, & Ryan, 2001). The standardized values and standard deviation of the laboratory results were calculated and altogether five parameters were used: concentrations of Zn, Cu and P served as marker for human influence, Ca was considered as a natural component of the sediment, and the mean grain size helped to differentiate between low- and high-energetic depositional environments, e.g. alluvial vs. fluvial (Oonk, Slomp, & Huismann, 2009; Dirix et al., 2015). The distribution of the data was explained by the first two components (PC 1: 44.8 % and PC 2: 25.1 %).

3.3.3 Dating Techniques

Twelve samples (plant remains and charcoal) from cores ERG1-1, ORU1-1 and ORU2-1 were chosen for radiocarbon dating (see Table 3.1 for details), with five samples from ERG1-1, four samples from ORU1-1 and three samples from ORU2-1. All samples derive from charcoal remains or terrestrial plants. All ages were calibrated using CALIB 7.1 software and IntCal13 data set (Stuiver & Reimer, 1993; Reimer et al., 2013).

3.3.4 Remote Sensing

In case of mound *Ergeta 1*, which seems to be less affected by human activities at present, close-range aerial photogrammetric images were taken. Therefore, six white poles were placed on the site and measured by DGPS to serve as Ground Control Points (GCP) to ensure precise georeferencing of the created model (Westoby et al., 2012). During the drone flight, 101 overlapping photos were taken of the settlement mound and its adjacent area, using a Nikon Coolpix camera with 16 MP 1/2.3" CMOS sensor that already includes coordinates and elevation above sea level of every photo.

To create a digital surface model (DSM) and a RGB orthophoto-mosaic of the settlement mound and its adjacent area, Structure-from-Motion techniques (SfM), a photogrammetric method for obtaining high-resolution datasets at a range of scales (Westoby et al., 2012), were applied by using Agisoft PhotScan 1.2.4. Correlating feature points between overlapping 2D images were detected and used to calculate the position and orientation of the camera at the moment of image acquisition (Verhoeven, 2011; Plets et al., 2012). To mitigate system errors, especially vertical offset, the created model was subsequently referenced with DGPS data. By manual identification, the correlating of the GCPs transformation from a relative to an absolute coordinated system was achieved and a meshed 3D surface was generated without any additional software needed for triangulation of the dense point cloud and orthomosaic generation (Westoby et al., 2012).

The DSM and the orthophoto were exported and further analyzed with ArcGIS software, namely with the Spatial Analysis module and the Grid Calculator toolbox, in order to calculate the area and volume of the settlement mound and potential source areas of the mound material.

3.4 Results

3.4.1 Sedimentology and Stratigraphy

3.4.1.1 Sediment Core ERG1-1

The core ERG1-1 was taken from the top of the mound *Ergeta 1* (Figures 3.1B, 3.4). From 12 to 10.71 m b.s. the core contains heterogeneous fine to medium sand (mean grain size 31-116 µm) which is characterized by low element concentrations of C, N, Zn, Cu and Pb. The Ca/Fe and Ca/K ratios reach levels of 0.4 (Ca/Fe) and 0.8 (Ca/K).

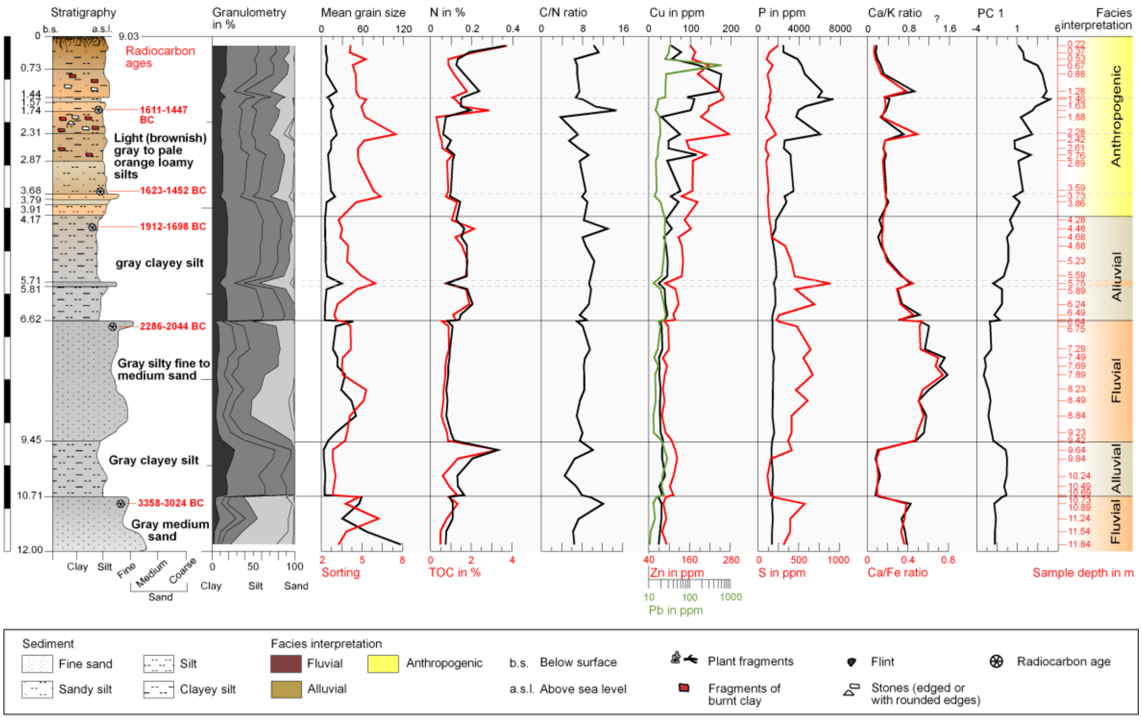

Figure 3.4: Facies interpretation, granulometry, geochemistry and ^{14}C age estimates of the sediment core ERG1-1 from the top of the settlement mound Ergeta 1. It represents the natural floodplain stratigraphy of alternating alluvial and fluvial sediments in the lower part and the settlement layers in the upper part.

The subsequent layer (10.71-9.45 m b.s.) consists of well sorted clayey silt (mean grain size ≤6 μm). In contrast to the preceding layer, there are higher values of N and C while metal ion concentrations remain at a low level, and Ca/Fe and Ca/K ratios are significantly lower. Subsequently, heterogeneous silty sand to sandy silt with a mean grain size between 10 and 50 μm reveals certain similarities to the lowermost strata in its geochemical composition in terms of increased S contents (~250-670 ppm), elevated Ca/Fe (0.47-0.74) and Ca/K ratios (0.96-1.56), and low C and N concentrations.

Well-sorted, gray silt (mean grain size <8 μm) was deposited between 6.62 and 4.17 m b.s. In the lower part of this core section, high and subsequently decreasing Ca/K and Ca/Fe ratios and S values are noticeable. However, intercalating sandy silt between 5.81 and 5.71 m b.s. shares characteristics with the layer below.

The uppermost part of the core, between 4.17 m b.s. and the surface, contains a succession of silt-dominated (mean grain size 6-22 μm) layers which are clearly distinguishable by their colour (in general light brownish gray to pale orange) and their content of burnt clay flitters, charcoal remains, and angular to subangular stones. This unit clearly differs from the other ones in terms of the higher concentrations of Zn, Cu and Pb, increased P and generally low S values, as well as low Ca/K and Ca/Fe ratios. Some remarkable turning points in the geochemistry subdivide layers of this unit at 3.68 m, 2.31 m and 1.44 m b.s. which coincide with the layers with and without an enrichment of brick and charcoal remains. The uppermost subunit is characterized by a Pb peak, decreasing P values as well as Ca/Ka and Ca/Fe ratios; N and C concentrations rise in the uppermost 50 cm.

3.4.1.2 Sediment Core ORU1-1

The lowermost stratum of core ORU1-1 (7.00-6.67 m b.s.; Figure 3.5), taken close to the top of mound *Orulu 1* (Figure 3.1C), is composed of homogeneous gray sand (mean grain size 20-80 μm) which is clearly separated from the subsequent silt (mean grain size <10 μm) between 6.67 and 3.46 m b.s. While sediments are well sorted between 6.67 and 5.61 m b.s. and contain reed remains coincident with high C/N ratios, the upper part of this unit is void of coarse plant fragments. A significant peak of C, N and S values occurs at 4.88 m b.s. The overlying strata consist of several layers of light brownish gray silt (slightly increased mean grain size between 7 and 15 μm) which are characterized by fluctuating amounts of burnt clay, charcoal fragments and several small stones. Beside the different colour and scattered anthropogenic macro remains, contents of S and ratios

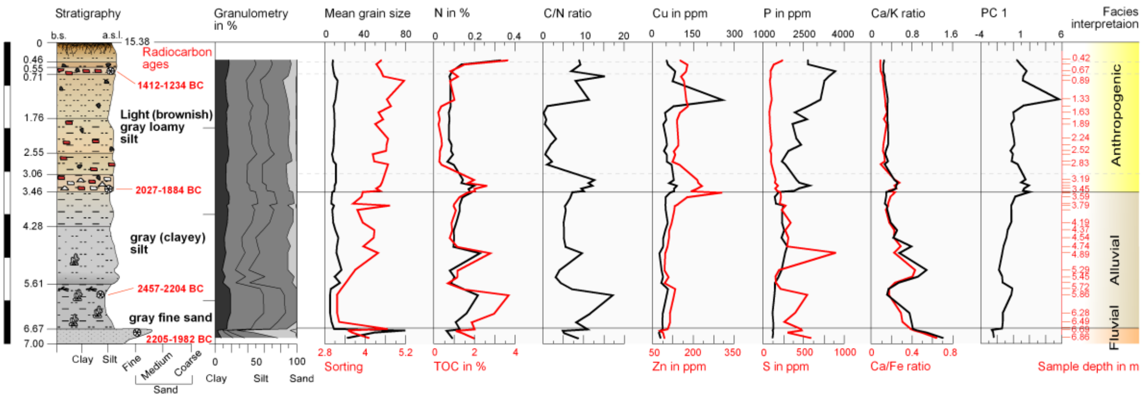

Figure 3.5: Facies interpretation, granulometry, geochemistry and ¹⁴C age estimates of the sediment core ORU1-1 from the top of the settlement mound Orulu 1 (legend see Fig. 3.4). In the small lowermost section the natural floodplain stratigraphy of alluvial and fluvial strata occurs while the upper part consists of the settlement layers.

of Ca/K and Ca/Fe remain at constantly low levels, the content of P rises steadily towards the surface, and Zn and Cu values peak at 3.47 and 1.33 m. b.s. up to 306 and 260 ppm, respectively. The uppermost 50 cm of the core are characterized by a grayish brown colour and a sudden increase in N and C.

3.4.1.3 Sediment Core ORU 2-1

ORU2-1 was taken from the top of mound *Orulu 2* (Figures 3.1C, 3.6). From the base of the sediment core at 5 m to 4.53 m b.s. it is composed of grayish silty fine sand (mean grain size ~30 µm). The section is characterized by poor sorting, low values of S, C and N, and high values of Ca/K and Ca/Fe. The subsequent silt layers (4.53-2.69 m b.s.) are

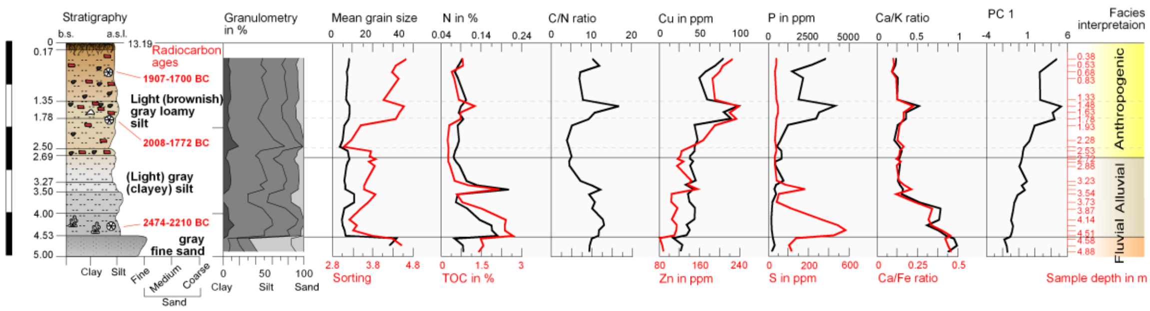

Figure 3.6: Facies interpretation, granulometry, geochemistry and ¹⁴C age estimates of the sediment core ORU2-1 from the top of the settlement mound Orulu 2 (legend see Fig. 3.4). The core is dominated by settlement layers. Only in the lowermost part the natural strata of the floodplain was reached.

light gray in colour, and have decreasing Ca/K and Ca/Fe ratios. In the lower part of the silt layers (4.53-4.00 m b.s.), various plant remains and relatively high values of S (up to 573 ppm) and N occur, which are absent in the upper part (except from 3.50 to 3.27 m b.s.).

From 2.69 m b.s. to the surface, several light (brownish) gray layers of changing charcoal flitter content (also reflected in TOC), and burnt clay fragments are present. A plant-rich zone with poor sorting and higher Cu, Zn and P concentrations and an elevated C/N ratio can be distinguished from the preceding strata. Especially the section between 1.78 and 1.35 m b.s. reveals peaks of Cu and Zn. In contrast, N, C, S and the mean grain size remain at constantly low levels without remarkable changes. At a depth of 1.62 m a flint flake of 3 cm was detected (Figure 3.3C).

3.4.1.4 Sediment Core ORU3

The lowermost stratigraphic unit between 12 m to 9.13 m b.s. is composed of homogeneous dark gray partly clayey fine silt (Figure 3.7). The mean grain size does not exceed 10 µm and, with the exception of a slight increase in Ca/K and Ca/Fe ratios, there are no remarkable changes in the geochemistry. Between 9.13 and 7.88 m b.s., alternating sandy silt to silty fine sand reveal a more heterogeneous and coarser mean grain size (6-65 µm) but no significant difference from the previous layer in their geochemical composition.

Above, the sedimentary succession is characterized by gray fine silt, with elevated levels of S, Ca/K and Ca/Fe between 7.24 and 6.54 m b.s. This section continues until 3.87 m b.s. where sand is intercalated. Between 3.53 and 3.28 m b.s., clayey silts, which match the previous silts in terms of geochemistry, were deposited. The overlying sand unit (3.28-2.24 m b.s.) reveals constantly high levels of Ca/K and Ca/Fe, as well as an elevated S concentration, while metal ions and P remain low.

The poorly sorted silt of the uppermost unit between 2.24 m b.s. and the surface differs from the preceding strata. S, Ca/K and Ca/Fe only reach constantly low levels. In contrast, P, Cu and Zn, to some extent also N and C, rise. Throughout the whole unit several small fragments of charcoal and burnt clay can be found.

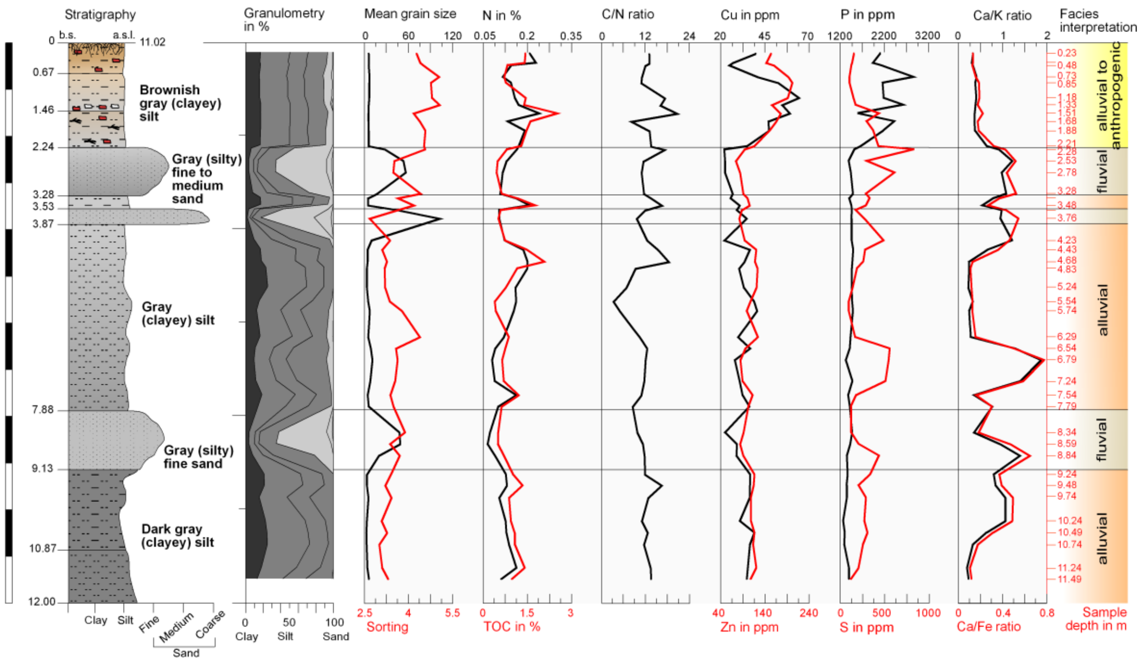

Figure 3.7: Facies interpretation, granulometry and geochemistry of the sediment core ORU3 from the area between the two mounds Orulu 1 and Orulu 2 (legend see Fig. 4). The natural floodplain stratigraphy of alternating alluvial and fluvial sediments is topped by layers with human impact.

3.4.1.5 Other Sediment Cores

In the area of the mounds *Orulu 1* and *Orulu 2*, three more cores were drilled (Figures 3.1C, 3.9). Sediment core ORU1-2 was taken from the slope of *Orulu 1*. It starts with poorly sorted clayey silt between 3.00 m b.s. and 1.39 m b.s. (in Figure 3.9A 11.38-9.77 m a.s.l.). The upper part is separated by a ca. 6 cm thick layer which consists of flitters of burnt clay and charcoal remains, embedded in clayey silts. The layers between 1.33 m b.s. and the surface (12.77-11.44 m a.s.l.) are similar to the lower part of the core, although they are slightly less sorted and contain charcoal remains.

Sediment core ORU2-2 was taken at the slope of mound *Orulu 2* (Figure 3.9). Its lowermost part (3.00-2.00 m b.s., 9.02-8.03 m a.s.l.) consists of loamy silt with several plant fragments. Above, a 22 cm thick fine sand layer was deposited, followed by several silt layers. Several remains of burnt clay and charcoal can be found in the upper part between 1.31 m b.s. and the surface. Another sediment core, ORU2-3, was taken in direct vicinity of mound Orulu 2, 6 m from ORU2-2 and 3 m from the ditch surrounding the mound. This 2-m-long core consists of loam. While the lower part contains some scattered plant remains, some fragments of burnt clay occur in the upper 0.67 m of the core.

Two further drillings were performed at mound *Ergeta 1* (Figure 3.1B). One sediment core (ERG1-2) was taken from the mound's slope, and another one in the plain surrounding the mound, ca. 7 m from its base (ERG1-3). The bottom part of ERG1-2 (4-2.51 m b.s.) consists of silt; plant fragments are abundant in its lower part. Above 2.51 m b.s., several layers of silt with charcoal remains and flitters of burnt clay occur. Sediment core ERG1-3 consists of homogeneous, very clayey silt with a lot of large plant fragments between 3 m and 0.89 m b.s. Above, laminated silts were deposited, which contain charcoal and burnt clay flitters.

3.4.2 Radiocarbon Dating Results

Altogether 12 samples from the three mounds were dated by ^{14}C-AMS. The results are given in the profile figures (Figures 3.4 to 3.7 and 3.9; all data in Table 3.1) with calibrated values (2 σ). In case of mound *Ergeta 1*, five samples from sediment core ERG1-1 were

Table 3.1: Radiocarbon data sheet. Calibration with Calib 7.1 software and IntCal13 data set (Reimer et al. 2013, following Stuiver & Reimer, 1993). Dating was carried out at the Poznan Radiocarbon Laboratory (lab code: Poz), Poland, and the ^{14}CHRONO Centre, Queens University Belfast (lab code: UBA), Northern Ireland, UK.

Sample ID	**Lab code**	**Depth below surface (m)**	**Material**	**δ^{13}C (‰)**	**Conventional ^{14}C-age BP**	**Calibrated ^{14}C-age (cal BC), 2 σ**
ERG1-1/10	Poz-83123	1.72	charcoal	-19.2	3245 ± 30	1611-1447 BC
ERG1-1/17	Poz-83124	3.60	charcoal	-19.5	3265 ± 35	1623-1452 BC
ERG1-1/21	Poz-83125	4.48	charcoal	-19.3	3495 ± 35	1912-1698 BC
ERG1-1/32	Poz-83126	6.75	wood	-22.3	3760 ± 30	2286-2044 BC
ERG1-1/48	Poz-83127	10.89	wood	-22.4	4490 ± 50	3358-3024 BC
ORU1-1/3	Poz-83128	0.67	charcoal	-22.6	3065 ± 30	1412-1234 BC
ORU1-1/20	Poz-83130	3.39	charcoal	-24.3	3590 ± 30	2027-1884 BC
ORU1-1/36	Poz-83131	5.86	plant remains	-18.1	3845 ± 35	2457-2204 BC
ORU1-1/41	Poz-83169	6.73	plant remains	-32.6	3715 ± 35	2205-1982 BC
ORU2-1/4	UBA-30020	0.68	charcoal	-22.3	3497 ± 32	1907-1700 BC
ORU2-1/9	UBA-30021	1.77	charcoal	-24.9	3550 ± 31	2008-1772 BC
ORU2-1/25	UBA-30022	4.26	wood	-26.0	3891 ± 41	2474-2210 BC

dated. The lowermost sample derives from the upper boundary of the sand layer at 10.89 m b.s. and dates to 3358-3024 B.C. (ERG1-1/48). The four other samples were taken from strata below (ERG1-1/32: 2286-2044 B.C.; ERG1-1/21: 1912-1698 BC) and within (ERG1-1/17: 1623-1452 BC; ERG1-1/10:1611-1447 BC) the settlement layers at depths between 6.75 and 1.72 m b.s. They cover a time span from the late 3rd to the mid-2nd millennium BC.

Samples for radiocarbon dating were also taken from both mounds at Orulu: Four samples from ORU1-1 (*Orulu 1*) at depths between 6.73 and 0.67 m b.s., covering a time span between the late 3rd millennium the second half of the 2nd millennium BC. In case of mound *Orulu 2* three samples of core ORU2-1 from depths between 4.26 and 0.68 m b.s. were dated, covering a time span from the second half of the 3rd millennium to the first half of the 2nd millennium B.C.

3.4.3 Statistical Analyses of Sedimentological and Geochemical Data

Based on the geochemical and granulometric results different bi- and multivariate plots were constructed (Figures 3.8A, B) to compare and contrast different facies, and to separate natural layers from anthropogenic ones.

To determine a potential anthropogenic origin of sediment layers comprising the mounds, metal ions (Zn, Cu, Pb) and P concentrations were chosen as elements associated with human activity (Oonk, Slomp, & Huismann, 2009; Dirix et al., 2015). For a further determination of the different facies, a statistical tool (PCA) was used based on five parameters (Ca, Zn, Cu, P and mean grain size; Figure 3.8A). While an increasing grain size and high Ca contents coincide with negative loadings of PC 1, elevated values of P, Zn and Cu correspond to positive loadings of PC 1. The analysed samples of cores ERG1-1, ORU1-1, ORU2-1 and OUR3 cluster in three groups: while the first two groups reveal negative values of PC 1 and are separated due to differences in grain size (i.e. positive and negative values of PC 2), the third sample group is indicated by positive values of PC 1, i.e. these samples are characterised by comparatively high P, Zn and Cu contents. For cores ERG1-1, ORU1-1 and ORU2-1, PC 1 (ERG1-1: 65 %, ORU1-1: 58.3 %, ORU2-1: 78.7 %) was plotted against depth. In general, samples taken from the upper part of the mounds' stratigraphy positively correlate with PC 1, while samples from sediment layers reveal decreasing values.

In addition, we used the enrichment of Zn as a marker for anthropogenic activity and plotted the parameter against Al, which is acknowledged as a general geogenic element often used as a normalizer in calculations of enrichment ratios (Walraven et al., 1997; Dung et al.,

2013) (Figure 3.8B). Even though the Zn/Al ratio shows a distribution in x-direction which derives from generally elevated Al values of the samples of core ORU2-1, the graph indicates a clear grading in the Zn contents. Samples with high Zn values correlate with the samples which reveal high positive correlation to the PC 1 in Figure 3.8A.

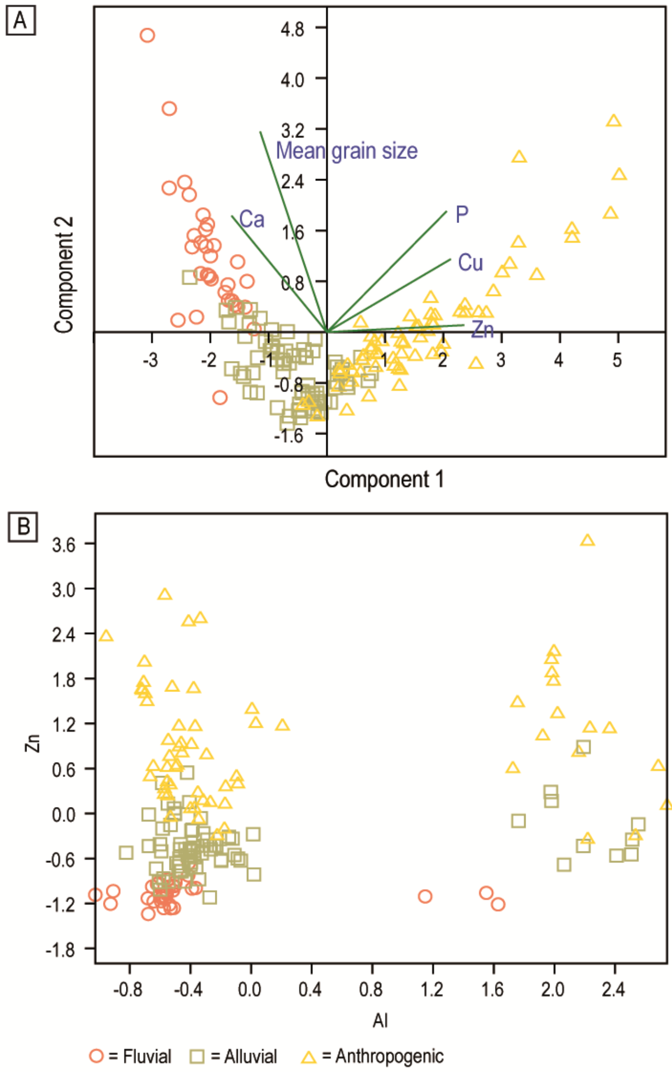

Figure 3.8A: Principal component analysis (PCA) of the samples taken from the cores ERG1-1, ORU1-1, ORU2-1 and ORU 3. Five PCs were used. The spatial distribution is based on components 1 and 2 with a variance of 44.8 % and 25.1 %, respectively (further variances: PC 3: 14 %, PC 4: 11.5 %, PC 5: 4.6 %). The differential clustering of the three different facies types "fluvial", "alluvial" and "anthropogenic" is obvious.

Figure 3.8B: Plot of normalized Al and Zn concentrations to decipher the human influence. The distribution in x-direction is considered to be caused by the higher content of Al in the sediment core ORU2-1 (Walraven et al., 1997; Dung et al., 2013).

3.4.4 Remote Sensing, DSM and volume estimation of Mound *Ergeta 1*

Using drone survey and SfM techniques in combination with DGPS information, a total area of 0.98 ha could be measured with a ground pixel resolution of 0.01 m of the orthophoto. The provided error estimations for the reconstructed 3D model with regards to GCPs are less than 0.1 m, thus allowing us to perform high accuracy calculations. Based on the average elevation of the present surface around the Ergeta mound (DSM resolution 0.05 m), estimated to 3.87 m a.s.l., the present-day area and volume of mound *Ergeta 1* (Figures

3.1B, 3.2A & 3.4) were calculated (Figure 3.10). The mound covers an area of 1241 m^2 and contains a volume of approximately 4205 m^3. It is encircled by a wide moat (depth 40-60 cm) which covers 6610 m^2, with a total volume of 355 m^3 with respect to the average elevation of the surrounding surface (3.87 m a.s.l.).

3.5 Discussion

3.5.1 Facies Determination

Based on the results of the geochemical, granulometric and statistical analyses, the stratigraphy of the Ergeta and Orulu cores is characterised by the succession of three different facies types. They represent different depositional environments.

3.5.1.1 Facies 1: Fluvial (Channel Deposits)

In the lower parts of all sediment cores taken from the top of the settlement mounds (ERG1-1, ORU1-1, ORU2-1), and in large sections of core ORU3 taken between the settlement mounds *Orulu 1* and *Orulu 2* (Figures 3.4 to 3.7), layers void of micro- and macrofauna and composed of sandy silt to silty sand with poor sorting (in general values of ~3-5, i.e. poorly to very poorly sorted) were found. Low values of N and TOC represent low contents of organic matter, while the low C/N ratio probably implies non-terrestrial vascular plants or algae (Meyers & Teranes, 2001). Low contents of Cu, Zn, Pb and P indicate the absence of anthropogenic activities, e.g. due to metallurgy and agriculture (Nicosia et al., 2013; Miller et al., 2014). Considering these characteristics and the sites' location on the floodplain, which is dominated by numerous rivers of different size (Figure 3.1A), these sediments can be considered fluvial deposits (Sun et al., 2002; Boggs, 2006).

3.5.1.2 Facies 2: Alluvial (Floodplain Deposits/Overbank Deposits)

Facies 2 forms, together with the interdigitating fluvial sediments of Facies 1, the foundation of the mounds, and particularly occurs directly below the settlement strata (Figures 3.4 to 3.7). It consists of silty clay to clayey silt, which is slightly better sorted in comparison to the other facies. The Ca/Fe and Ca/K ratios are lower than in Facies 1, but can still be considered as aquatic, although the decrease can also be an effect of the smaller grain size (Vött, Handl, & Brückner, 2002; Vaněk et al., 2005; Davies, Lamb, & Roberts, 2015). Peaks of S, often accompanied by elevated Fe concentrations, may indicate anoxic conditions (Harff et al., 2011; Kylander et al., 2011) which would reflect the varying hydrodynamic conditions typical for wetlands with swamp areas and fluctuating freshwater input. The relatively low C/N ratios (values of ~8) suggest a dominance of non-terrestrial vascular plant material, algae and sphagnum (Meyers & Teranes, 2001). Based on these results Facies 2 is assumed to represent wetland-related deposition, i.e. on an alluvial floodplain with a diverse spectrum of swamps, ponds, stagnant water and (flooded) plains. The further lowering of S, Ca/Fe and Ca/K in the uppermost parts of Facies 2 can be explained by the increasing terrestrial character and the transition to less swampy conditions (Davies, Lamb, & Roberts, 2015).

3.5.1.3 Facies 3: Anthropogenic

The grain size of Facies 3 is dominated by silt and clay, similar to the alluvial deposits below. Facies 3 occurs in the upper sections of the cores from the centre of the settlement mounds where it can be clearly separated (sharp boundary) from the underlying alluvial deposits of Facies 2. However, in the uppermost part of ORU3, a more gradual transition from Facies 2 to Facies 3 is observed, making a clear separation difficult. In contrast to the underlying alluvial facies, the samples of Facies 3 are less sorted which might be explained by anthropogenic disturbance. The presence of burnt clay flitters and charcoal suggests possible anthropogenic surface or destruction layers (Figures 3.3 to 3.6), though there were no diagnostic ceramics, wooden beams or other macro-remains of constructions found. While Ca/K and Ca/Fe ratios and S concentrations remain on a continuously low level, suggesting terrestrial and non-swampy conditions (Arz, Pätzold, & Wefer, 1998; Kylander et al., 2011; Davies, Lamb, & Roberts, 2015), heavy metals (Pb, Cu, Zn) stand out with high concentrations which is expressed in increased values of PCA-Axis 1 and the enrichment of Zn (PC 1, Figures 3.3 to 3.7). These characteristics may be explained by metallurgy (Guyard et al., 2007; Oonk, Slomp, & Huismann, 2009; Miller et al., 2014). The selective peaks of Pb, in contrast to the rather uniform pattern of higher Cu and Zn values, can be explained by the different mobility of the elements (Vaněk et al., 2005). The elevated P values indicate agriculture and animal husbandry (McLauchlan, 2006; Corella et al., 2012; Nicosia et al., 2013). Due to the relatively immobility of P, in both organic and inorganic forms, it can persist for centuries to millennia at ancient farming sites (Eidt, 1977; Dupouey et al., 2002; Holliday & Gartner, 2007). All of these characteristics indicate a high anthropogenic influence and differentiate Facies 3 clearly from Facies 1 and 2.

3.5.2 Chronostratigraphic Interpretation and Palaeoenvironmental Setting

The three settlement mounds and their environments share several similarities: In all sediment cores the lower layers are built up by a sequence of interdigitated fluvial and alluvial sediments of Facies 1 and 2, which can be interpreted as a typical stratigraphy of a coastal plain, with constantly shifting river beds and flooding on an alluvial plain (Boggs, 2006; Figure 3.9). This interplay existed at the site of the Ergeta at least since the second half of the 4th millennium BC, which is indicated by a ^{14}C-dated sample at 10.89 m b.s. of sediment core ERG1-1 (Table 3.1). As for the Orulu mounds, a ^{14}C age estimate from an alluvial layer proves that these conditions existed since the 3rd millennium BC. ORU3 reveals the alternation of fluvial and alluvial deposits down to 12 m b.s., which suggests that these conditions had already established during mid-Holocene times, as observed in the central part of the Kolkheti lowlands (Laermanns et al., 2017).

As Facies 2 is underlying Facies 3 in most cases, the settlement mounds are based on alluvial sediments. They consist of several layers of varying thickness, potentially representing different phases of occupation or construction. The oldest anthropogenic stratum of Facies 3 was found at mound *Orulu 1* dating to the late 3rd to early 2nd millennium BC (ORU1-1/20, 3.39 m b.s., 2027-1884 B.C.; Table 3.1, Figure 3.5).

Based on the stratigraphic analysis of the mounds, the anthropogenic layers do not continue below the present ground level and have similar or even higher elevations with respect to the surrounding ground surface. While in case of the mound *Ergeta 1* a difference of 10 cm and in case of *Orulu 2* of 15 cm is negligible, there is a significant discrepancy of ~80 cm in case of *Orulu 1*, which may hint at a naturally elevated position during the time of foundation.

Facies 3 is also present in the core between the settlement mounds (e.g. sediment core ORU3; Figure 3.7). It is deposited on top of Facies 2; but in contrast to the sharp boundary below the mounds, a gradual transition from Facies 2 to 3 occurs here. It is unclear whether these sediments were mixed by ploughing, whether they represent colluvial/alluvial material, or whether they belong to an in-situ settlement layer. The enrichment of burnt clay fragments between ~1.35 and 1.46 m b.s., for example, could hint at an anthropogenic surface. However, for the part located directly above the fluvial sand (2.24-1.46 m b.s.), the latter assumption seems unlikely. Nevertheless, it confirms that the area between the hills was also used for settlements or agriculture in ancient times (Lordkipanidze, 1991; Fähnrich, 2010; Gamkrelidze, 2012). An intensive use of the environs of the mounds would be comparable to the situation of the mounds of the Great Hungarian plain (Raczky & Anders, 2008).

A comparison with the well-investigated site of Ispani, which is also located on the Colchian plain in a comparable setting ca. 60 km south of the research area, gives information on possible climatic conditions during the time of the mounds' construction. Pollen records indicate species-rich open wetland forests which persisted from the 3rd to 1st millennia BC (Connor, Thomas, & Kvavadze, 2007; de Klerk et al., 2009; Shatilova, Rukhadze, & Mchedlishvili, 2010). Based on the pollen evidence of expanding *Zelkova* and *Castanea* forests, Kvavadze & Connor (2005) highlight a warm and humid Sub-Boreal climate optimum between 1850 and 400 B.C. for Western Georgia. This implies a predominance of humid, swampy conditions during the mounds' formation (cf. Connor, Thomas, & Kvavadze, 2007; Connor & Kvavadze, 2008; de Klerk et al., 2009; Figure 3.11), which may point to an intentional construction of the mounds allowing their inhabitants to establish small settlements within the swampy Colchian floodplain.

Additionally, a rising groundwater table, attributed to the sea-level evolution of the Black Sea, should be discussed, as it would possibly have provoked successive enlargements of the mounds. The relative sea level (RSL) reached nearly its current state (between -1.5 and 0 m below mean sea level) about 3000 BC (Giosan et al., 2006; Brückner et al., 2010; Fouache et al., 2012; Kelterbaum et al., 2012; Laermanns et al., 2017), and subsequent sea-level oscillations of ~1 m might have affected the settlement conditions in the marshlands close to the coast. However, it can be considered to have had only a minor effect on the areas of the investigated mounds, which are located at an altitude between ca. 4 and 11 m a.s.l. Although they did not live nor travel to this area, some ancient authors – starting with Hippocrates, at the end of the 5th century BC, mentioned above – were aware of the settlement hills with surrounding moats located in swampy forests of the Colchis. Even though such historical sources are to be considered with caution, the descriptions match the geoarchaeological results of this study and palaeoclimatical scenarios (e.g. de Connor, Thomas, & Kvavadze, 2007).

3.5.3 Size and Source Material of the Mounds

In comparison with settlement mounds of other regions (e.g. Thessaly: >20,000 m² [Runnels et al., 2009], Çukuriçi Höyük: ca. 16,000 m²; Arvalya Höyük: 5,000 m² [Stock et al.,

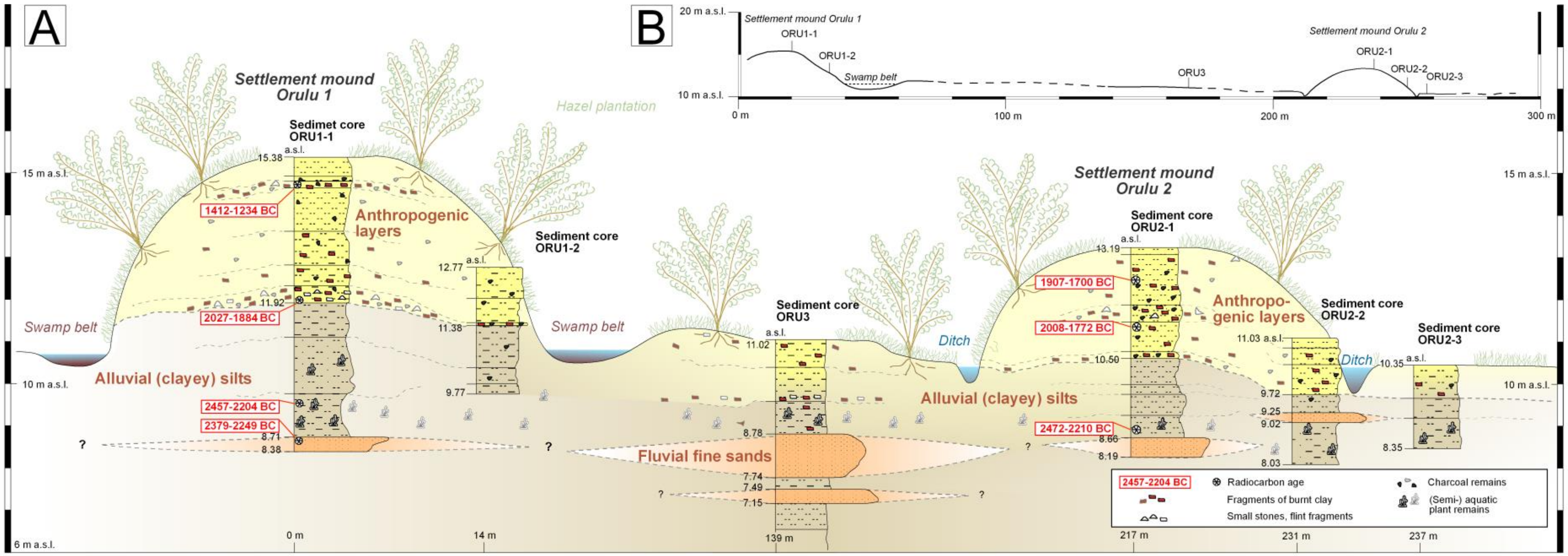

Figure 3.9A: Schematic cross section of the two settlement mounds Orulu 1 and Orulu 2, with the sediment cores taken from this area. Real distances shown in B (further comparison in Figure 3.1B). The calibrated radiocarbon ages indicate the succession of fluvial and alluvial deposits and the subsequent anthropogenic construction of the mounds. The colours were chosen in correspondence with the determined facies of Figure 3.8.

2015], Hungarian plain: >10,000 m² [Parkinson & Gyucha, 2012]), Flanders: 3,600 m² [Ervynck et al., 2012], Groningen, NL: 75 m diameter = ~4,000 m² [van Es, 1983]), *Ergeta 1* – with an area of ~1,250 m² and a volume of ca. 4,200 m³ – is of comparably small size. As to the origin of the mound material, sediments of Facies 3 have a similar mean grain size as the underlying Facies 2. The ditch, dug by the present landowner (Figure 3.10A, B), encircles an area with a 40 to 60 cm lowered surface elevation compared to the level outside the ditch (Figure 3.10C). The farmer reported that he did so in order to drain the very swampy area surrounding the mound.

The area encircled by the ditch covers 6,610 m^2, with a total volume of only 355 m^3 below the average level of the surrounding surface (Figure 3.10A). Assuming that this was the source for the construction material, we have to estimate the possible initial depth of the surrounding moat. Considering that for the given area each layer of 0.01 m thickness will produce 66 m^3, the moat must have been at least deeper than 0.65 m to contain a volume equivalent to the current total volume of the recent mound. Also, considering the transportation of the material, it appears as the most obvious source for the construction material of *Ergeta 1*. The infill of this ancient moat was probably a consequence of the erosion of the mound, which must be assumed since its erection 4000 years ago bearing in mind the warm and humid climate, especially during the Sub-Boreal climate optimum lasting from 1850 to 1400 BC (Kvavadze & Connor 2005; Arslanov, Dolukhanov, & Gei, 2007; see Figure 3.11). The swampy conditions in the moat are reflected in the fine-grained deposits, which are revealed in the sediment core ERG1-3. It is, therefore, very likely that the mound once was higher and consequently the moat deeper.

In comparison, the recent situation of the other investigated mounds in Orulu is different due to the overprint by plantations and gardening. In the case of *Orulu 1*, a ca. 10 m wide circular swamp surrounds the mound (Figures 3.1C, 3.2, 3.9); this gives an impression what the area around *Ergeta 1* had looked like before the modern drainage. In the case of *Orulu 2*, no circular depression is recognizable except for the narrow ditch at the foothill, which is probably a product of recent drainage to reclaim that area for agriculture.

The oldest examples of the phenomenon of ditching circular moats around (artificially) elevated settlements were found in the lower Danube Valley and date around 5500 BC (Parkinson & Duffy, 2007). It is known from other regions all over Europe and the Middle East, e.g. the Bronze Age settlement of Fidvár, Slovakia (Gauss et al., 2013), and the Körös Valley, Hungary (Parkinson et al., 2004), where comparably wide circular moats in the forefront of a mound were built for fortification. Although similar patterns are observed in our study area and particularly around mounds *Ergeta 1* and *Orulu 1*, it remains open if the conclusions from Slovakia and Hungary can be transferred to the Colchian mounds, which are of considerably smaller size and which are situated in different morphological and climatic contexts.

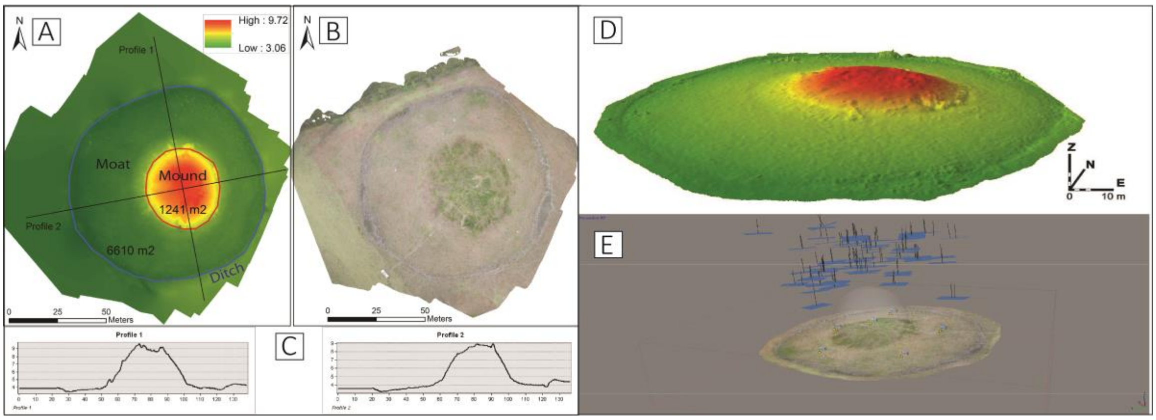

Figure 3.10: A: DEM. The blue line marks the encompassing ditch that was dug by the present landowner. B: Orthophoto. The green colour of the mound originates from the scrub vegetation while the surrounding humid area reveals the brownish-green colour of the swamp vegetation. C: Elevation cross sections. The topographic cross sections show that the encompassing area lies below the surrounding surface; it probably served as the source of the construction material. D: 3D model of the settlement mound Ergeta 1 and its surrounding with the angles of the single pictures (E). The projections combine overlapping 2D UVA-pictures with Agisoft PhotoScan 1.2.4 software, finally created with ArcMAP GIS software.

3.5.4 Mode of Construction and Occupation Phases

In the case of the mounds *Ergeta 1* and *Orulu 2* (Figures 3.4, 3.6, 3.9), the stratigraphic layers of the mounds are roughly of similar age. At *Ergeta 1*, ages from below and above a 2.12 m-thick anthropogenic layer are overlapping (1623-1452 B.C. and 1611-1447 B.C.; Table 3.1, Figure 3.4). At *Orulu 2*, the overlapping ages of 2008-1772 B.C. and 1907-1700 B.C. comprise 1.1 m of anthropogenic layers (Table 3.1, Figure 3.6). At *Orulu 1*, material from the lowermost, and therefore oldest, anthropogenic layer (3.46-3.06 m b.s.) was dated to the beginning of the 2^{nd} millennium BC (charcoal; 2027-1884 B.C.; Figures 3.5, 3.9, Table 3.1), thus overlapping with the radiocarbon ages from *Orulu 2*. In contrast, the second radiocarbon age, 2.72 m above the first one, is 1412-1234 B.C. Hence, the upper layer at *Orulu 1* seems to be ~470-800 years younger, and the construction and/or occupation of *Orulu 1* may have taken place over several centuries, while the other two mounds were built during one phase.

Nevertheless, the possibility of reworked charcoal must be taken into consideration as well, which might lead to an erroneous age estimate for (i) the duration of the temporal gap between the different ages, and/or (ii) the onset of the occupation. Although reworking cannot be excluded for the lower radiocarbon ages at the base of the anthropogenic layers at *Orulu* 1 and *Orulu* 2, and these ages thus represent maximum ages only, the age overlap suggest a contemporary construction and/or occupation of both mounds at ~2000-1800 B.C. At least one further period of construction and/or occupation must be assumed due to the chronological and stratigraphic gap in *Orulu 1*, which took place at around or after ~1400-1230 B.C.

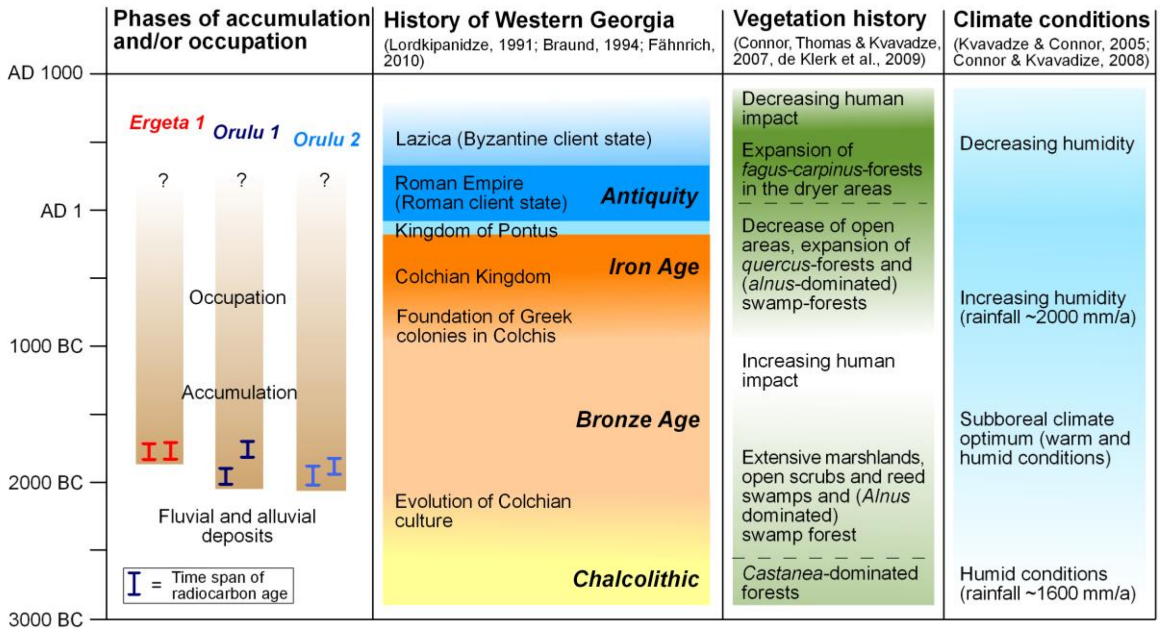

Figure 3.11: Chronology of the geoarchaeological and palaeoenvironmental evolution of the settlement mounds and their surroundings. The first column shows time span of accumulation of the mounds based on the radiocarbon dating results and the possible occupation. While the second column gives an overview of the early and ancient history of the region (Lordkipanidze, 1991; Braund, 1994; Fähnrich, 2010), the third and fourth columns are based on assumptions on the vegetation history (Connor, Thomas, & Kvavadze, 2007; de Klerk et al., 2009) and on climate variations (Kvavadze & Connor, 2005; Connor & Kvavadze, 2008) derived from palynological research.

In addition, determining the type and purpose of the settlements mounds – i.e., constructed or cumulative – remains challenging. In general, the warm and humid climate and the swampy conditions at that time (Connor, Thomas, & Kvavadze, 2007; de Klerk et al., 2009; Laermanns et al., 2017), the rather short accumulation phase of *Ergeta 1* and *Orulu 2* (Figure 3.11), and the similar ages at the base of *Orulu 1* and *Orulu 2* all suggest an intentional construction of the mounds within a short time period. This contradicts the nature of formation of tells with their successive accumulation in space and time, e.g. in Thessaly with >20,000 m² (Runnels et al., 2009) and in Western Anatolia with ca. 16,000 m² and 5,000 m² (Stock et al., 2015). In this case, the radiocarbon ages represent maximum ages for the mounds' construction rather than information on occupation periods. On the other hand, assuming a successive evolution of the mounds due to the stepwise accumulation of settlement layers, the radiocarbon ages would indicate the effective time span of occupation. In the case of *Orulu 1*, where a chronostratigraphic gap and a subsequent second re-occupation phase is recorded, a tell-type mound or a hybrid form can be assumed, i.e. with an intentional initial construction of the mound's lower part, and a subsequent re-occupation several centuries later. In any case, the circular moat comparable to *Ergeta 1* and the same setting with *Orulu 2* suggest that *Orulu 1* has, at least, a similar cultural background and originates from the same period.

However, since the initial formation of all three mounds can be dated to the first half of the 2nd millennium BC, they coincide with the local Early to Middle Bronze Age (Figure 3.11). These results corroborate previous assumptions about the mounds' ages based on archaeological findings at different sites (Lordkipanidze, 1991; Greppin, 1991; Fähnrich, 2010). Apparently, the phenomenon of settlement mounds occurs relatively late in Western Georgia, compared to the settlement mound *Aruchlo I* in eastern Georgia dated to the 6th millennium BC (Hansen, Mirtskhulava, & Bastert-Lamprichs, 2007) and other regions, e.g. in Anatolia (Çilingiroğlu, Çevik, & Çilingiroğlu, 2012; Horejs, 2012), where sites date back to the 7th millennium BC. Even in areas with a comparable distance to the source region in the Fertile Crescent (e.g. Thessaly and the Hungarian Plain), Neolithic mounds already existed 5000 BC (Parkinson & Gyucha, 2012).

3.6 Conclusions

In this study, three Bronze Age settlement mounds in the northern part of the Colchian plain of Western Georgia were investigated within the framework of geoarchaeological research. Using geochemical and granulometric analyses, anthropogenic sediment layers, i.e. relating to the construction of the mounds, could clearly be distinguished from the underlying alluvial deposits. As has been shown in previous studies for the central Colchian plain, palaeoenvironmental conditions in its northern part before and at the time of the mounds' construction were characterised by extensive wetlands with fluctuating alluvial to fluvial deposition, at least since the 4th millennium BC. By means of DPGS data and aerial images we showed that the construction material of the mounds most likely originated from the area directly surrounding the mounds, which is indicated by wide circular moats.

The initial construction of the mounds took place during the Bronze Age, more precisely in the first half of the 2nd millennium BC. The new data confirm the assumption that the Colchian mounds are of Bronze age origin; thus, they are rather young as compared to mounds in Eastern Georgia, the Mediterranean, Anatolia or on the Balkans. While mound *Orulu 1* seems to have been built in several phases, spanning between ~470 and 800 years, it seems that the mounds *Orulu 2* and *Ergeta 1* were erected in one construction phase. The site of *Ergeta 1* was occupied some time later during this period. However, while the radiocarbon ages of this study and the sedimentary succession of the investigated cores suggest an internal stratification of the mounds, it remains challenging to chronologically differentiate particular consecutive construction or occupation phases, or to identify the timing of the abandonment. Though an ultimate classification as tell-type mounds or intentional construction is yet to be verified, the short-term occupation and the wetland landscape of the two millennia BC lend support to constructed settlement mounds. Further chronological investigations, e.g. using optically stimulated luminescence, may help to detail the chronostratigraphy. While the geoarchaeological investigations of this study already present valuable data on the origin of the settlement mounds in the northern Colchian plain, follow-up archaeological excavations are needed to clarify the internal structure of the mounds. These data will help in ultimately resolving the question whether the mounds consist of a constructed or cumulative stratigraphy, and, thereby, provide important and new information on these Colchian prehistoric communities, e.g. implications for land use practices, labor organization, and/or construction technology.

The mounds on the Colchian plain stand out with their young age, small size and grouped occurrence; as such, they notably differ from numerous mounds described from other regions. In this regard, the rather late time of construction may be explained by the landscape evolution in the Colchian plain. Due to the presence of extensive wetlands during the mid-Holocene, and the transformation from open lagoons to an alluvial plain that took place between the 4th and the mid-2nd millennium (Laermanns et al., 2017), favourable conditions for the occupation of the Colchian lowlands seem to have developed only shortly before the 2nd millennium BC.

3.7 Acknowledgements

H.L. gratefully acknowledges the funding of his PhD project by the Heinrich Böll Foundation as well as by the Graduate School of Geosciences (GSGS) and the Albertus Magnus Graduate Center, both at the University of Cologne; the latter funded his research stay at the Université de Franche-Comté in Besançon. We express our thanks to the students from the Ilia State University at Tbilisi and the University of Cologne involved in fieldwork in March-April 2015, and to all colleagues from Georgia who rendered scientific, administrative and logistic help. The Ilia State University provided accommodation during fieldwork in the Grigoleti Marine Research Centre. The Georgian farmers in Orulu allowed us to perform fieldwork on their grounds and generously offered us their hospitality. Finally, we thank the anonymous reviewers for their constructive and encouraging advice and feedback.

3.8 References

Adamia, S., Zakariadze, G., Chkhotua, T., Sadradze, N., Tsereteli, N., Chabukiani, A., & Gventsadze, A. (2011). Geology of the Caucasus: A review. Turkish Journal of Earth Sciences, 20, 489-544.

Arslanov, K.A., Dolukhanov, P.M., & Gei, N.A. (2007). Climate, Black Sea levels and human settlements in the Caucasus Littoral 50,000-9000 BP. Quaternary International, 167-168, 121-127.

Arz, H.W., Pätzold, J., & Wefer, G. (1998). Correlated millennial-scale changes in surface hydrography and terrigenous sediment yield inferred from last-glacial marine deposits off Brazil. Quaternary Research, 50, 157-166.

Bazhenov, M.L., & Burtman, V.S. (2002). Eocene paleomagnetism of the Caucasus (southwest Georgia): Oroclinal bedding in the Arabian syntaxis. Tectonophysics, 344, 247-259.

Blott, S.J., & Pye, K. (2001). Technical communication, GRADISTAT: A grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surface Processes and Landforms, 26, 1237-1248.

Boggs, S. (2006). Principles of Sedimentology and Stratigraphy. New Jersey, USA. Pearson Prentice Hall.

Braund, D. (1994). Georgia in Antiquity. A history of Colchis and Transcaucasian Iberia 550 BC – AD 562. 359 pp. Oxford: Clarendon Press.

Brückner, H., Kelterbaum, D., Marunchak, O., Porotov, A., & Vött, A. (2010). The Holocene sea level story since 7500 BP – lessons from the Eastern Mediterranean, the Black and the Azov Seas. Quaternary International, 225, 160-179.

Çilingiroğlu, A., Çevik, Ö., Çilingiroğlu, Ç. (2012). Ulucak Höyük. Towards Understanding the Early Farming Communities of Middle West Anatolia: The Contribution of Ulucak. In: M. Özdoğan, M. Başgelen, & P. Kuniholm (Eds.), The Neolithic in Turkey, 4 (pp. 139-175). Istanbul: Archaeology and Art Publications

Connor, S., Thomas, I., & Kvavadze, E. (2007). A 5600-yr history of changing vegetation, sea levels and human impacts from the Black Sea coast of Georgia. The Holocene, 17, 25-37.

Connor, S., & Kvavadze, E. (2008). Modelling late Quaternary changes in plant distribution, vegetation and climate using pollen data from Georgia, Caucasus. Journal of Biogeography, 36, 529-545.

Corella, J., Brauer, A., Mangili, C., Rull, V., Vegas-Vilarrúbia, T., Morellón, M., & Valero-Garcés, B. (2012). The 1.5-ka varved record of Lake Montcortès (southern Pyrenees, NE Spain). Quaternary Research, 78, 323-332.

Dan, A. (2014). Xenophon's Anabasis and the common Greek mental modelling of spaces. In: K. Geus, & M. Thiering (Eds.), Features of Common Sense Geography: Implicit Knowledge Structures in Ancient Geographical Texts (pp. 157-198). Münster: LIT Verlag.

Dan, A. (2016). The rivers called Phasis. Ancient West and East, 15, 245-277.

Darvill, Th. (2008). The Concise Oxford Dictionary of Archaeology. (432 pp.) Oxford University Press.

Davies, S., Lamb, H., & Roberts, S. (2015). Micro-XRF core scanning in palaeolimnology: Recent developments. In: I. Croudace, & R. Rothwell (Eds.), Micro-XRF Studies of Sediment Cores, Developments in Paleoenvironmental Research, 17 (pp. 189-226). Cambridge, UK: Springer.

Denk, T., Frotzler, N., & Davitashvili, N. (2000). Vegetational patterns and distribution of relict taxa in humid temperate forests and wetlands of Georgia (Transcaucasia). Biological Journal of the Linnean Society, 72, 287-332.

Dirix, K., Muchez, P., Degryse, P., & Poblome, J. (2015). Spatial distribution of elemental enrichments around archaeological sites: Insights from the ancient city of Sagalassos in Southwest Turkey. Geoarchaeology, 31, 34-48.

Dung, T.T.T., Cappuyns, V., Swennen, R., & Phung, N.K. (2013). From geochemical background determination to pollution assessment of heavy metals in sediments and soils. Reviews in Environmental Science and Biotechnology, 12, 335-353.

Dupouey, J.L., Dambrine, E., Laffite, J.D., & Moares, C. (2002). Irreversible impact of past land use on forest soils and biodiversity. Ecology, 83, 2978-2984.

Eidt, R.C. (1977). Detection and examination of anthrosols by phosphate analysis. Science, 1971, 1327-1333.

Eppelbaum, L., & Khesin, B. (2012). Geophysical Studies in the Caucasus. Lecture Notes in Earth System Sciences. Berlin, Heidelberg: Springer.

Ervynck, A., Deckers, P., Lentacker, A., Tys, D., & Van Neer, W. (2012). 'Leffinge-Oude Werf': the first archaeozoological collection from a terp se lement in coastal Flanders. In: D.C.M. Raemaekers, E. Esser, R.C.G.M. Lauwerier & J.T. Zeiler (Eds.), A Bouquet of Archaeozoological Studies. Essays in Honour of Wietske Prummel (Groningen Archaeological Studies 21). Groningen, Barkhuis/Groningen University Library.

Es, W.A. van (1983). Paddepoel, Excavations of frustrated terps, 200 BC-250 AD. Palaeohistoria, 25, 187-352.

Fähnrich, H. (2010). Geschichte Georgiens. Handbuch der Orientalistik (Volume 21). Leiden, Koninklijke Brill NV.

Foerster, V., Junginger, A., Langkamp, O., Gebru, T., Asrat, A., Umer, M., Lamb, H., Wennrich, V., Rethemeyer, J., Nowaczyk, N., Trauth, M., & Schaebitz, F. (2012). Climatic change recorded in the sediments of the Chew Bahir basin, southern Ethiopia, during the last 45,000 years. Quaternary International, 274, 25–37.

Folk, R.L., & Ward, W.C. (1957). Brazos river bar: A study in the significance of grain size parameters. Journal of Sedimentary Petrology, 27, 3-26.

Fouache, E., Kelterbaum, D., Brückner, H., Lericolais, G., Porotov, A., & Dikarev, V. (2012). The Late Holocene evolution of the Black Sea – a critical view on the so-called Phanagorian regression. Quaternary International, 266, 162-174.

Gamkrelidze, G. (2012). Researches in the Iberia-Colchology (History and Archaeology of ancient Georgia). Tbilisi, Georgian National Museum.

Gauss, R.K., Bátora, J., Nowaczinski, E., Rassmann, K., & Schukraft, G. (2013). The Early Bronze Age settlement of Fidvár, Vráble (Slovakia): Reconstructing prehistoric settlement patterns using portable XRF. Journal of Archaeological Science, 40, 2942-2960.

Giosan, L., Donnelly, J.P., Filip, F., Ovejanu, I., Vespremeanu-Stroe, A., Vespremeanu, E., & Duller, G.A.T. (2006). Young Danube delta documents stable Black Sea level since the middle Holocene: Morphodynamic, paleogeographic, and archaeological implications. Geology, 34, 757-760.

Giosan, L., Filip, F., & Constantinescu, S. (2009). Was the Black Sea catastrophically flooded in the early Holocene? Quaternary Science Reviews, 28, 1-6.

Gobejishvili, R., Lomidze, N., & Tielidze, L. (2011). Late Pleistocene (Würmian) Glaciations of the Caucasus. In: J. Ehlers, P. Gibbard, & P. Hughes (Eds.), Developments in Quaternary Science, 15 (pp. 141-147). Amsterdam.

Greppin, D. (1991). Some effects of the Hurro-Urartian people and their languages upon the earliest Armenians. Journal of the American Oriental Society, 111.4, 720-730.

Groenhuijzen, M., Kluiving, S., Gerrtsen, F., & Künzel, M. (2015). Geoarchaeological research at Barcın Höyük: Implications for the initial Neolithic occupation of northwest Anatolia. Quaternary International, 367, 51-61.

Guyard, H., Chapron, E., St-Onge, G., Anselmetti, F., Arnaud, F., Magand, O., Francus, P., & Mélières, M.-A. (2007). High-altitude varve records of abrupt environmental changes and mining activity over the last 4000 years in the Western French Alps (Lake Bramant, Grandes Rousses Massif). Quaternary Sciences Reviews, 26, 2644-2660.

Hammer, Ø., Harper, D.A.T., & Ryan, P.D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica, 4, 9-11.

Hansen, S., Mirtskhulava, G., & Bastert-Lamprichs, K. (2007). Aruchlo: Neolithic Settlement Mound in the Caucasus. Neo-Lithics, 1/07, 13-18.

Harff, J., Endler, R., Emelyanov, E., Kotov, S., Leipe, T., Moros, M., Olea, R., Tomczak, M., & Witkowski, A. (2011). Late Quaternary climate variations reflected in Baltic Sea sediments. The Baltic Sea Basin, 3, 99-132.

Hodder, I. (2005). Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons. British Institute of Archaeology at Ankara 2005 (BIAA), 38. Cambridge, London.

Holliday, V.T., & Gartner, W.G. (2007). Methods of soil P analysis in archaeology. Journal of Archaeological Science, 34, 301–333.

Horejs, B. (2012). Çukuriçi Höyük - A Neolithic and Bronze Age settlement in the region of Ephesos. In: M. Özdoğan, N. Başgelen, & P. Kuniholm (Eds.), The Neolithic in Turkey, 4 (pp. 117-131). Istanbul: Archaeology and Art Publications.

Janelidze, Z., & Tatashidze, Z. (2010). Palaeogeographical interpretation of archaeological sites of swamps of the Black Sea coast of Georgia. Bulletin of the Georgian National Academy of Sciences, 4, 159-161.

Jouanna, J. (1996). Hippocrate 2.2. Airs, eaux, lieux. 374 pp. Paris: Les Belles Lettres.

Kelterbaum, D., Brückner, H., Dikarev, V., Gerhard, S., Pint, A., Porotov, A., & Zin'ko, V. (2012). Palaeogeographic changes at Lake Chokrak on the Kerch Peninsula, Ukraine, during the Mid- and Late-Holocene. Geoarchaeology, 27, 206-219.

Klerk, P. de, Haberl, A., Kaffke, A., Krebs, M., Matchutadze, I., Minke, M., Schulz, J., & Joosten, H. (2009). Vegetation history and environmental development since ca 6000 cal yr BP in and around Ispani 2 (Kolkheti lowlands, Georgia). Quaternary Science Reviews, 28, 890-910.

Kohl, P. (2001). Migrations and cultural diffusions in the later Prehistory of the Caucasus. In: R. Eichmann, & H. Parzinger (Eds.), Migration und Kulturtransfer. Der Wandel vorder- und zentralasiatischer Kulturen im Umbruch vom 2. zum 1. vorchristlichen Jahrtausend (= Kolloquien zur Vor- und Frühgeschichte. Bd. 6). Akten des internationalen Kolloquiums, Berlin, 23. bis 26. November 1999. Bonn, Habelt.

Kvavadze, E.V., & Connor, S. (2005). *Zelkova carpinifolia* (Pallas) K. Koch in Holocene sediments of Georgia – an indicator of climatic optima. Review of Palaeobotany and Palynology, 133, 69-89.

Kylander, M., Ampel, L., Wohlfarth, B., & Veres, D. (2011). High-resolution X-ray fluorescence core scanning analysis of Les Echets (France) sedimentary sequence: new insights from chemical proxies. Journal of Quaternary Sciences, 26, 109-117.

Laermanns, H., Kelterbaum, D., May, S.M., Elashvili, M., Opitz, S., Hülle, D., Rölkens, Verheul, J., Riedesel, S., & Brückner, H. (2017). Mid- to Late Holocene landscape changes in the Rioni Delta area (Kolkheti lowlands, W Georgia). Quaternary International

Lericolais, G., Bulois, C., Gillet, H., & Guichard, F. (2009). High frequency sea-level fluctuations recorded in the Black Sea since the LGM. Global and Planetary Change, 66 (1-2), 65-75.

Lindauer, O., & Blitz, J.H. (1997). Higher Ground: The Archaeology of North American Platform Mounds. Journal of Archaeological Research, 5 (2), 169-207.

Lordkipanidze, O. (1991). Archäologie in Georgien. Von der Altsteinzeit zum Mittelalter. Weinheim, Germany: VCH Verlagsgesellschaft mbH.

Lubos, C., Dreibrodt, S., Nelle, O., Klamm, M., Friedrich, S., Meller, H., Nadeau, M., Grootes, P., Fuchs, M., & Bork, H.-R. (2011). A multi-layered prehistoric settlement structure (tell?) at Niederröblingen, Germany and its implications. Journal of Archaeological Science, 38, 1101-1110.

McLauchlan, K. (2006). The nature and longevity of agricultural impacts on soil carbon and nutrients: A review. Ecosystems, 9, 1364-1382.

Menze, B.H., Ur, J.A., & Sherratt, A.G. (2006). Detection of ancient settlement mounds: archaeological survey based on the SRTM terrain model. Photogrammetric Engineering & Remote Sensing, 72 (3), 321-327.

Meyers, P.A., & Teranes, J.L. (2001). Sediment organic matter. In: W.M. Last, & J.P. Smol (Eds.), Tracking Environmental Change Using Lake Sediments (pp. 239-269). Dordrecht, NL: Kluver Academic Publishers.

Miller, H., Croudace, I.W., Bull, J.M., Cotterill, C.J., Dix, J.K., & Taylor, R.N. (2014). Sediment lake record of anthropogenic and natural inputs to Windermere (English Lake District) using double-spike lead isotopes, radiochronology, and sediment microanalysis. Environmental Science & Technology, 48, 7254–7263.

Mitchell, J., & Westaway, R. (1999). Chronology of Neogene and Quaternary uplift and magmatism in the Caucasus: constraints from K-Ar dating of volcanism in Armenia. Tectonophysics, 304, 157-186.

Nicosia, C., Langohr, R., Carmona González, P., Gómez Bellard, C., Modrall, E.B., Ruíz Pérez, J.M., & van Dommelen, P. (2013). Land use history and site formation processes at the Punic site of Pauli Stincus in West Central Sardinia. Geoarchaeology, 28, 373-393.

Nikolaishvili, D.A., Elizarbarashvili, N., & Meladze, G.G. (2011). Evaluation of degree of landscape's anthropogenic transformation (landscapes of Georgia). Procedia – Social and Behavioral Sciences, 19, 547-555.

Oonk, S., Slomp, C.P., & Huisman, D.J. (2009). Geochemistry as an aid in archaeological prospection and site interpretation: Current issues and research directions. Archaeological Prospection, 16, 35-51.

Papuashvili, R., & Papuashvili, I. (2014). Kolchian Lowland in the Context of the Black Sea Palaeoregime (In III-I millennium B.C.). Tbilisi, Georgia: Mtsignobari [in Georgian].

Parkinson, W.A., Gyucha, A., Yerkes, R.W., Hardy, M., & Morris, M. (2004). Settlement reorganization at the end of the Neolithic in Central Europe: Recent research in the Körös River Valley, southeastern Hungary. Journal of Eurasian Prehistory, 2, 57-73.

Parkinson, W.A., & Duffy, P.R. (2007). Fortifications and enclosures in European Prehistory: A cross-cultural perspective. Journal of Archaeological Research, 15, 97-141.

Parkinson, W.A., & Gyucha, A. (2012). Tells in Perspective: Long-Term Patterns of Settlement Nucleation and Dispersal in Central and Southeast Europe. In: R. Hoffmann, F.-K. Moetz, & J. Müller (Eds.), Tells: Social and Environmental Space – Universitätsforschungen zur prähistorischen Archäologie (pp. 105-116) Bonn, Germany: Verlag Dr. Rudolf Habelt GmbH.

Plets, G., Gheyle, W., Verhoeven, G., De Reu, J., Bourgeois, J., Verhegge, J., & Stichelbaut, B. (2012). Three-dimensional recording of archaeological remains in the Altai Mountains. Antiquity, 86, 884-897.

Raczky, P., & Anders, A. (2008). Late Neolithic Spatial Differentiation at Polgar-Csoszhalom, Eastern Hungary. In: D. Bailey, A. Whittle, & D. Hoffman. (Eds.): Living Well Together? Settlement and Materiality in the Neolithic of South-East and Central Europe. (pp. 35-53). Oxford, UK: Oxbow Books.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Turney, C., & van der Plicht, J. (2013). InterCal13 and Marine13 radiocarbon age calibration curves 0-50,000 years cal BP. Radiocarbon, 55, 1869-1887.

Rosenstock, E. (2010). Entstehen Siedlungshügel ‘von selbst’? Ein Versuch der Quantifikation des naturräumlichen Einflusses auf die Tellbildung. In: Hansen, S. (Ed.), Leben auf dem Tell als soziale Praxis. Kolloquien zur Vor- und Frühgeschichte, 14 (pp. 1-11). Bonn, Germany: Dr. Rudolf Habelt GmbH.

Runnels, C.R., Payne, C., Rifkind, N.V., White, C., Wolff, N.O., & LeBlanc, S. (2009). Warfare in Neolithic Thessaly: A case study. Hesperia: The Journal of the American School of Classical Studies at Athens, 78 (2), 165-194.

Ryan, W.B.F. (2007). Status of the Black Sea Flood Hypothesis. In: V. Yanko-Hombach, A.S. Gilbert, N. Panin, & P.M. Dolukhanov (Eds.), The Black Sea Flood Question (pp. 63-88) Dordrecht, NL: Springer.

Sens, U. (2009). Kulturkontakt an der östlichen Schwarzmeerküste. In: F. Bertemes, & A. Furtwängler (Eds.), Schriften des Zentrums für Archäologie und Kulturgeschichte des Schwarzmeerraumes, 15. Stuttgart: Beier & Beran.

Shatilova, I., Rukhadze, L., & Mchedlishvili, N. (2010). The stages of development of vegetation climate of Western Georgia during the Middle and Late Pleistocene. Proceedings of the Natural and Prehistoric Section, 2, 75-81. Tbilisi, Georgia: Georgian National Museum [in Georgian].

Steadman, S.R. (2000). Spatial and social complexity on Prehistoric Anatolian tell sites: Models for mounds. Journal of Anthropological Archaeology, 19, 164-199.

Stock, F., Ehlers, L., Horejs, B., Knipping, M., Ladstätter, S., Seren, S., & Brückner, H. (2015). Neolithic settlement sites in Western Turkey – palaeogeographic studies at Çukuriçi Höyük and Arvalya Höyük. Journal of Archaeological Science: Reports, 4, 565-577.

Stuiver, M., Reimer, P., 1993. Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. Radiocarbon, 35, 215-230.

Sun, D., Bloemenda, J., Rea, D.K., Vandenberghe, J., Jiang, F., An, Z., & Su, R. (2002). Grain-size distribution function of polymodal sediments in hydraulic and aeolian environments, and numerical partitioning of the sedimentary components. Sedimentary Geology, 152, 263-277.

Tsetskhladze, G.R. (1997). How Greek colonists adapted their way of life to the conditions in Kolkhis. In: J.M. Fossey (Ed.), Proceedings of the first international conference on the archaeology and history of the Black Sea (pp. 121-136).

Vaněk, A., Borůvka, L., Drábek, O., Mihaljevič, M., & Komárek, M. (2005). Mobility of lead, zinc and cadmium in alluvial soils heavily polluted by smelting industry. Plant, Soil and Environment, 51 (7), 316-321.

Verhoeven, G. (2011). Taking computer vision aloft – archaeological three-dimensional reconstructions from aerial photographs with photoscan. Archaeological Prospection, 18 (1), 67-73.

Vött, A., Handl, M., & Brückner, H. (2002). Rekonstruktion holozäner Umweltbedingungen in Akarnanien (Nordwestgriechenland) mittels Diskriminanzanalyse von geochemischen Daten. Geologica et Palaeontologica, 36, 123-147.

Walraven, N., van Os, B.J.H., Klaver, G.T., Baker, J.H., & Vriend, S.P. (1997). Trace element concentrations and stable lead isotopes in soils as tracers of lead pollution in Graft-De Rijp, the Netherlands. Journal of Geochemical Exploration, 59, 47-58.

Westoby, M.J., Brasington, J., Glasser, N.F., Hambrey, M.J., & Reynolds, J.M. (2012). 'Structure-from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications. Geomorphology, 179, 300-314.

Yılmaz, A., Adamia, S., & Yılmaz, H. (2013). Comparisons of the suture zones along a geotraverse from the Scythian Platform to the Arabian Platform. Geoscience Frontiers, 5 (6), 855-875.

Chapter 4

4 Coastal lowland and floodplain evolution along the lower reach of the Supsa River (Western Georgia)

Hannes Laermanns[1], Simon Matthias May[1], Daniel Kelterbaum[1], Giorgi Kirkitadze[2], Stephan Opitz[1], Levan Navrozashvili[2], Mikheil Elashvili[2], Helmut Brückner[1]

[1] Institute of Geography, University of Cologne, Germany

[2] School of Natural Sciences and Engineering, Ilia State University, Georgia

Abstract

In the southernmost part of the Colchian plain (Georgia), the Supsa and Rioni rivers represent important catchments to reconstruct Holocene landscape changes. Using granulometric methods, geochemical analyses and radiocarbon dating, we demonstrate that significant palaeoenvironmental changes have taken place in the surroundings of the Supsa fan since at least 4000 BC. The area has been separated from the open sea by a sand bar, creating lagoonal conditions. Due to continued fluvial sediment supply, mainly from the Rioni, the lagoons silted up and extended peat bogs formed east of the beach ridges. Meanwhile, the Supsa fan formed, first prograding northwards (since the 3rd millennium BC), and later shifting westwards, eventually following an avulsion of the Rioni. However, Supsa deposits remain limited to the area of the fan and the modern estuary, while the alluvial fines of the Rioni dominate the surrounding areas. The relative sea-level (RSL) index points of the region suggest a gradual RSL rise from ~-10 to -8 m between 4000 and 3500 cal BC to -3/-2 m below the modern sea level in the second half of the 1st millennium BC, the period during which Greek colonisation and Colchian settlements are attested by archaeological remains.

Landschaftsgenese der Küstenebene am Unterlauf der Supsa (Westgeorgien)

Im südlichsten Teil der kolchischen Tiefebene (Georgien) stellen die Einzugsgebiete des Rioni und der Supsa wichtige Areale zur Rekonstruktion des holozänen Landschaftswandels dar. Mittels granulometrischer und geochemischer Analysen sowie Radiokohlenstoffdatierungen lässt sich der signifikante Landschaftswandel im Bereich des Supsa-Schwemmfächers seit etwa 4000 v. Chr. nachweisen. Das Areal wurde von einer Sandbarre vom offenen Meer getrennt, hinter der sich große Stillwasserbereiche bildeten. Der anhaltende fluviale Sedimenteintrag, hauptsächlich durch den Rioni, begünstigte die allmähliche Verlandung und die Entstehung von Torfmooren. Gleichzeit baute sich – zuerst nach Norden (etwa ab dem 3. Jahrtausend v. Chr.) und später durch den Rioni nach Westen abgelenkt – der Schwemmfächer der Supsa vor. Während sich die Supsa-Ablagerungen im Wesentlichen auf den Schwemmfächer und die aktuelle Mündung beschränken, dominieren die feinkörnigen Ablagerungen des Rioni die Umgebung. Die Indexpunkte für den relativen Meeresspiegel deuten auf einen anhaltenden Anstieg des Meeres hin, ausgehend von etwa -10 bis -8 m unter dem heutigen Niveau um 4000 bis 3500 v. Chr. auf -3 bis -2 m in der zweiten Hälfte des 1. Jahrtausends v. Chr. Für den gleichen Zeitraum sind kolchische und griechische Siedlungen durch archäologische Funde in der Umgebung der Supsa-Mündung belegt.

Keywords

Supsa, Rioni, alluvial fan, sea-level rise, floodplain, chronostratigraphy, Black Sea, Georgia

submitted to *Eiszeitalter und Gegenwart*

4.1 Introduction

Deltas, estuaries and low-lying coastal plains render important information on the postglacial coastal evolution and Holocene sea-level rise (ARSLANOV, DOLUKHANOV & GEI 2007, MARRINER, MORHANGE & GOIRAN 2010, HAGHANI et al. 2015). At the same time deltaic regions played an important role for the ancient colonization (e.g. by the Greeks, Romans and Phoenicians; ANTHONY, MARRINER & MORHANGE 2014), providing access to the hinterland as well as to the open sea. Especially in the Mediterranean many important ancient cities were founded on the coast of large embayments and estuaries, e.g. Troy at the Karamenderes (KRAFT et al. 2003), Ephesus at the Küçük Menderes (STOCK et al. 2013, 2016), Miletus and Priene at the Büyük Menderes (BRÜCKNER et al. 2002), Aquileia, Laguna di Grado north-eastern Italy (ARNAUD-FASSETTA et al. 2003), or the Turia River in Spain (CARMONA & RUIZ 2011).

While a significant amount of research on both sea-level evolution and human-environment-interactions exists from Mediterranean coastal lowlands and delta regions (e.g., LARIO et al. 2002, PAVLOPOULOS et al. 2006, CAROZZA et al. 2011; BRÜCKNER et al. 2017) – many of them in geoarchaeological contexts and especially at ancient harbour sites (MARRINER & MORHANGE 2007; e.g. for Rome's harbours Portus and Ostia: DELILE et al. 2014, GOIRAN et al. 2014, for Miletos BRÜCKNER et al. 2014, for Alexandria: FLAUX et al. 2017, for Ephesos STOCK et al. 2013, 2014) – studies on sea-level evolution of the Black Sea are scarce. Only during the last decade, the number of publications has increased for particular areas (e.g. Danube delta: GIOSAN et al. 2006, Taman peninsula: Kelterbaum et al. 2012) and in the context of the controversial debate about sea-level evolution and fluctuations (e.g., BRÜCKNER et al. 2010, FOUACHE et al. 2012, ERGINAL et al. 2013, BOLIKHOVSKAYA et al. 2017).

In particular, the Georgian Black Sea coast remains understudied so far, although it stands out with a unique vegetation history and its long-time of occupation, with the ancient kingdom of Colchis and several Greek colonies of which the lost city of Phasis is the most famous one (LORDKIPANIDZE 1991). Overall, the Georgian coast and its central section, the Colchian plain, offers – with estuaries of numerous rivers and extensive wetlands – promising geo-bio-archives. The potential of the Colchian plain (i.e. the area between the rivers Supsa and Enguri) for palaeoenvironmental and geoarchaeological studies has been shown only in the very recent past by elucidating the mid- to late Holocene development of the Rioni delta (LAERMANNS et al. 2018a) and presenting new data on the evolution of Bronze Age settlements (LAERMANNS et al. 2018b).

However, while most major rivers in the northern and central Colchian plain are sourced in the Greater Caucasus to the north and formed the vast alluvial Colchian plain, the southernmost river, the Supsa, is fed by the Lesser Caucasus from the south. While presently flowing into the Black Sea, it has built a prominent, semi-circular alluvial fan at the interface between the mountains and the southern the Colchian plain, which now constitutes an arable area along the southern margin of Lake Paliastomi. Colchian and Greek amphorae as well as graves were found at several sites in the surroundings (LORDKIPANIDZE 1985, MIRON & ORTHMANN 1995, SENS 2009), and indeed the area may have represented a favourable settlement place due to its slightly elevated position next to Lake Paliastomi; even speculations on a possible location of Phasis in this area exist (cf. an overview in GAMKRELIDZE 2012). Yet there is neither detailed information on the Holocene evolution of the Supsa fan and its surroundings nor on its occupation history.

Against this background, the overall aim of our study is to provide first data on the Holocene evolution of the Supsa fan and its surroundings during the past millennia. Therefore, we aim to: (i) document the chronostratigraphy of the Supsa fan and its surroundings; (ii) reconstruct the palaeogeographical and palaeoenvironmental changes of the delta area; and (iii) differentiate between the sediments originating from the Supsa and the Rioni catchments. Furthermore, we intend to (iv) probe if archaeological findings can testify that the palaeoenvironmental conditions favoured human occupation in this particular area.

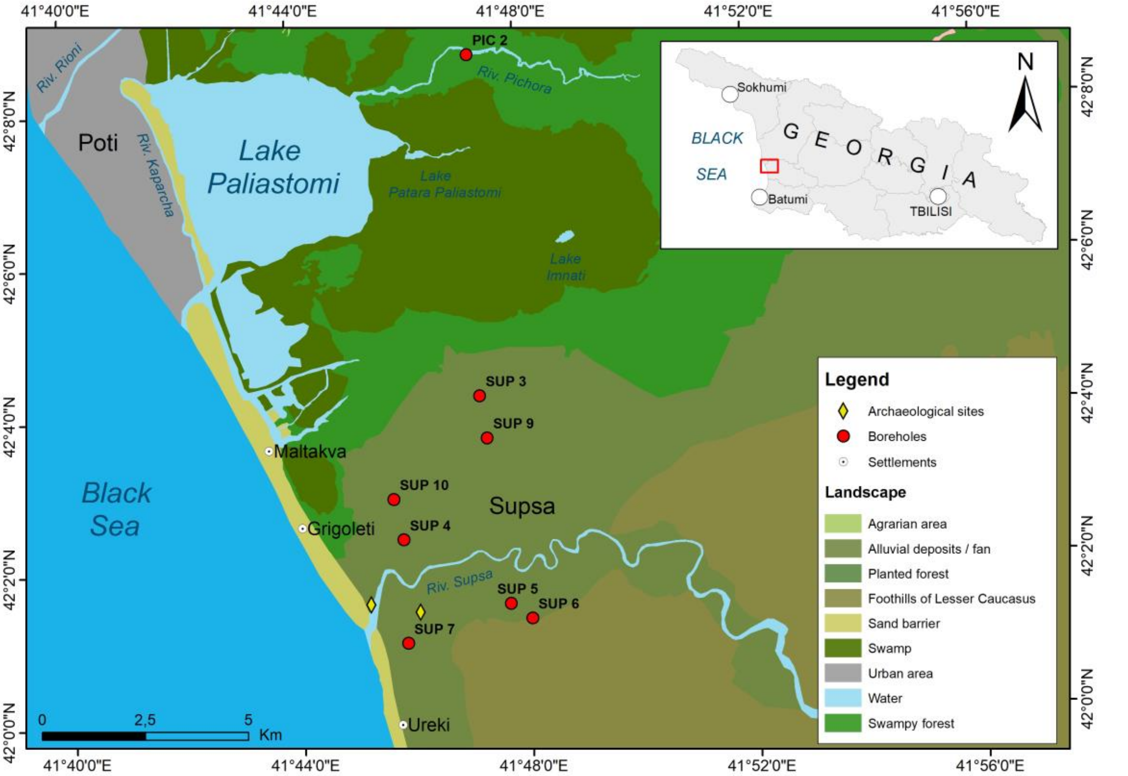

Fig. 4.1: Map of the research area. Red dots indicate the coring sites (based on ASTER Digital Elevation Model, Shaded Model).

4.2 Regional Setting

4.2.1 Physical Setting

The Kolkheti lowlands or Colchian plain, which correspond to the historical region of Colchis, form a triangular-shaped coastal plain of western Georgia (Fig. 4.1). They are limited by the Black Sea in the west, the slopes of the Greater Caucasus in the northeast, and the Lesser Caucasus in the southeast. The lower Likhi range connects both Caucasian ranges and forms the easternmost border of the plain. It separates the Colchian lowlands from the Kura catchment, which discharges into the Caspian Sea (EPPELBAUM & KESHIN 2012).

The Colchian plain is, like the whole of Georgia, located in the convergence zone between the Arabian and Eurasian plates (DHONT & CHOROWICZ 2006). During the closure of the Northern Neo-Tethys Ocean (SOSSON et al. 2010) and the subsequent Alpine-Himalayan orogeny this former Mesozoic to Cenozoic back-arc marginal extensional basin was closed and the folded mountains of the Caucasus evolved (ADAMIA et al. 2011, FORTE, COWGILL & WHIPPLE 2014). Triggered by the northward drift of the Arabian plate, the ongoing continent-continent collision between the Lesser Caucasus arc and the Eurasian basement still coincides with convergence rates between ~12 mm/a in the eastern part and ~2 mm/a in the western part, e.g. the Colchian plain (AVDEEV & NIEMI 2011, YILMAZ, ADAMIA & YILMAZ 2013). There, convergence occurs along the Adjara-Trialeti Thrust Belt (ATTB) in the south and the Chaladidi-Tsaishi Thrust (CTT) in the north (REILINGER 2006, FORTE, COWGILL & WHIPPLE 2014) (Fig. 4.1).

Though the Caucasus mountains evolved from the same tectonic processes they differ in their geology from the Colchian plain: The Greater Caucasus in the north is a polycyclic, folded-nappe formation (OKROSTSVARIDZE, GAGNIDZE & AKIMIDZE 2016) and consists of a Pre-Alpine crystalline basement complex and a younger cover of Mesozoic to Neogene ophiolites, (marine) sedimentary and volcanic rocks. On the southern side the Lesser Caucasus inherits additional andesitic pyroclastica and effusiva (MITCHELL & WESTAWAY 1999) and granite and gneiss intrusions (YILMAZ, ADAMIA & YILMAZ 2013).

In contrast, the Colchian plain is primarily covered by Cretaceous and Palaeogene sediments and by volcanoclastics (BAZHENOV & BURTMAN 2002). These deposits are overlain by Quaternary molasses and river terraces of eroded material from the surrounding mountains and their foothills (ADAMIA et al. 2011). During the Holocene, these fluvial and alluvial accumulations and the large-scale sea-level rise dominated the morphology on the Colchian plain. Here, massive coastline changes were provoked, especially by the reconnection of the Black Sea with the Mediterranean Sea ~8400 years ago (RYAN 2007, GIOSAN, FILIP &

CONSTANTINESCU 2009), and huge areas of former dry land drowned. Probably around 3000 BC, the sea level nearly reached its current position (~1.5-0 m) (e.g. BRÜCKNER et al. 2010, FOUACHE et al. 2012, KELTERBAUM et al. 2012, LAERMANNS et al. 2018a). Detailed information about the geology of the Supsa fan are still lacking.

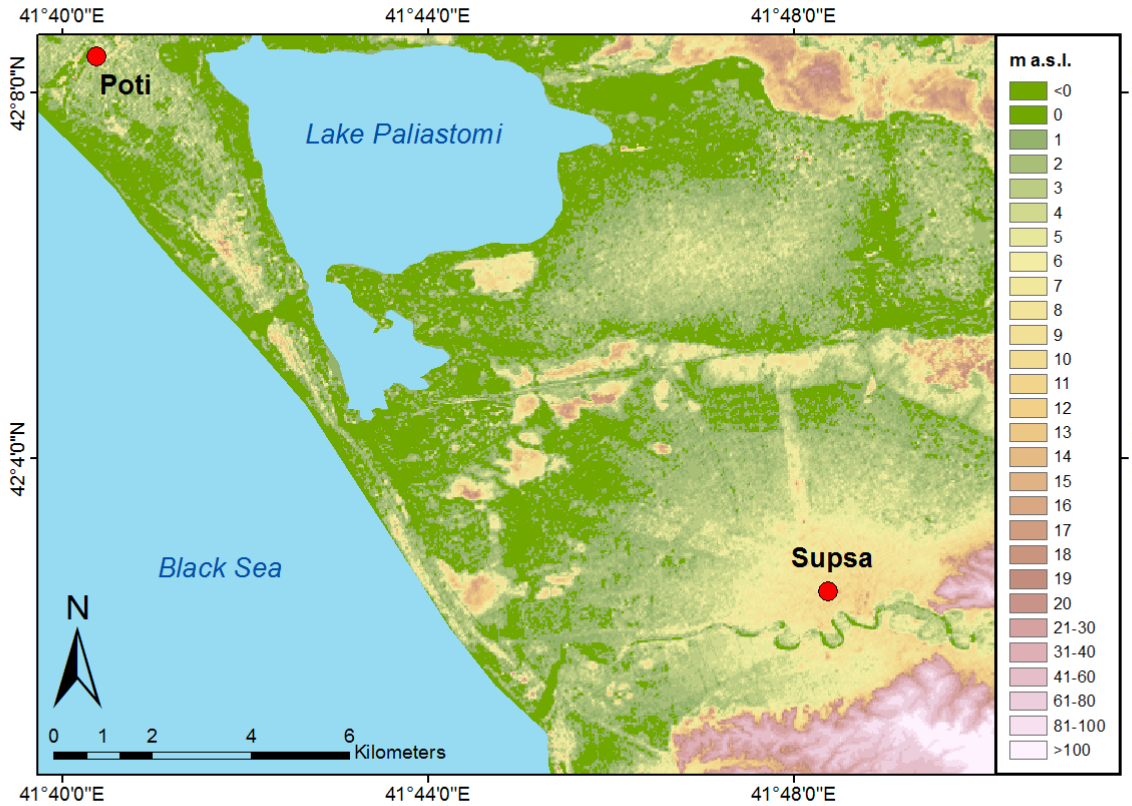

Fig. 4.2: Digital elevation model (DEM) of the research area. The Supsa fan rises above the adjacent areas of the plain. The linear elevated structures between the fan and Lake Paliastomi and eastwards of the latter are woodland areas; their 'elevation' is due to the vegetation not to the morphology. The linear structures – mostly perpendicular to the progradation of the Supsa fan – are caused by modern agriculture (cf. Fig. 4.3b) (based on ALOS World 3D with 30 m resolution [AW3D30]).

Today, the central plain is dominated by four rivers (from N to S): Enguri, Khobistsqali, Rioni and Supsa. While the former three have their sources in the Greater Caucasus, the latter originates from the Lesser Caucasus. Compared with the Rioni catchment area of ca. 13,400 km², average water volume contribution of 13.38 km³/a and sediment load of 6.02 x 10^6 t/a (BERKUN, ARAS & AKDEMIR 2015), the Supsa constitutes a far smaller part: With a catchment area of ca. 1,100 km², a discharge far less than 3.00 km³/a water volume, and a sediment load of 0.246 x 10^6 t/a, it can be considered as a river of regional importance; however, it contributes more water and sediment than the two northernmost rivers (BERKUN, ARAS & AKDEMIR 2015). Plus, the Supsa is the only river which built a major lobate fan in the Kolkheti lowlands that extends in its centre up to several metres over the surrounding swamp areas while its outermost edges are of almost the same elevation as the surrounding swamp areas. It is located directly north of the foothills where the Supsa discharges into the open plain. Its recent river mouth is located further west and forms an estuary comparable to those of the Enguri and Khobistsqali.

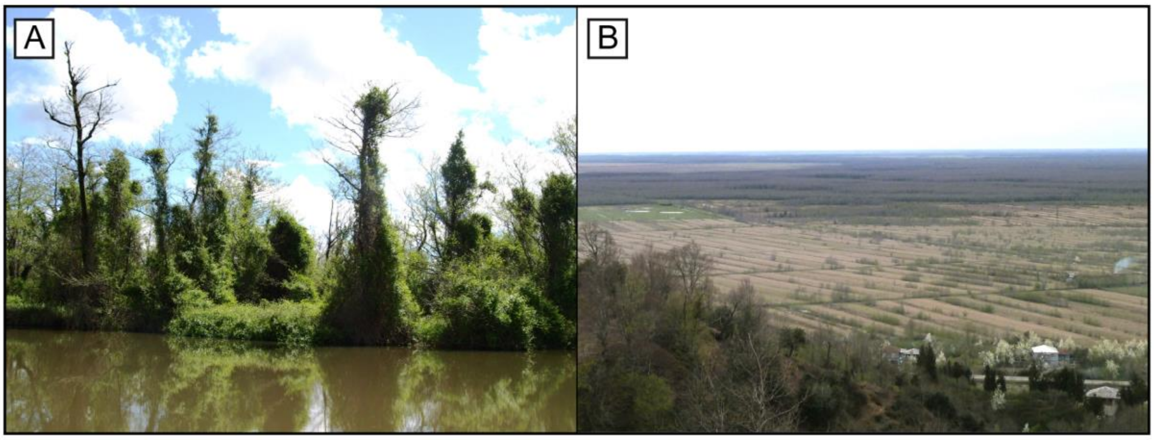

Fig. 4.3: A: Natural swamp forest vegetation close to the site of sediment core PIC 2 on the banks of the Pichora River. B: Northward view from the foothills to the south of the village of Supsa. The ridge-and-furrow system of the agrarian areas is contrasted by the swamplands in the background (Photos: Laermanns 2014, 2015).

The regional climate is characterized by high precipitation (>2000 mm/a) and average annual temperatures around 14°C, without regular winter frosts (mean January temperatures are 6°C in Batumi) (BOX et al. 2000; see also DENK, FROTZLER & DAVITASHVILI 2000, HIJMANS et al. 2005). Extensive wetlands, consisting of swamps, peat bogs, shallow lakes, open reed areas and forests of evergreen understory cover huge parts of the plain; mixed forests dominate the neighbouring foothills (BOX et al. 2008). As a result of centuries of deforestation and drainage activities, most of the natural vegetation along the coast, rivers and foothills has been replaced by open grassland and fields for crop growth (DE KLERK et al. 2009). The inevitable extensive system of drainage ditches and ridge-and-furrow fields forms a significant part of the recent relief on the Colchian plain (NIKOLAISHVILI, ELIZARBARASHVILI & MELADZE 2015). This holds especially true for the slightly elevated Supsa fan where preferably drier conditions are observed, in contrast to the swampier surroundings.

4.2.2 Human Occupation

Georgia has been populated since the Palaeolithic; bones discovered at the site of Dmanisi are presently the oldest hominid remains outside of Africa (LORDKIPANIDZE et al. 2007). During the Holocene, an early transition from hunting and gathering to farming and animal husbandry set in between 10,000 and 9,000 BC (ARSLANOV, DOLUKHANOV & GEI 2007). People spread from the foothills into the plain where the oldest settlement sites of Ontsakoshia (JANELIDZE & TATASHIDZE 2010) and Ispani (CONNOR, THOMAS & KVAVADZE 2007; DE KLERK et al. 2009) date back to the transition between the Chalcolithic and the Early Bronze Age in mid-3rd millennium BC (LORDKIPANIDZE 1991). Furthermore, settlement mounds in the northern part of Colchis have yielded evidence for the evolving Colchian culture of that time (SENS 2009, LAERMANNS et al. 2018b). The ancient region experienced its heyday between the 6th-4th centuries BC under the Kingdom of Colchis, a time of intensive trade contact with (mainly Milesian) Greek merchants, who founded several colonies along the Colchian Black Sea coast (SENS 2009, GAMKRELIDZE 2012). In the late 2nd to early 1st century BC, Colchis fell into the sphere of influence of the Kingdom of Pontus and became later a client state of the Roman Empire (GAMKRELIDZE 2012) and finally a Roman province (RAYFIELD 2013).

4.2.3 Research area

Our investigations focus on the Supsa delta region and its adjacent areas, i.e. on the southernmost part of the Colchian plain (Fig. 4.1). Here, the Supsa River leaves the foothills and forms its lobate-shaped alluvial fan. The eponymous village covers the central part of the fan while its surroundings are dominated by agricultural areas (Fig. 4.3B). The prevailing ridge-and-furrow fields, which are divided by an extensive network of drainage channels, have overprinted the natural fluvial structures (cf. Fig. 4.2). Only in few swampy grassland areas near-natural conditions have prevailed. The recent river mouth is located ca. 6.5 km west of the fan apex. The graded shoreline is formed by a straight beach with several beach ridges behind and it is strongly influenced by the long-shore current (KOROTAEV et al. 2003). North of the river mouth stretch the villages Maltakva and Grigoleti atop the linear structure of the beach ridges parallel to the coast. The coast section is separated from the alluvial fan by swamplands (Fig. 4.3A) and peat bogs which extend to the southern shores of Lake Paliastomi. On the southern side of the river mouth, the foothills reach close to the graded shoreline.

Within this area several archaeological sites are known. Whole amphorae and fragments from Heraclea Pontica and Sinope were found between the village Maltakva and the Supsa river mouth (Fig. 4.1); they date to the 4th to 3rd centuries BC (SADZRADZE, DAVLIANIDZE & MURVANIDZE 1999). At the villages of Ureki and Maltakva, several Colchian amphorae (2nd to 1st centuries BC) were found (MIRON & ORTHMANN 1995, GAMKRELIDZE 2012). Some historians (e.g. SHAFRANOV, 1880, in: GAMKRELIDZE 2012) even speculate that the ancient city of Phasis was located on the southern shore of Lake Paliastomi at the river mouth of the Supsa. Further upstream, many smelting furnaces are known through different surveys (KHAKHUTAISHVILI 2008, KHAKHUTAISHVILI 2009, ERB-SATULLO, GILMOUR & KHAKHUTAISHVILI 2014). Their spatial concentration in this region can be explained by the occurrence of chalcopyrite, the dominant copper-bearing mineral in veins of quartz or in iron oxide matrices (GUGUSHVILI et al. 2010, ERB-SATULLO, GILMOUR & KHAKHUTAISHVILI 2014). It outcrops on the surface there due to the tectonic faults and erosion at the Adjara-Trialeti Thrust Belt (OKROSTSVARIDZE, GAGNIDZE & AKIMIDZE 2016).

4.3 Methods

4.3.1 Geochemical and Sedimentological Analyses

The sediment cores originate from different sites of the delta area that were chosen due to their accessibility and relevance. They were retrieved using a Cobra TT (Atlas Copco) percussion-coring device. Only sediment core PIC 2 was taken further north, at the riverside of the Pichori, which discharges into Lake Paliastomi (Fig. 4.1). The cores are 6 and 5 cm in outer diameter, respectively, and reached a maximum depth of 12 m below surface (b.s.); they form the basis for further stratigraphic and geochemical analyses and interpretations. A preliminary core lithology in the field was established on basis of sediment texture, colour and $CaCO_3$ test (with HCl, 10 %) of the different sediment units. Samples were taken with intervals of ca. 20 cm for further treatment in the laboratory.

The pre-treatment for all samples and all analyses were conducted at the glaboratory of the Institute of Geography, University of Cologne, Germany. The samples were oven-dried at 40 °C for 48 h, subsequently sieved <2 mm and gently crushed with a mortar to disintegrate the aggregates.

For granulometric analyses, the samples were pre-treated with hydrogen peroxide (H_2O_2, 15 %) to remove organic matter, and with sodium pyrophosphate ($Na_4O_7P_2$, 46 g/l) to avoid coagulation. Before measurement, the samples were shaken for at least 12 hours in an overhead shaker. Granulometric analyses were performed in 116 channels from 0.04 to 2000 μm with a Laser Diffraction Particle Size Analyzer (LS 13320 Beckmann Coulter$_{TM}$) where each sample was measured three times using the optical Fraunhofer model. Grain-size parameters based on FOLK & WARD (1957) were calculated using the GRADISTAT software version v8 (BLOTT & PYE 2001). All grain-size categories are given according to the DIN 18196 norm based on AG Boden (1994).

After separating the <63 µm fraction by sieving the grain shape of samples from the sandy beds was analysed using a Retsch CAMSIZER® P4. This fraction was measured in 52 channels up to 22.4 mm to define roundness, sphericity and elongation using the principle of dynamic image analysis (ISO 13322-2) to identify different deposition modes and possible sources. The results were calculated using the software CAMSIZER® 4.4.1.

Loss on ignition (LOI) was used to estimate the organic matter content of the sediments. 5 g of sample material were oven-dried at 105 °C for 12 h and subsequently ignition was determined in a muffle furnace (Carbolite ELF) at 550 °C for 5 h. Although possible uncertainties may result from the combustion of clay minerals and/or carbonates, LOI is often used to estimate the organic matter content (e.g., BARSCH, BILLWITZ & BORK 2000, HEIRI, LOTTER & LEMCKE 2001).

Element concentrations (Ca, Fe, K, S, Cu, Zn, Pb) were measured by a portable XRF Analyzer (NITON XL3t, THERMO SCIENTIFIC, analyticon) to draw conclusions on the depositional environment (marine or terrestrial origin etc.). Triplicate measurements were performed on pellets of dried and ground sample aliquots, which were pressed into a teflon ring with 12 $N.mm^{-2}$, and subsequently covered with a 4 µm polypropylene film (X-ray film, TF-240-255). A gold anode emitted X-ray (70 kV) needed to preform measurements within the ‘mining-minerals-mode’, which uses four different filters for 40 seconds each. The secondary X-rays of element specific wavelength are detected and processed by a digital signal processor. Si concentrations (in ppm) are calculated from the element-specific fluorescence energies and compared with external and internal reference materials (STDS-4, BCR142R, BCR-CRM 277).

Magnetic susceptibility (MagSus) measurements were performed three times for each sample using a Bartington MS2B sensor.

In order to identify different facies, Principal Component Analyses (PCA) were applied using the software PAST (version 3.1.1, HAMMER, HARPER & RYAN 2001). Therefore, normalized values of the granulometric parameters (mean grain size, sorting, kurtosis and skewness) were used to differentiate between the depositional modes (FOLK & WARD 1957). Additionally, the geochemical parameters Ca, K, Fe and Cu provided information on the sediments' origin and, in the case of Cu, possible human activity (OONK, SLOMP & HUISMAN 2009, DUNG et al. 2013, DIRIX et al. 2015). An additional PCA was applied for the sandy layers to differentiate their origins. The distribution of the data was explained by the first two components of each PCA.

4.3.2 Dating Techniques

Twelve samples (plant remains and charcoal) from the three sediment cores SUP 3, SUP 4 and SUP 10 were taken for radiocarbon dating (Tab. 4.1) at the ^{14}CHRONO Centre, Queens University Belfast, Northern Ireland, UK. All ages were calibrated using Calib 7.1 (calibration data set: intcal13.14c; STUIVER & REIMER 1993, REIMER et al. 2013). An age-depth model was calculated for the sediment core SUP 4 using the R-based software Bacon 2.2 (BLAAUW & CHRISTEN 2011).

4.4 Results

4.4.1 Sediment cores

4.4.1.1 Sediment core SUP 3

The sediment core SUP 3 was recovered in the northern part of the Supsa fan (Figs. 4.1, 4.4, 4.5). The lowermost section (11.00-10.16 m b.s.) is composed of brown to dark brown

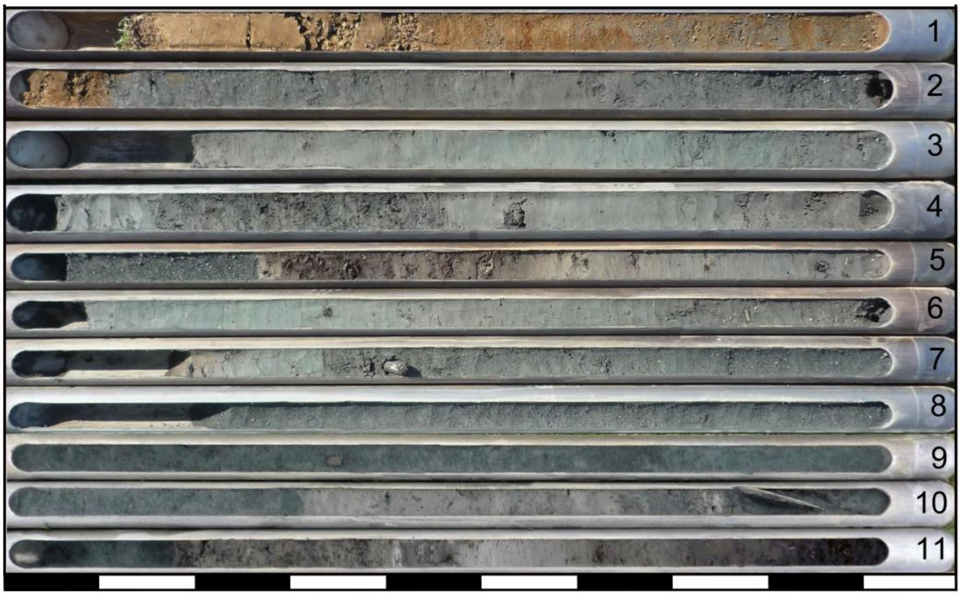

Fig. 4.4: Sediment core SUP 3 from the maximum depth at 11 m b.s. (bottom right) to the surface (top left): Outer diameter of augerheads: 6 cm (0-4m), 5 cm (4-11 m) (Photo: Laermanns, 2013).

silty to sandy peat. The layer is characterized by a heterogeneous grain size composition and poor sorting. The S, Ca/Fe and Ca/K values drop significantly, while metal ions, Fe, Al and magnetic susceptibility (MagSus) remain at low levels. Between 10.16 and 8.75 m b.s., (dark) brownish grey clayey silt reveals a more homogeneous grain size which does not exceed 7 µm. The layer of fine to medium sand between 8.75 and 6.33 m b.s. is separated by sharp boundaries, indicated by a sudden rise of the mean grain size that stands out (except for the uppermost 20 cm) with values of >100 µm and elevated values of Ca, K, magnetic susceptibility, Ca/K and Ca/Fe ratios. In contrast, S content continuously reaches low levels. Between 6.33 m b.s. and the surface dominate greyish brown to grey silts with changing sand and clay contents and low values of LOI, MagSus, Ca/K and Ca/Fe. Only between 4.53 and 4.00 m b.s., two layers of peat and sand are interdigitated, each ~25 cm thick and defined by sharp boundaries. While the peat comprises naturally high LOI values (up to ~47 %), the sand is characterized by a sharp peak in its Ca/Fe ratio.

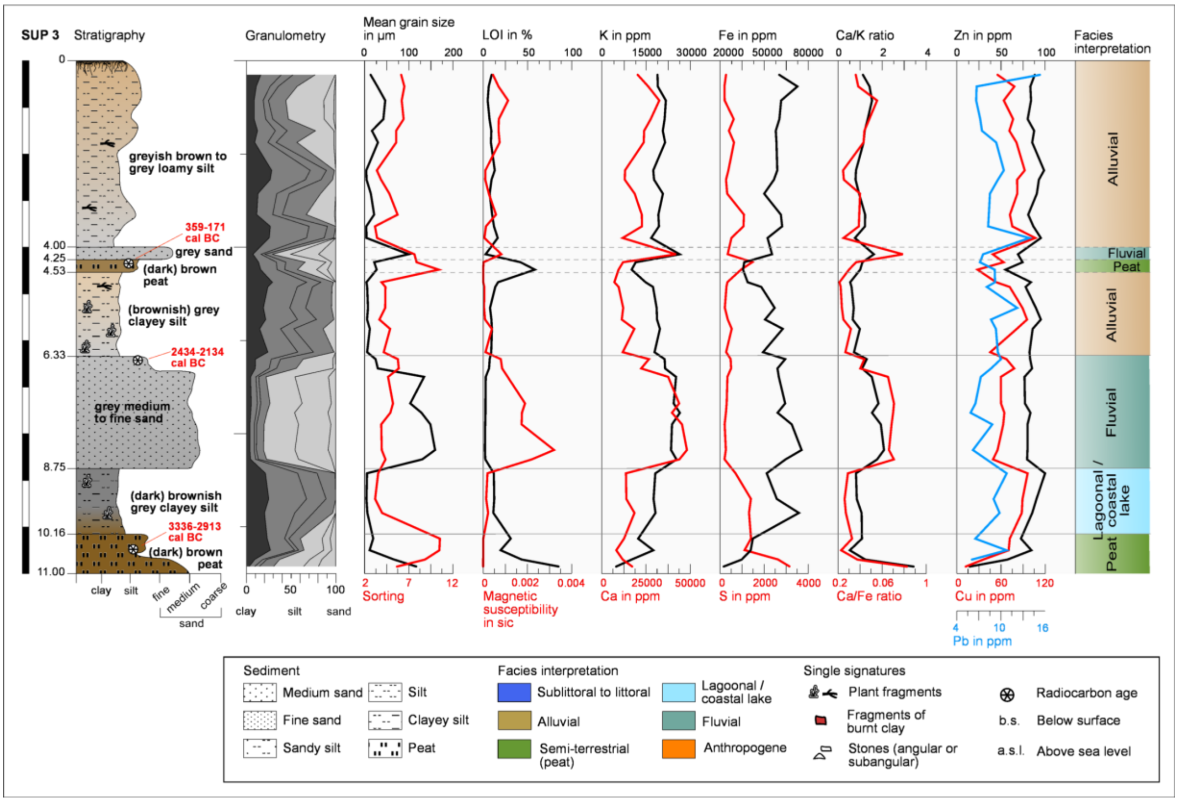

Fig. 4.5: Profile, facies interpretation, granulometry, geochemistry and ^{14}C age estimates of sediment core SUP 3 from the northern part of the Supsa fan (location in Fig. 4.1). The sediment core is dominated by fine-grained alluvial layers, which are interdigitated with peats in the lower part of the fluvial deposits (see Fig. 4.4).

4.4.1.2 Sediment core SUP 9

150 m south of the site of SUP 3, the sediment core SUP 9 was taken (Fig. 4.1). The lowermost part between 10 and 9.55 m b.s. consists of organic-rich (brownish) clayey silt. Above, heterogeneous grey silt to silty sand was deposited with high sand content. From 7.13 to 3.41 m b.s., homogeneous (brownish) grey clayey silts dominate once again; the mean grain size does not exceed 10 µm. Only an intercalation of brownish silt between 5.75

and 5.33 m b.s. stands out with its coarser grain size and different colour. At 3.41 m b.s., the sediment abruptly shifts to heterogeneous brownish grey to grey fine to medium sand of two metres thickness. The main grain size decreases slightly to the upper facies limit at 1.41 m b.s., where brown sandy silt was deposited. The uppermost part, between 0.72 m b.s. and the surface, is formed of brown to reddish brown loamy silt.

4.4.1.3 Sediment core SUP 4

The sediment core SUP 4 was recovered at the western margin of the Supsa fan (Figs. 4.1, 4.6). The basal part consists of (brownish) grey silty fine sand with very poor sorting, low MagSus values and relatively low Ca/Fe and Ca/K ratios, but high LOI values. This layer gradually merges into the subsequent peat which stands out with the high Ca/Fe and Ca/K

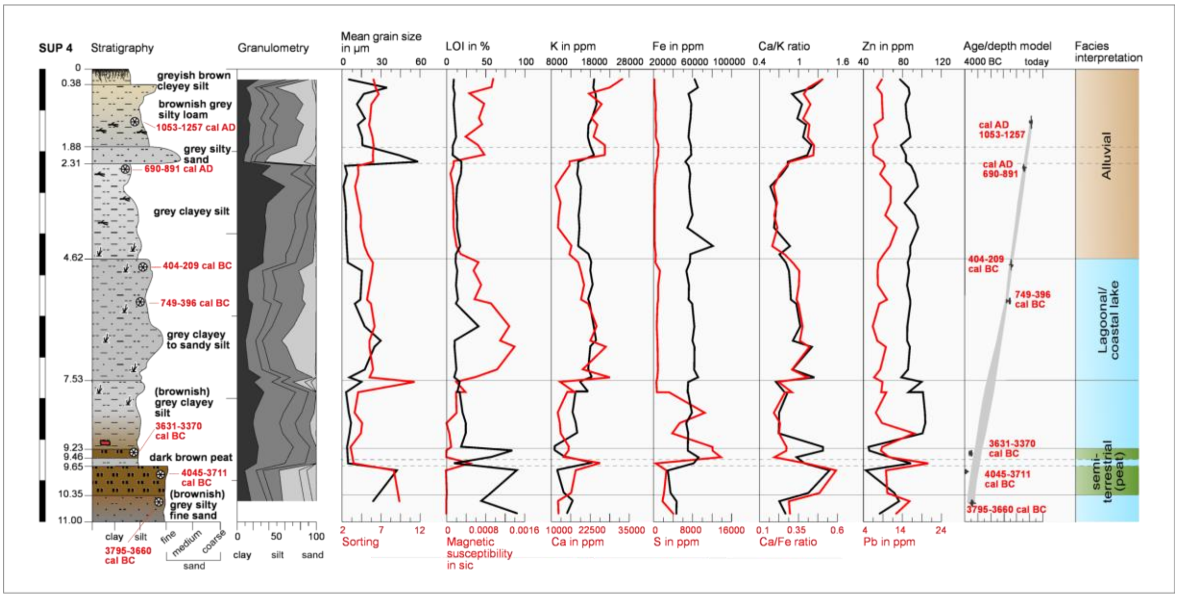

Fig. 4.6: Profile, facies interpretation, granulometry, geochemistry and ^{14}C age estimates of sediment core SUP 4 from the western edge of the Supsa fan (legend see Fig. 4.5). Except from the peat interdigitations below 9 m b.s., the entire sediment core is formed of fine-grained lagoonal to alluvial deposits that document the gradual change from a lagoon to a floodplain. The age/depth model was estimated with the R-based software Bacon 2.2 (BLAAUW & CHRISTEN 2011).

ratios and low MagSus values. Above a sharp boundary, well-sorted clayey silt was deposited. High concentrations of Pb, Zn, P and low values of S are remarkable. Between 9.46 and 9.23 m b.s. another peat layer occurs which differs in terms of smaller matrix grain size, better sorting and very high S values compared to the peat layer below. While its lower boundary is hard to define due to the gradual transition from the silt below, the upper boundary is rather sharp. Between 9.23 and 2.31 m b.s. grey silt occurs. The lowermost (9.23 and 7.53 m b.s.) and uppermost (4.62 and 2.31 m b.s.) parts of this unit are characterized by relatively low Ca/K and Ca/Fe ratios, while S, Pb and Zn reach very high levels. By contrast, the in-between section (7.53 and 4.62 m b.s.) shows with higher sand content, poorer sorting, elevated Ca/K and Ca/Fe ratios and a high magnetic susceptibility. Clearly separated, the subsequent layer of silty sand has elevated values of Ca, Ca/K, Ca/Fe and MagSus. The uppermost part of the core (between 1.88 m b.s. and the surface) is formed by silty loam, which is characterized by a similar geochemical composition as the sand layer.

4.4.1.4 Sediment core SUP 10

Northwest of SUP 4, the sediment core SUP 10 was recovered beyond the western margin of the alluvial fan of the Supsa (Figs. 4.1, 4.7). The stratigraphy is dominated by fine to medium sand with interdigitated peat units. From the maximum depth at 12 m b.s. to 10.46 (dark) grey fine sand is present which is characterised by high Ca/Fe and Ca/K ratios. Separated by a sharp boundary follows above a sequence of several peat and organic-rich greyish brown silt layers where Ca/Fe and Ca/K ratios drop notably, while LOI rises up to >20 %. In general, this sequence is characterized by heterogeneous but generally low values of Fe, Cu, Zn, Pb and Ca. Between 7.91 and 7.51 m b.s. a layer of massive wood occurs. Above, between 7.51 and 6.56 m, brownish grey silt was deposited which contains many ceramic fragments, up to 2 cm in size, which were observed throughout this unit. Here, Ca/Fe and Ca/K reach their minimum values, while Fe, Al, Pb, Zn and Cu rise significantly. Subsequently, grey medium sand with a changing mean grain size of 90 to 450 µm was deposited. The sand is characterized by low LOI contents and constantly low values of Ca/K and Ca/Fe ratios caused by high Fe and K concentrations and sharp lower and upper boundaries. The uppermost two metres comprise grey to greyish brown loamy to clayey silt where the values of Zn and Pb rise to the surface.

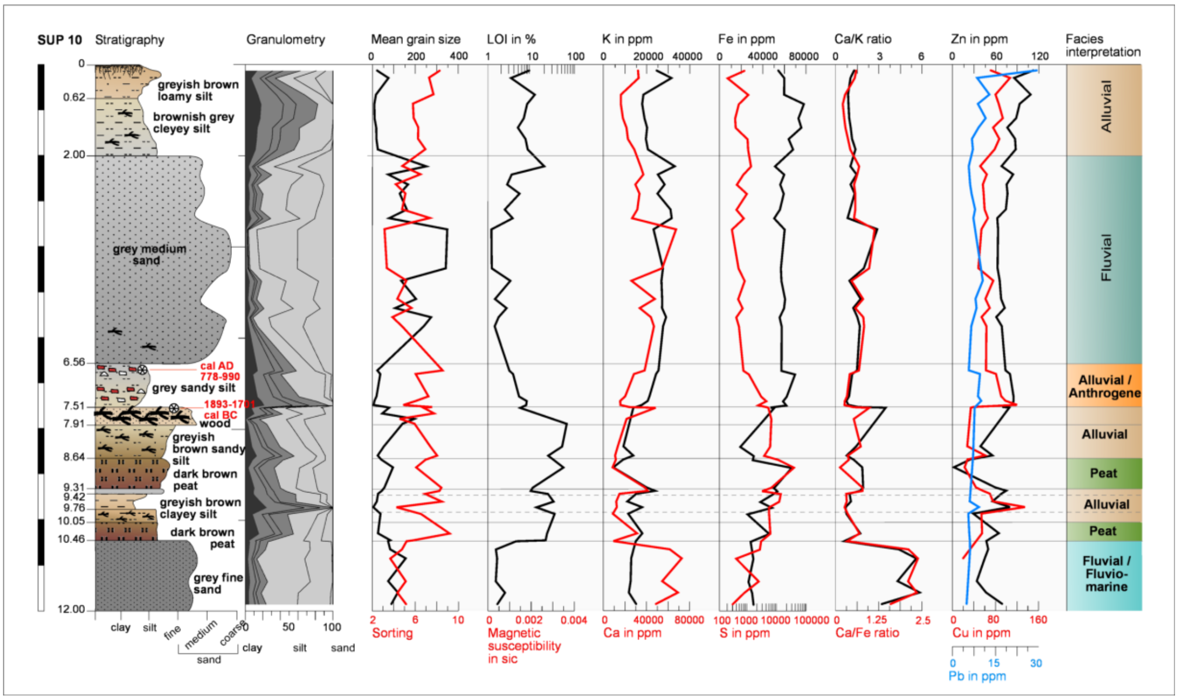

Fig. 4.7: Profile, facies interpretation, granulometry, geochemistry and ^{14}C age estimates of sediment core SUP 10 from the area between the shoreline and the Supsa fan (see Fig. 4.1). Atop fluvio-littoral deposits, peat is interdigitated with alluvial silts and topped by a layer with many ceramic finds between 7.51 and 6.56 m b.s. Above, fluvial sand dominates until 2 m b.s. (legend see Fig. 4.5).

4.4.1.5 Sediment core SUP 5

Sediment core SUP 5, conducted on a grassland ca. 200 m north of the foothills (Fig. 4.1), is one of the two sediment cores taken on the southern riverside of the Supsa. The entire 10-m core consists of clayey to loamy silt. Its lowermost part contains several plant fragments. The sand content increases slightly between 8.31 and 4.56 m b.s. The grey to dark grey colour of the core changes in the uppermost 2.00 m to a greyish brown (Fig. 4.8).

4.4.1.6 Sediment core SUP 6

SUP 6, the second core taken from the southern side of the Supsa, originates from an outlet of a small tributary brook valley ca. 600 m southeast of the SUP 5 site (Fig. 4.1). In contrast to SUP 5's fine-grain dominated stratigraphy, SUP 6 is dominated by several layers of medium sand (mean grain size varies between ca. 100 and 380 µm) from its final depth at 8 to 0.88 m b.s. (Fig. 4.8). The single sand layers can be divided by the occurrence of pebbles (<3 cm) at different depths. Above a small silt intercalation between 3.58 and 3.52 m b.s.,

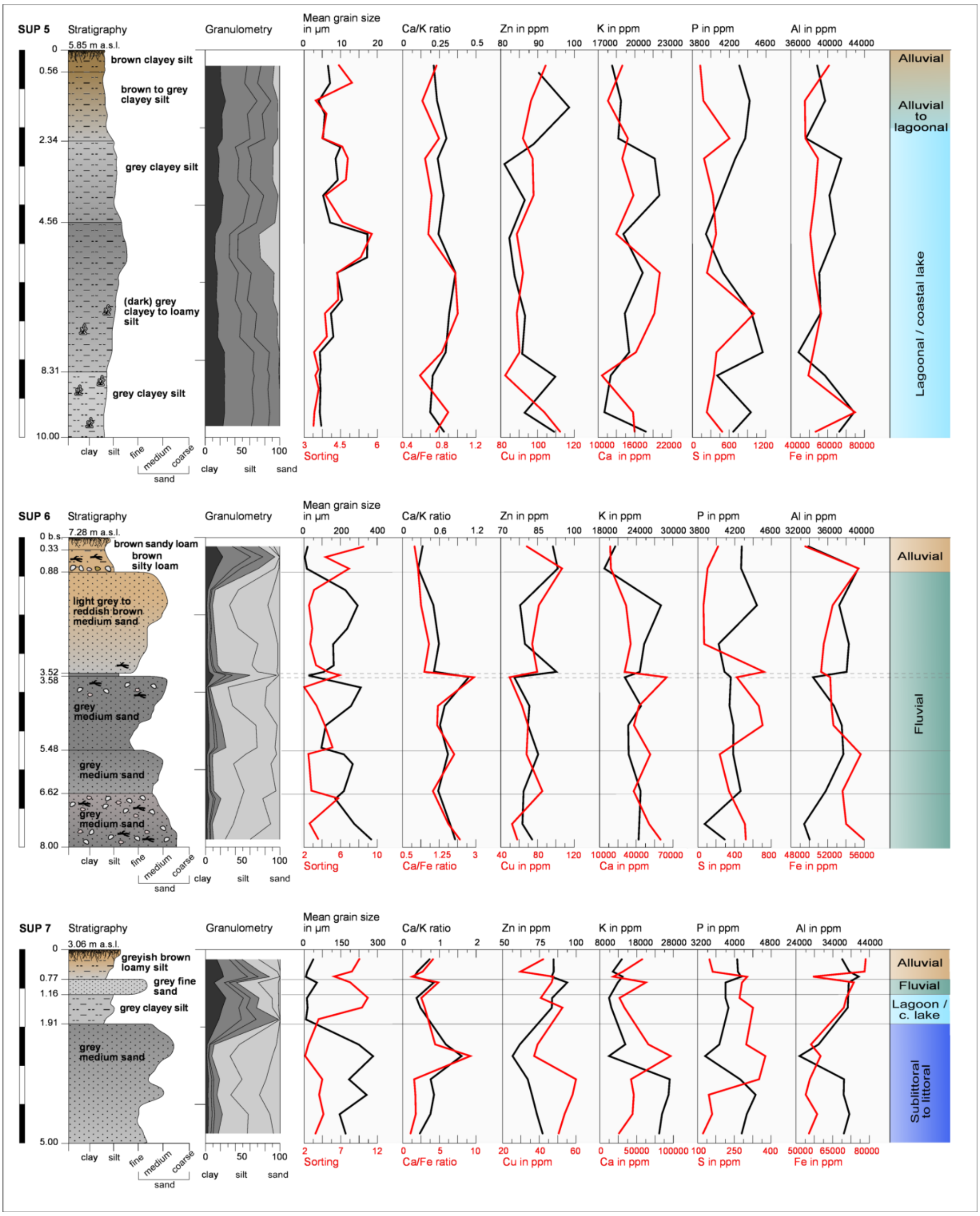

Fig. 4.8: Profiles, facies interpretation, granulometry and geochemistry of the sediment cores SUP 5, SUP 6 and SUP 7. The former two are located at southern banks of the Rioni in the vicinity of a smaller tributary. The latter is located close to the coastline south of the recent river mouth (cf. Fig. 4.1).

the Ca/K and Ca/Fe ratios fall to lower levels while the concentrations of Zn and Cu rise. The uppermost 0.88 m of the core consist of brown sandy loam, which includes a certain amount of pebbles and coarse plant fragments.

4.4.1.7 Sediment core SUP 7

SUP 7, the westernmost sediment core, is from a grassland between the shoreline and the village of Tskaltsminda (Fig. 4.1). The lowermost part between 5 and 1.91 m b.s. consists of (dark) grey medium sand with a mean grain size between ~140 and 300 µm. Above, grey clayey silt was deposited between 1.91 and 1.16 m b.s. Homogeneous grey fine sand (mean grain size ~50 µm) is interdigitated between 1.16 and 0.77 m b.s. The uppermost part is built-up of (greyish) brown loamy silt (Fig. 4.8).

4.4.1.8 Sediment core PIC 2

The sediment core PIC 2 was recovered on the banks of the Pichora River (Figs. 4.1, 4.3 A). Its lowermost part consists of dark grey to greyish brown medium sand. While P, Zn and S remain at low levels, a marked decrease in Ca, Ca/Fe and Ca/K values occurs within this layer. The subsequent stratum (2.93 and 1.26 m b.s.) of poorly sorted loamy silt is clearly

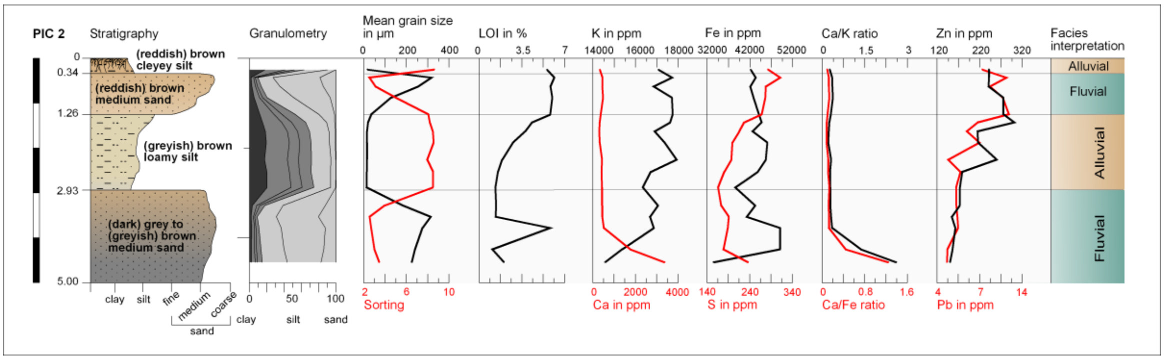

Fig. 4.9: Profile, facies interpretation, granulometry, geochemistry and ^{14}C age estimates of the sediment core PCI 2 from the banks of the Pichora River ca. 7 km north of the Supsa fan (Figs. 4.1 & 4.3 A). The sand-dominated sediment core is strongly influenced by the Pichora and Rioni deposits.

separated from the previous and subsequent sand layers; it reveals slightly increasing values of Pb, Zn, P and S, while Ca/K and Ca/Fe ratios remain on low levels. The upper sand layer stands out with a mean grain size of up to ~320 µm, comparable to the sand layer in the lower part of the core (Fig. 4.9). Most of the geochemical values are close to the loam layer in between. The uppermost part is a humus-rich fine-grained deposit.

4.4.2 Radiocarbon Dating Results

Altogether twelve samples were taken from the sediment cores SUP 3, SUP 4 and SUP 10 and dated by ^{14}C-AMS (see Figs. 4.5 to 4.7 and Tab. 1). The results are given with 2 σ confidence interval.

The seven age estimates of sediment core SUP 4 cover a time span of roughly 5000 years (3756 cal BC to 1261 cal AD; mean ages). Though the 2 σ ranges of the two lowermost samples, SUP 4/39 and SUP 4/41, overlap, an age inversion cannot be excluded.

The age estimates from sediment core SUP 3 cover ~3000 years and ca. six metres of sediment. For sediment core SUP 10, only two samples were used for radiocarbon dating. They derive from the lower and upper facies limit of the archaeological layer between 7.51 and 6.56 m b.s., covering a time span between 1893-1701 BC and 778-990 AD (~1800 to 2900 years).

Tab. 4.1 Radiocarbon data set. Measurements were carried out at the 14CHRONO Centre, Queens University Belfast, Northern Ireland, UK. All ages are calibrated using Calib 7.1 (calibration data set: intcal13.14c; Stuiver & Reimer 1993, Reimer et al. 2013), and are presented with 2 sigma.

Sample ID	Lab code	Depth below surface (m)	δ^{13}C (‰)	Material	Conventional ^{14}C-age BP	Calibrated ^{14}C-age (cal BC/AD), 2 σ
SUP 3/14	UBA-34221	4.32	-30.5	Wood	2180 ± 27	359-171 BC
SUP 3/22	UBA-34222	6.40	-28.5	Wood	3818 ± 30	2434-2143 BC
SUP 3/34	UBA-34223	10.50	-26.1	Wood	4423 ± 58	3336-2913 BC
SUP 4/6	UBA-26767	1.35	-28.3	Plant fragment	854 ± 28	AD 1053-1257
SUP 4/11	UBA-26768	2.35	-21.0	Wood	1214 ± 34	AD 690-891
SUP 4/19	UBA-26769	4.70	-30.9	Wood	2281 ± 37	404-209 BC
SUP 4/23	UBA-26770	5.70	-24.7	Wood	2404 ± 39	749-396 BC
SUP 4/36	UBA-26771	9.27	-26.3	Wood	4699 ± 42	3631-3370 BC
SUP 4/39	UBA-26772	9.75	-27.6	Wood	5111 ± 74	4045-3711 BC
SUP 4/41	UBA-26773	10.50	-24.9	Wood	4983 ± 38	3795-3660 BC
SUP 10/23	UBA-34224	6.72	-26.4	Wood	1126± 27	AD 778-990
SUP 10/29	UBA-34225	7.52	-25.7	Wood	3492 ± 29	1893-1701 BC

4.4.3 Statistical Analyses of the Sedimentological and Geochemical Data

By means of a principal component analysis using granulometric parameters (mean grain size, sorting, kurtosis and skewness) and the geochemical parameters Ca, K, Fe and Cu the three main components were estimated as follows: PC 1: 41.4 %, PC: 24.9 % and PC 3: 11.6 % (Fig. 4.10 A & B). The majority of samples in Fig. 4.10 A cluster on the left side of the y-axis (quadrants I & III) and refer to high values of Cu, Fe and skewness. They are

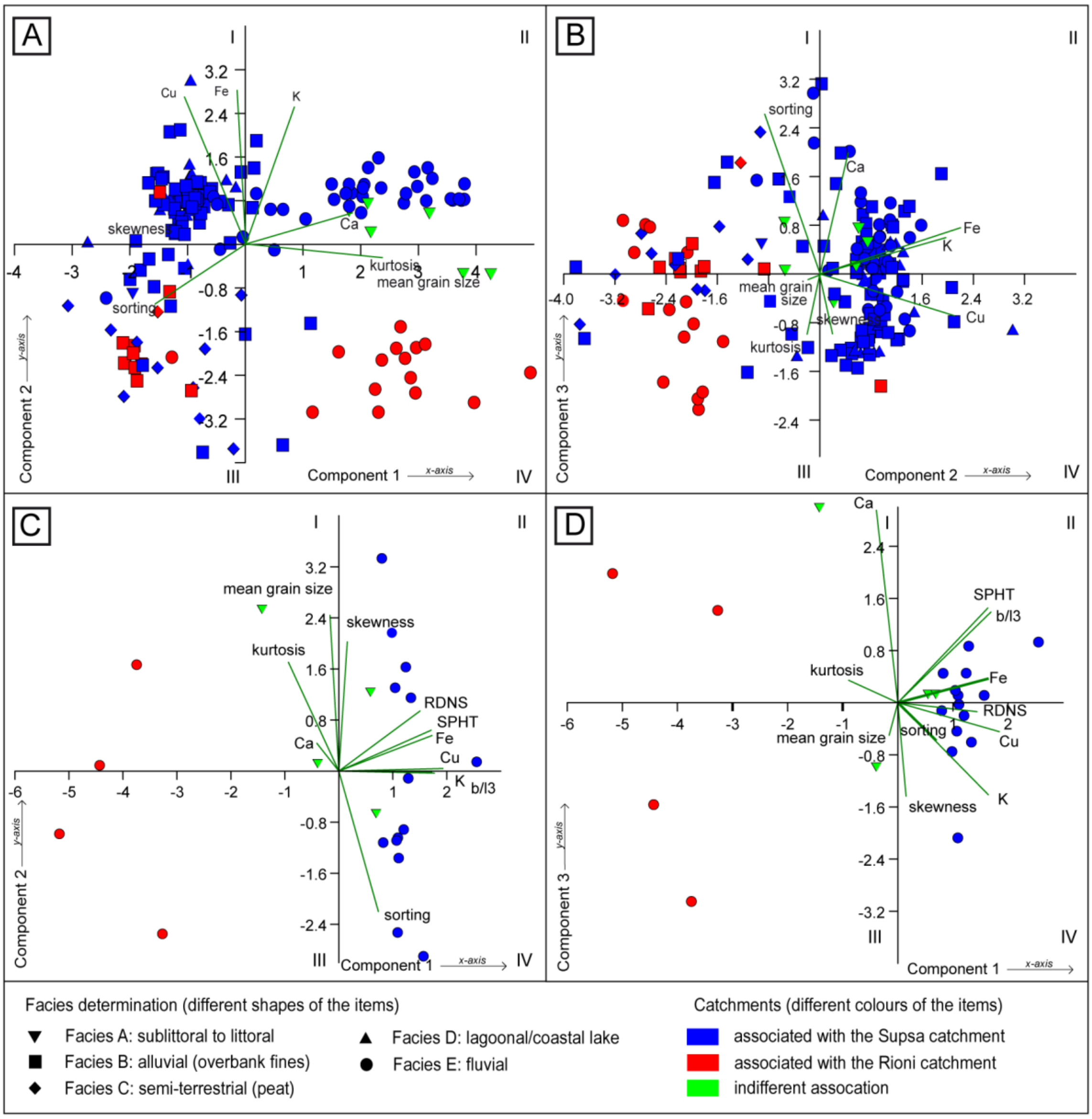

Fig. 4.10: PCAs to decipher the origins and depositional modes of the sediments. A: PCA uses the geochemical parameters Ca, Fe, K and Cu as well as the granulometric parameters mean grain size, sorting, skewness and kurtosis (PC 1: 41.4 %, PC 2: 24.9 %, PC 3: 11.6 %). The axes represent components 1 and 2, while PCA B is based on the components 1 and 3. C and D: PCA on a selection of sandy samples using the parameters of PCA A plus the grain-shape parameters roundness (RNDS), sphericity (SPHR) and elongation (b/l) (PC 1: 40.3 %, PC 2: 25.5 %, PC 3: 14.5 %), plotted on the components 1 and 2 (PCA C) and components 1 and 3 (PCA D).

considered to be of lagoonal or alluvial origin. The poor sorting of and scattered distribution in quadrant III coincide with high values of loss on ignition (cf. Figs. 4.5-4.9) and therefore an enrichment of organic matter. In quadrant II cluster samples of high values of Ca, mean grain size and (to a certain extend) K that are considered to be of fluvial origin. In quadrant IV samples of the sediment core PIC 2 and the lower part of SUP 10 are found. Between these two groups sandy samples that derive from SUP 7 are situated.

Further, a PCA (Fig. 4.10 C & D) that focuses on the sandy sediments was calculated with 25 representative samples. Beside the factors used in the former model, the grain shape parameters of roundness (RNDS), sphericity (SPHR) and elongation (the length-width ratio b/l) (KASPER-ZUGBILLAGA et al. 2005, EAMER et al. 2017) were included. Within this PCA, the first three axes explain 40.3 %, 25.5 % and 14.5 %, respectively. The outlier position of the samples of sediment core PIC 2 and the lower part of SUP 10 is confirmed as well as the exception of the samples of SUP 7.

4.5 Discussion

4.5.1 Facies determination

Based on the granulometric, geochemical and statistical results, six different depositional facies units were defined:

4.5.1.1 Facies A: sublittoral to littoral

The majority of the relatively well-sorted medium sand of sediment core SUP 7 stands out with very coarse mean grain size up to ~300 µm and a unimodal grain-size distribution. This points to hydrodynamic conditions with rather high sediment transport capacities, consistent with wave-dominated coastal conditions (FOLK & WARD 1957, HESP 2002, DINGLER 2005). The geochemistry is characterized by relatively high values of Ca and K and low values of Fe. In Fig. 4.10 A they scatter between the two outlier groups in quadrants II and IV. However, a separation from facies D remains challenging due to the proximity of the Supsa river mouth and its fluvial deposits. Nonetheless, the littoral deposits show a slightly better sorting.

4.5.1.2 Facies B: alluvial (overbank deposits)

This facies is in general characterised by silty to clayey deposits with elevated K and Ca contents and relatively low LOI values. It can be found in all of the analysed sediment cores and dominates the stratigraphy of SUP 3, SUP 4 and SUP 6. It was deposited as suspended sediment load across the floodplain surface by diffuse and channelized flows (DUNNE & AALTO 2013). These channel suspended loads and overbank deposits (overbank fines) are accumulated in slack waters of floodplain depressions (BLAIR & MCPHERSON 1994). In this facies, coarser deposits with varying fine sand content and Ca/Fe and Ca/K values represent fluctuating hydrodynamic conditions during the outflow of fluvial deposits, e.g. during the formation of crevasse splays by breaching of levees of the Supsa (or Rioni) River (NORTH & DAVIDSON, 2012).

4.5.1.3 Facies C: semi-terrestrial (peat and organic-rich deposits)

Facies C is characterized by poor sorting and considerably elevated LOI and K values. The numerous well-preserved macroscopic plant remains and, to some extent, elevated Fe and S values point to anoxic conditions (TURNEY et al. 2005). The typical high TOC/N ratios (JOOSTEN, KAFFKE & MATCHUTADZE 2003) indicate the dominance of cellulosic plants of peat bogs (MEYERS & TERANES, 2001). Although there are many layers with high LOI values and plant fragments, real peat layers were only found in the sediment cores SUP 3, SUP 4 and SUP 10 where LOI contents rise above 30 to 40 % (Arbeitsgruppe Boden 1994).

4.5.1.4 Facies D: lagoonal/coastal lake

In terms of grain size and geochemistry, the sediments of this facies closely resemble the sediments of Facies B. However, this facies can be separated by slightly higher Ca/Fe and Ca/K ratios and lower Si and Ti contents (CUVEN, FRANCUS & LAMOUREUX, 2011, MARTIN-PUERTAS et al. 2011). The strong resemblance to Facies B can be explained by the slow transition from still water environment to deltaic semi-dry conditions. Since there is no microfaunal evidence it remains challenging to estimate the salinity. Therefore, we cannot differentiate between a lagoon or a coastal lake. Although deposited under low-energy conditions, several samples from the lagoonal/coastal lake strata reveal a coarser grain size. The grain-size variations may be explained by changing conditions within the water body such as proximity of fluvial currents caused by river avulsion and floods or storms.

4.5.1.5 Facies E: fluvial

A large portion of the sandy deposits in the sediment cores are characterized by moderate to poor sorting and slightly elevated Fe and K values which hints at an increased input of terrestrial material (ARZ, PÄTZOLD & WEFER 1998, KUJAU et al. 2010). They were found in sediment cores SUP 3, SUP 4, SUP 6, SUP 7, SUP 10 and PIC 2 and can be assumed to be of fluvial origin, primarily linked to sediment input by distributary channels of the Supsa. The varying grain size can, for instance, be explained by river avulsion and temporary lateral channel migration and by deposition during larger floods in areas close to distributary channels. Though there are some terrestrial markers (e.g. increased Fe and K values, e.g. DAVIES, LAMB & ROBERTS 2015) and, generally speaking, the facies is quite heterogeneous (DUNNE & AALTO 2013), the differentiation to facies A remains challenging. The similar characteristics can be explained by the close proximity of the river mouth to the shoreline. Many littoral deposits derive from the Supsa and are only transported for a very short distance along the shore and are then relocated by the sea. By means of the lower values of roundness and sphericity (Fig. 4.10 C), an approximate separation can be achieved (cf. KASPER-ZUBILLAGA et al. 2005). The lowermost stratum of sediment core SUP 10 shows a slightly better sorting than most other layers of this facies. A certain marine or littoral influence may be assumed; it will be discussed in chapter 5.3.

4.5.1.6 Facies F: anthropogenic

This facies occurs only in the sediment core SUP 10 between 6.56 and 7.51 m b.s. The fine-grained matrix closely resembles facies B. However, the large number of burnt clay, ceramic fragments and charcoal indicate a human-induced deposition or, at least, a strong post-depositional human influence. In the other cores, only random findings of burnt clay flitters and charcoal indicate possible human activity.

4.5.2 Implications for the local relative sea-level evolution

As for reconstructing former sea levels, the most reliable samples of this research derive from peat layers, which are directly related to the back-barrier groundwater table and, thus, to the local relative sea level (PIRAZZOLI 1991, VÖTT 2007, BRÜCKNER et al. 2010, LAERMANNS et al. 2018a). Regarding the stratigraphical position of most peat layers – they are superimposed by lagoonal/coastal lake deposits – a peat growth in a situation comparable to the swamps and peat bogs of floodplains today and a subsequent drowning in the course of RSL rise seems most likely. Although the peat might also derive from riverine environments of the Supsa fan, e.g. oxbows, we assume a comparable groundwater table due to the proximity to coast and floodplain environments and, therefore, an indirect sea-level indicator even if marine layers were not reached. However, there may be a significant vertical error range to be considered for RSL reconstructions based on these peat layers which is still debated. Only limited data exists to compare and quantify compaction (TÖRNQUIST et al. 2008). While PIRAZZOLI (1996) calculated a vertical confidence interval of ±0.5 m, recent publications rather hint to varying rates, depending on grain size distribution, organic matter and water content (HORTON & SHENNAN 2009). These factors affect not only the peat layers, but with varying influence also the (fine grained) Holocene sediments below (BUNGENSTOCK & WEERTS 2010). From such layers derive the samples that were taken from alluvial facies.

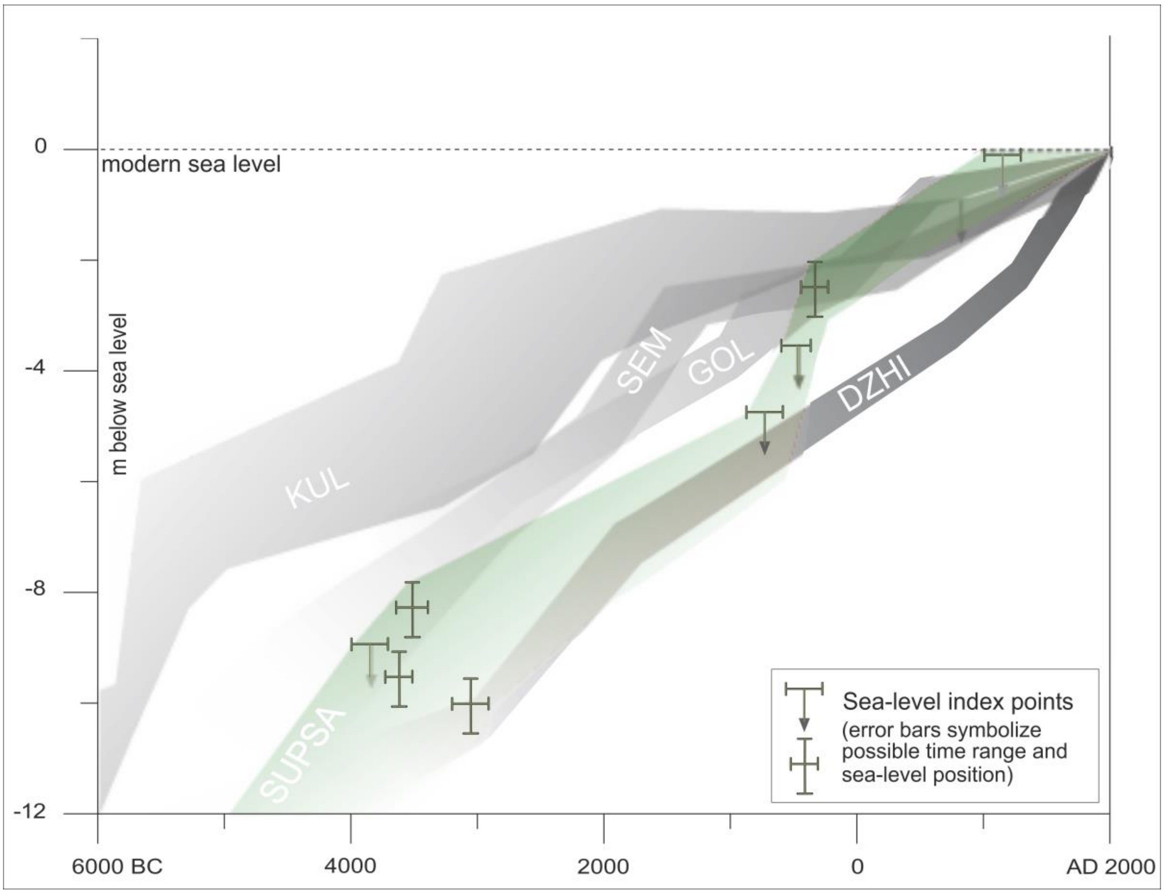

Fig. 4.11: Sea-level index points based on radiocarbon dating of the Supsa delta region with a first estimated sea-level curve (SUPSA, in green). An arrow pointing downwards indicates ^{14}C-dated material from an alluvial context; a cross indicates ^{14}C-dated paralic peat. For comparison, sea-level curves from the central part of the Colchian plain (KUL) and from sites of the Taman Peninsula (SW Russia, north-eastern Black Sea: SEM, GOL, DZHI) are also shown. KUL = Kulevi area north of Poti (Laermanns et al. 2017a), SEM = Semebratnee (Brückner et al. 2010), GOL = Golobitskaya (Kelterbaum et al. 2011), and DZHI = Dschiginka (Fouache et al. 2012).

These index points serve as indicators for the maximum sea-level position at a certain time. Beside compaction, other mechanisms such as tectonic subsidence must be taken into consideration (Bungestock & Weerts 2010). Therefore, the relative sea-level position for each data point can only be seen as a relative indicator (Fig. 4.11) and must not be transferred to other locations where different sedimentary and tectonic settings may prevail (BUNGENSTOCK & WEERTS 2012).

Although establishing a relative sea-level curve for the Supsa area remains challenging due to the small number of radiocarbon samples that can be used as index points of the former sea levels, a local relative sea-level position at about -10 to -8 m can be reconstructed for the time between 4000 and 3500 cal BC. Later, during the 1st millennium BC, a gradual but relatively steep rise from -5 to -3/-2 m is suggested. During the 2nd millennium AD, the RSL approximates the modern level. We are aware that these ^{14}C-dated sea-level indicators and the limited knowledge about tectonics, compaction and subsidence rates (GAMKRELIDZE 1998, ADAMIA et al. 2011) include several uncertainties (BRÜCKNER et al. 2010). Furthermore, changes of the coastline, e.g. opening or closing of the lagoon (Lake Paliastomi) or dislocations of the palaeochannel of the Supsa, might have had a major influence on the samples' setting as well. However, the comparison with earlier studies of the regions reveals at least similar trends. In general, the sea-level evolution in the Supsa area mirrors the investigations between the rivers Rioni and Khobistskali (LAERMANNS et al. 2018a). However, the steeper RSL rise the 4th to the 1st millennium BC presented there (Fig. 4.11) might be attributed to the different location closer to the Rioni and the resulting different compaction and subsidence.

Further, there are several similarities between these RSL data from Georgia and data from the Taman Peninsula at the sites of Semebratnee (BRÜCKNER et al. 2010), Golobitskaya (KELTERBAUM et al. 2011), and Dschiginka (FOUACHE et al. 2012). Especially when compared to the RSL curves of Semebratnee and Golobitskaya for the last ~3000 years, these curves look much alike the one from the Supsa delta region. Beyond 2000 cal BC, our RSL indicators fit well with the curves of Semebratnee and Dschiginka. In general, the RSL curve from the Colchian coast of Georgia resembles quite well those of the Taman Peninsula and others of the Mediterranean (VÖTT 2007, VÖTT et al. 2007, BRÜCKNER et al. 2010). As already stated, the differences between the single curves most likely originate from local effects, e.g. different subsidence and compaction rates as well as local tectonics. It is in any case noteworthy that no hints for significant sea-level oscillations during the mid- to late Holocene, as proposed by various authors (e.g. BALABANOV 2007), were detected in our data.

4.5.3 Palaeo-environmental evolution of the Supsa delta area

The sediment record elucidated by the drillings from the Supsa area yields some hints for the landscape change that has taken place since the mid-Holocene. While being a contribution to the complex formation of the fan, the data from individual cores can only provide local information. However, several repetitive patterns were identified, so that a general trend of processes can be assumed.

The sands in the lowermost part of sediment core SUP 10 resemble closely in terms of geochemistry, sorting and grain shape parameters (Figs. 4.7, 4.9 & 4.11) to those of sediment core PIC 2, suggesting a similar (Rioni-based) origin, i.e. a possible littoral relocation of deposits originating from the Rioni may explain their differentiation from the Supsa fan deposits. Due to their slightly better sorting and a possible relocation they were considered not to be deposits of the alluvial fan and were classified as fluvio-marine deposits instead (Fig. 4.7). Considering the 25-times higher sediment load of the Rioni today (BERKUN, ARAS & AKDEMIR 2015), this seems quite likely. However, there is no evidence for a progradation of the Supsa fan to any of the investigated sites by 3000 BC (Fig. 4.12 A). Instead, the growth of paralic (coastal) peat continued, comparable to the Rioni area further north (LAERMANNS et al. 2018a). This holds true for northern and western parts of the Supsa fan, where at the sites of sediment cores SUP 3 and SUP 4 peat growth is indicated since the mid-5th to the mid-4th millennium BC (Figs. 4.5, 4.6 & 4.12, Tab. 4.1). This would indicate that at least since some time before 3000 BC, a sand spit had evolved by the longshore drift, which separated the research area from the open sea; then lagoonal conditions represented the continuation of the Holocene transgression (RYAN 2007, GIOSAN, FILIP & CONSTANTINESCU 2009, FOUACHE et al. 2010). When the growth of the paralic peat could not keep pace with the ongoing rise in sea level, it was covered by fine-grained sediments related either to standing water bodies such as shallow lagoons, coastal lakes or alluvial deposits (for SUP 4 see Fig. 4.6).

In contrast to this general process, which can be assumed for the entire Colchian plain during the mid-Holocene, the evolution of the Supsa fan forms an outstanding element of the local geomorphology. While in the open plain fine-grained material dominates the stratigraphy, the Supsa introduced an exceptional share of coarser sediments on the plain, related to the formation of the semi-circular alluvial fan just north of the foothills of the Lesser Caucasus. Its natural shape is clearly visible and protrudes beyond the surrounding plain (Fig. 4.2), although an intensive agricultural use and drainage systems strongly reshaped the terrain.

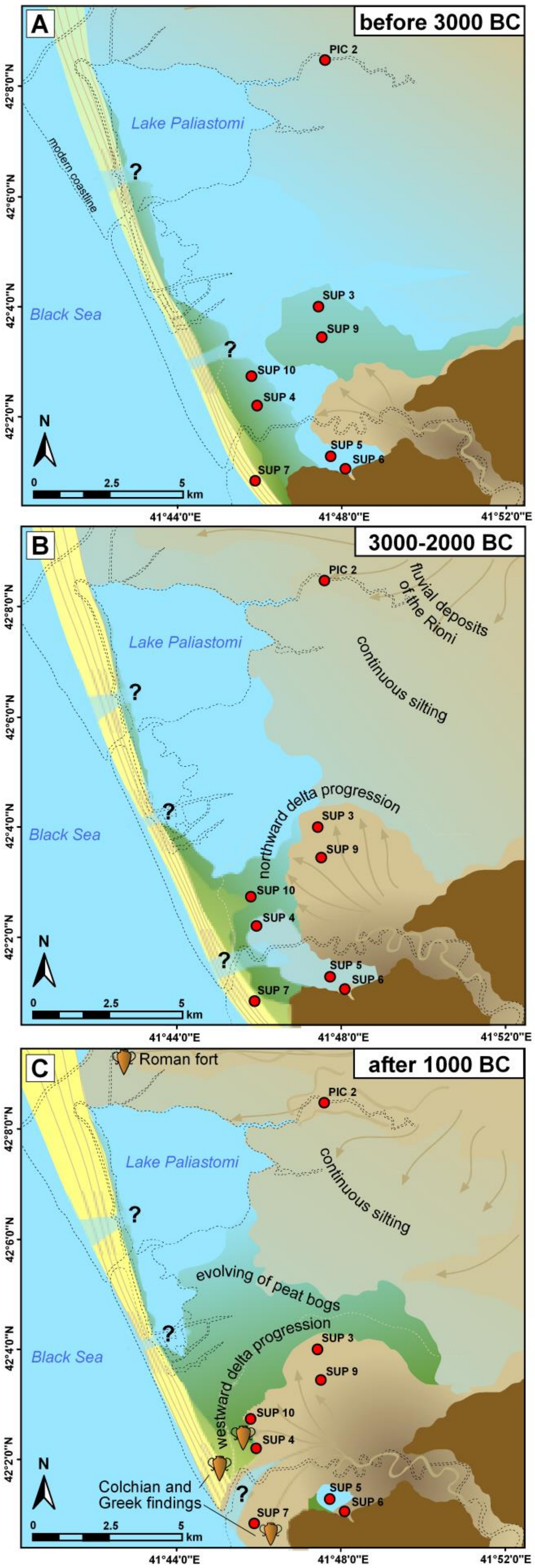

Fig. 4.12: Palaeoenvironmental evolution of the Supsa delta region and the adjacent areas. The transformation from lagoonal conditions to an alluvial plain took place since at least 3000 BC. The Supsa built a remarkable fan that prograded first to the north (B) and shifted later westward (C). During the 1st millennium BC, Colchians and Greeks settled between the fan and the coastline which is documented by several ceramic findings and graves.

Furthermore, the sandy sediment of the Supsa fan can be separated from sandy deposits of the Rioni-dominated floodplain sediments by higher K and Fe contents, a higher grade of sphericity and slightly poorer sorting (Fig. 4.10), which most likely derived from the different geologic settings and transport distances. The typical interdigitations of alluvial fan-related distributary channels and fine-grained alluvial deposits are reflected in sediment core SUP 3 and in the upper part of SUP 10. The chronostratigraphy of SUP 3 in the northern part of the fan indicates that channel deposits of ~2.40 m thickness reached that site after the mid-3rd millennium BC (Fig. 4.12 B). Similar deposits were found in sediment cores SUP 4 and SUP 10 in the western section of the fan, although of different thickness and grain size; here, these channel deposits accumulated considerably later, i.e. in the 1st millennium AD (Fig. 4.12 C). A comparable layer recurs in the northern sediment core SUP 3 as well, just above a peat layer, which dates back to the second half of the 1st millennium BC. These results indicate that the main activity and progradation of the Supsa fan shifted between the 2nd millennium BC and the 1st millennium AD from north to west.

Beside this general fan evolution several areas were only marginally affected by the progradation. Sediment core SUP 5, where only fine sediments were found, exemplifies that close to the foothills of the lesser Caucasus the quiescent depositional conditions of the central Colchian plain prevailed over a longer period. Close by, sediment core SUP 6 shows in contrast a different stratigraphy, which is clearly dominated by fluvial deposits emerging from the small tributary valley (Figs. 4.1, 4.12).

In contrast, the area west of the Supsa fan, around the modern river mouth, reveals a different stratigraphy. In the sediment core SUP 7 (Fig. 4.1), coarse sand of most likely littoral origin dominates, which is reflected by the relatively high Ca/K and Ca/Fe ratios and the low Fe contents (Davies, Lamb & Roberts 2015). However, the lower sections resemble to a certain extend the (fluvial) deposits of the sediment cores taken from the Supsa fan, although the main grain size is coarser and comparable to the fluvial deposits of sediment core PIC 2 in the Rioni catchment. Plus, the sand is better sorted which indicates the littoral relocation and reworking through longshore drift (Folk & Ward 1957, Hesp 2002). The location in the PCAs in Fig. 4.10 confirms the different composition and deposition. Conditions gradually change upwards, documenting the increasing influence of the Supsa River at the site of SUP 7.

Considering the sediment successions at all the investigated sites we can assume that ~4000 BC the research area was characterised by standing water bodies, likely related to lagoonal environments, with fine-grained sediments separated from the open sea by a continuously evolving beach barrier complex. Due to continued riverine sediment input, the lagoons silted up (Berkun et al. 2015), and extended peat bogs formed east of the beach ridges. Comparable processes are known from the central Kolkheti lowlands (LAERMANNS et al. 2018a), as well as from areas further south (CONNOR, THOMAS & KVAVADZE 2007, DE KLERK et al. 2009). The formation of the Supsa fan advanced at least since the 3rd millennium BC, first to the north and later to the west.

4.5.4 Human occupation

Traces of human occupation in the research area can be found in sediment core SUP 10 where between 7.51 and 6.56 m b.s. the entire layer is full of brick fragments, ceramic remains and charcoal flitters. Obviously a human settlement existed at or close to this coring site. The radiocarbon ages, which were gained from the uppermost part from the layer below and the uppermost part of the archaeological layer, indicate an occupation between 1893-1701 cal BC and 778-990 cal AD (Table 1). The huge age gap within a rather small vertical distance could have been caused by the removal sediments during construction activities. Although the homogeneity of the brick fragments hints at a same origin, it remains unclear if this settlement is of Colchian, Greek or Roman/Byzantine origin. In any case, beside the artefacts, the geochemical evidence, namely the sharp increase in Cu and Zn values, confirms human activities.

The area of the findings is located between the present shoreline in the west and the northern part of the Supsa fan in the east. This suggests that ancient people settled in the vicinity of the swampy but fertile back-barrier areas, which are dominated by alluvial deposits since at least ca. 2000 BC (in case of the site of sediment core SUP 10). According to the radiocarbon ages, the gradual shift to a floodplain environment was completed between the 9th and the 11th centuries AD (Figs. 4.5, 4.6). Such settlement locations are known from different sites along the Colchian coast, e.g. close to Ureki (MIRON & ORTHMANN 1995, GAMKRELIDZE 2012), or near Kobuleti, where the ancient settlement of Ispani was situated in a similar back-barrier position (CONNOR, THOMAS & KVAVADZE 2007, DE KLERK et al. 2009); it was later covered by sands.

4.6 Conclusions

Based on the analysis of eight sediment cores a significant landscape change could be proven for the Supsa delta fan and the adjacent areas on the Colchian plain. By using a combination of sedimentological and geochemical parameters different depositional facies were classified. Their succession reflects the palaeoenvironmental evolution of the area over the last 6000 years. The southern part of the Colchian plain underwent a similar morphogenesis as the areas of the Rioni and other rivers further north (LAERMANNS et al. 2018a). Although the complex setting of the delta forms a challenging geo-archive several general trends can be assumed.

After the deceleration of the postglacial sea-level rise around 7000 years ago (BRÜCKNER et al. 2010), deltaic progradation became the dominant landscape-forming coastal process (ANTHONY, MARRINER & MORHANGE 2014). In the research area, a beach barrier complex evolved which led to the formation of extensive lagoons. Thus, the area was separated from the open sea by longshore-transported sediments. The Supsa river debouched into that vast lagoon and later floodplain environment, thus having formed a remarkable alluvial fan at least since the 3rd millennium BC. This fan stands out with its elevated relief and a sediment stratigraphy that can well be differentiated from the Rioni-dominated deposits of the plain by grain-shape characteristics and geochemical parameters. The beach barrier complex was formed first with material that had been eroded from cliff sections to the south, later also by sediments that originated from the Rioni and the Supsa.

The indicated sea-level evolution must be considered with caution due to limited information on subsidence and compaction rates, the complex delta setting and only few index points. Nevertheless, an overall continuous rise is suggested, and the sea-level trend resembles those RSL curves from Taman Peninsula (FOUACHE et al. 2012) and the central parts of the Colchian plain (LAERMANNS et al. 2018a). However, considering the mentioned challenges our results should be rather taken as an indication for the sea-level trend, not as a sea-level curve.

4.7 Acknowledgements

H.L. gratefully acknowledges the funding of his PhD project by the Heinrich Böll Foundation and by the Graduate School of Geosciences (GSGS) of the University of Cologne. Furthermore, he thanks the Albertus Magnus Graduate Center (University of Cologne) for funding his research stay at the Université de Franche-Comté in Besançon. We thank the colleagues and students from the Ilia State University at Tbilisi who were involved in fieldwork in 2013 and 2015 for their scientific, administrative and logistic help, as well as for providing accommodation at the Grigoleti Marine Research Centre of the Ilia State University during fieldwork.

4.8 References

ADAMIA, S., ZAKARIADZE, G., CHKHOTUA, T., SADRADZE, N., TSERETELI, N., CHABUKIANI, A. & GVENTSADZE, A. (2011): Geology of the Caucasus: A Review. – Turkish Journal of Earth Sciences, 20: 489-544.

ANTHONY, E.J., MARRINER, N. & MORHANGE, C. (2014): Human influence and the changing geomorphology of Mediterranean deltas and coasts over the last 6000 years: From progradation to destruction phase? – Earth-Science Reviews, 139: 336-361.

ARBEITSGRUPPE BODEN (1994): Bodenkundliche Kartieranleitung. – 392 pp.; Hannover.

ARNAUD-FASSETTA, G., CARRE, M.-B., MAROCCO, R., MASELLI SCOTTI, F., PUGLIESE, N., ZACCARIA, C., BANDELLI, A., BRESSON, V., MANZONI, G., MONTENEGRO, M.E., MORHANGE, C., PIPAN, M., PRIZZON, A. & SICHÉ, I. (2003): The site of Aquileia (northeastern Italy): example of fluvial geoarchaeology in a Mediterranean deltaic plain. – Géomorphologie: relief, processus, environment, 4: 227-246.

ARSLANOV, K.A., DOLUKHANOV, P.M. & GEI, N.A. (2007): Climate, Black Sea levels and human settlements in the Caucasus Littoral 50,000-9000 BP. – Quaternary International, 167-168: 121-127.

ARZ, H.W., PÄTZOLD, J., & WEFER, G. (1998): Correlated millennial-scale changes in surface hydrography and terrigenous sediment yield inferred from last-glacial marine deposits off Brazil. – Quaternary Research, 50: 157-166.

AVDEEV, B. & NIEMI, N.A. (2011): Rapid Pliocene exhumation of the central Greater Caucasus constrained by low-temperature thermochronometry, – Tectonics, 30: 1-16.

BALABANOV, I.P. (2007): Holocene sea-level changes of the Black Sea. – In: YANKO-HOMBACH, V., GILBERT, A.S., PANIN, N. & P. DOLUKHANOV (Eds.): The Black Sea Flood question: Changes in coastline, climate and human settlement. – Springer, Dordrecht: pp. 711-730.

BARSCH, H., BILLWITZ, K. & BORK, H. (2000): Arbeitsmethoden in der Physiogeographie und Geoökologie. – 612 pp.; Gotha (Klett-Perthes).

BAZHENOV, M.L. & BURTMAN, V.S. (2002): Eocene paleomagnetism of the Caucasus (southwest Georgia): oroclinal bedding in the Arabian syntaxis. – Tectonophysics, 344: 247-259.

BERKUN, M., ARAS, E. & AKDEMIR, U. (2015): Water runoff, sediment transport and related impacts in the southeastern Black Sea rivers. – Environmental Engineering and Management Journal, 14 (4): 781-791.

BLAAUW, M. & CHRISTEN, J.C. (2011): Flexible paleoclimate age-depth models using an autoregressive gamma process. – Bayesian Analysis, 6 (3): 457-474.

BLAIR, T.C. & MCPHERSON, J.G. (1994): Alluvial fans and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes, and facies assemblages. – Journal of Sedimentary Research, A64: 450-489.

BLOTT, S.J. & PYE, K. (2001): Technical communication, GRADISTAT: A grain size distribution and statistics package for the analysis of unconsolidated sediments. – Earth Surface Processes and Landforms, 26: 1237-1248.

BOLIKHOVSKAYA, N.S., POROTOV, A.V., RICHARDS, K., KAITAMBA, M.D., FAUSTOV, S.S. & KOROTAEV, V.N. (2017): Detailed reconstructions of Holocene climate and environmental changes in the Taman Peninsula (Kuban River delta region) and their correlation with rapid sea-level fluctuations of the Black Sea. – Quaternary International (2017), DOI: 10.1016/j.quaint. 2017.08.013.

BOX, E.O., FUJIWARA, K., NAKHUTSRISHVILI, G., ZAZANASHVILI, N., LIEBERMANN, R.J. & MIYAWAKI, A. (2000): Vegetation and landscape of Georgia (Caucasus) as a basis for landscape restoration. – Bulletin of the Institute of Environmental Science and Technology, Yokohama National University, 26: 69-102.

BRÜCKNER, H., MÜLLENHOFF, M., HANDL, M. & VAN DER BORG, K. (2002): Holocene landscape evolution of the Büyük Menderes alluvial plain in the environs of Myous and Priene (Western Anatolia, Turkey). – Zeitschrift f. Geomorphologie (Annals of Geomorphology), 127: 47-65.

BRÜCKNER, H., KELTERBAUM, D., MARUNCHAK, O., POROTOV, A. & VÖTT, A. (2010): The Holocene sea level story since 7500 BP – lessons from the Eastern Mediterranean, the Black and the Azov Seas. – Quaternary International, 225: 160-179.

BRÜCKNER, H., HERDA, A., MÜLLENHOFF, M., RABBEL, W. & STÜMPEL, H. (2014): On the Lion Harbour and other harbours in Miletos: recent historical, archaeological, sedimentological, and geophysical research. – Proceedings of the Danish Institute at Athens, vol. VII: 49-103; Aarhus.

BRÜCKNER, H., HERDA, A., KERSCHNER, M., MÜLLENHOFF, M. & STOCK, F. (2017): Life cycle of estuarine islands — From the formation to the landlocking of former islands in the environs of Miletos and Ephesos in western Asia Minor (Turkey). – Journal of Archaeological Science: Reports, 12: 876–894.

BUNGENSTOCK, F. & WEERTS, H.J.T. (2010): The high-resolution Holocene sea-level curve for Northwest Germany: global signals, local effects or data-artefacts? – International Journal of Earth Sciences, 99 (8): 1687-1706.

BUNGENSTOCK, F. & WEERTS, H.J.T. (2012): Holocene relative sea-level curves for the German North Sea coast – International Journal of Earth Sciences, 101: 1083-1090.

CARMONA, P. & RUIZ, J.M. (2011): Historical morphogenisis of the Turia River coastal flood plain in the Mediterranean littoral of Spain. – Catena, 86 (3): 139-149.

CAROZZA, J.-M., PUIG, C., ODIOT, T., VALETTE, P. & PASSARIUS, V. (2011): Geoarchaeological insight in the Tech basin (Roussillon, Gulf of Lion, Western Mediterranean). – Quaternary International, 266: 94-104.

CONNOR, S., THOMAS, I. & KVAVADZE, E. (2007): A 5600-yr history of changing vegetation, sea levels and human impacts from the Black Sea coast of Georgia. – The Holocene, 17: 25-37.

CUVEN, S., FRANCUS, P. & LAMOUREUX, S. (2011): Mid to Late Holocene hydroclimatic and geochemicalrecords from the varved sediments of East lake, Cape Bounty, Canadian High Arctic. – Quaternary Science Review, 30: 2651–2665.

DAVIES, S.J., LAMB, H.F. & ROBERTS, S.J. (2015): Micro-XRF Core Scanning in Palaeolimnology: Recent Developments. – In: CROUDACE, I.W. & ROTHWELL, R.G. (Eds.): Micro-XRF Studies of Sediment Cores. – Development in Paleoenvironmental Research, 17: 189-226.

DE KLERK, P., HABERL, A., KAFFKE, A., KREBS, M., MATCHUTADZE, I., MINKE, M., SCHULZ, J. & JOOSTEN, H. (2009): Vegetation history and environmental development since ca 6000 cal yr BP in and around Ispani 2 (Kolkheti lowlands, Georgia). – Quaternary Science Reviews, 28: 890-910.

DELILE, H., MAZZINI, I. BLICHERT-TOFT, J., ARNAUD-GODET, F., SALOMON, F. & ALBARÈDE, F. (2014): Geochemical investigation of a sediment core from the Trajan basin at Portus, the harbor of ancient Rome. – Quaternary Science Reviews, 87: 34-45.

DENK, T., FROTZLER, N. & DAVITASHVILI, N. (2000): Vegetational patterns and distribution of relict taxa in humid temperate forests and wetlands of Georgia (Transcaucasia). – Biological Journal of the Linnean Society, 72: 287-332.

DHONT, D. & CHOROWICZ, J. (2006): Review of the neotectonics of the Eastern Turkish-Armenian Plateau by geomorphic analysis of digital elevation model imagery. – International Journal of Earth Sciences, 95: 34-49.

DINGLER, J.R. (2005): Beach processes. – In: SCHWARTZ M.L. (Ed.): Encyclopedia of Coastal Sciences. Dordrecht (Springer), pp. 161-168.

DIRIX, K., MUCHEZ, P., DEGRYSE, P. & POBLOME, J. (2015): Spatial distribution of elemental enrichments around archaeological sites: Insights from the ancient city of Sagalassos in Southwest Turkey. – Geoarchaeology, 31: 34-48.

DUNG, T.T.T., CAPPUYNS, V., SWENNEN, R. & PHUNG, N.K. (2013): From geochemical background determination to pollution assessment of heavy metals in sediments and soils. – Reviews in Environmental Science and Biotechnology, 12: 335-353.

DUNNE, T. & AALTO, R.E. (2013): Larger River Floodplains. – In: WOHL, E. (Ed.): Fluvial Geomorphology, 9: 645-678.

EAMER, J.B.R., SHUGAR, D.H., WALKER, I.J., LIAN, O.B. & NEUDORF, C.M. (2017): Distinguishing depositional setting for sandy deposits in coastal landscapes using grain shape. – Journal of Sedimentary Research, 87: doi: 10.2110/Jsr.2016.92

EPPELBAUM, L. & KHESIN, B. (2012): Geophysical Studies in the Caucasus. Lecture Notes in Earth System Sciences. – 404 pp.; Berlin, Heidelberg (Springer).

ERB-SATULLO N., GILMOUR B. & KHAKHUTAISHVILI, N. (2014): Late Bronze and Early Iron Age copper smelting technologies in the South Caucasus: the view from ancient Colchis c. 1500-600 BC. – Journal of Archaeological Science, 49: 147-159.

ERGINAL, A.E., EKINCI, Y.L., DEMIRCI, A., BOZCU, M., OZTURK, M.Z., AVCIGLU, M. & OZTURA, E. (2013): First record of beachrock on Black Sea coast of Turkey: Implications for Late Holocene sea-level fluctuations. – Sedimentary Geology, 294: 294-302.

FÄHNRICH, H. (2010): Geschichte Georgiens. Handbuch der Orientalistik (Vol. 21). – 581 pp.; Leiden (Koninklijke Brill NV).

FLAUX, C., EL-ASSAL, M., SHAALAN, C., MARRINER, N., MORHANGE, C., TORAB, M. GOIRAN, J.P. & EMPEREUR, J.Y. (2017): Geoarchaeology of Portus Mareoticus: Ancient Aleandria's lake harbour (Nile Delta, Egypt) – Journal of Archaeological Science: Reports, 13: 669-681.

FOLK, R.L. & WARD, W.C. (1957): Brazos river bar: A study in the significance of grain size parameters. – Journal of Sedimentary Petrology, 27: 3-26.

FORTE, A., COWGILL, E. & WHIPPLE, K.X. (2014): Transition from a singly vergent to doubly vergent wedge in a young orogeny. The Greater Caucasus. – Tectonics, 33: 2077–2101.

FOUACHE, E., KELTERBAUM, D., BRÜCKNER, H., LERICOLAIS, G., POROTOV, A. & DIKAREV, V. (2012): The Late Holocene evolution of the Black Sea – a critical view on the so-called Phanagorian regression. – Quaternary International, 266: 162-174.

GAMKRELIDZE, G. (1998): Stress vector orientations and movement of the Earth's crust of territory of Georgia and the neotectonic stage. – Bulletin of the Georgian Academy of Science, 158: 284-287.

GAMKRELIDZE, G. (2012): Researches in the Iberia-Colchology (History and Archaeology of ancient Georgia) – 345 pp.; Tbilisi (Georgian National Museum).

GIOSAN, L., DONNELLY, J.P., FILIP, F., OVEJANU, I., VESPREMEANU-STROE, A., VESPREMEANU, E. & DULLER, G.A.T. (2006): Young Danube delta documents stable Black Sea level since the middle Holocene: Morphodynamic, paleogeographic, and archaeological implications. – Geology, 34: 757-760.

GIOSAN, L., FILIP, F. & CONSTANTINESCU, S. (2009): Was the Black Sea catastrophically flooded in the early Holocene? – Quaternary Science Reviews, 28: 1-6.

GOIRAN, J.P., SALOMON, F., MAZZINI, I., BRAVARD, J.P., PLEUGER, E., VITTORI, C., BOETTO, G., CHRISTIANSEN, J., ARNAUD, P., PELLEGRINO, A., PEPE, C. & SADORI, L. (2014): Geoarchaeology confirms location of the ancient harbour basin of Ostia (Italy). – Journal of Archaeological Science, 41: 389-398.

GREPPIN, D. (1991): Some effects of the Hurro-Urartian people and their languages upon the earliest Armenians. – Journal of the American Oriental Society, 111.4: 720-730.

GUGUSHVILI, V., POPKHADZE, N., BERIDZE, T. & KHUTSICHVILI, S. (2010): Sources of base, precious and rare metals during the Tethyan Phanerozoic evolution of the Caucasus and Pontides. – In: Proceedings of the XIX CBGA Congress. – Thessaloniki (School of Geology, Aristotle University of Thessaloniki): 333-341.

HAGHANI, S., LEROY, S., KHDIR, S., KABIRI, K., BENI, A.N. & LAHIJANI, H.A.K. (2015): An early 'Little Ice Age' brackish water invasion along the south coast of the Caspian Sea (sediment of Langarud wetland) and its wider impacts on environment and people. – The Holocene, 26: 3-16.

HAMMER, Ø., HARPER, D.A.T., & RYAN, P.D. (2001): PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica, 4, 9-11.

HEIRI, O., LOTTER, A. & LEMCKE, G. (2001): Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. – Journal of Paleolimnology, 25: 101-110.

HESP, P. (2002): Foredunes and blowouts: initiation, geomorphology and dynamics. – Geomorphology, 48: 245-268.

HIJMANS, R.J., CAMERON, S.E., PARRA, J.L., JONES, P.G. & JARVIS, A. (2005): Very high resolution interpolated climate surface for global land areas. – International Journal of Climatology, 25: 1965-1978.

HORTON, B.P. & SHENNAN, I. (2009): Compaction of Holocene strata and the implications for relative sea-level change on the east coast of England. – Geology, 37 (12): 1083-1086.

JANELIDZE, Z. & TATASHIDZE, Z. (2010): Palaeogeographical Interpretation of archaeological site of swamps of the Black Sea Coast of Georgia. – Bulletin of the Georgian National Academy of Sciences, 4: 159-161.

JOOSTEN, H., KAFFKE, A. & MATCHUTADZE, I. (2003): The mires of the Kolkheti lowlands (Georgia). – IMCG Newsletter, 2003/3: 19-23.

KASPER-ZUBILLAGA, J.J., DICKINSON, W.W., CARRANZA-EDWARDS, A. & HRONELAS-OROZCO, Y. (2005): Petrography of quartz grains in beach and dune sands of Northland, North Island, New Zealand. – New Zealand Journal of Geology and Geophysics, 48: 649-660.

KELTERBAUM, D., BRÜCKNER, H., POROTOV, A., SCHLOTZHAUER, U. & ZHURAVLEV, D. (2011): Geoarchaeology of Taman Peninsula (SW Russia) - the example of the ancient Greek settlement of Golubitskaya 2. – Die Erde, 142 (3): 235-258.

KELTERBAUM, D., BRÜCKNER, H., DIKAREV, V., GERHARD, S., PINT, A., POROTOV, A. & ZIN'KO, V. (2012): Palaeogeographic changes at Lake Chokrak on the Kerch Peninsula, Ukraine, during the Mid- and Late-Holocene. – Geoarchaeology, 27: 206-219.

KHAKHUTAISHVILI, N. (2008): An ancient Colchian center of iron metallurgy at Chorokhi: excavations in 2001. – In: SAGONA, A. & ABRAMASHVILI, M. (Eds.), Archaeology in Southern Caucasus: Perspectives from Georgia. – Leuven (Peeters): 397-405.

KHAKHUTAISHVILI, D.A. (2009 [1987]): The Manufacture of Iron in Ancient Colchis. – Archaeopress, Oxford.

KOHL, P. (2001): Migrations and cultural diffusions in the later Prehistory of the Caucasus. – In: EICHMANN, R. & PARZINGER, H. (Eds.), Migration und Kulturtransfer. Der Wandel vorder- und zentralasiatischer Kulturen im Umbruch vom 2. zum 1. vorchristlichen Jahrtausend (= Kolloquien zur Vor- und Frühgeschichte. Bd. 6). – Akten des internationalen Kolloquiums, Berlin, 23. bis 26. November 1999. – Bonn (Habelt): 313-327.

KOROTAEV, G., OGUZ, T., NIKIFOROV, A. & KOBLINSKY, C. (2003): Seasonal, interannual, and mesoscale variability of the Black Sea upper layer circulation derived from altimeter data. – Journal of Geophysical Research, 108 (C4): 19-1 – 19-15.

KRAFT, J.C., RAPP, G., KAYAN, İ. & LUCE, J.V. (2003): Harbor areas at ancient Troy: Sedimentology and geomorphology complement Homer's Iliad. – Geology 31 (2): 163-166.

KUJAU, A., NÜRNBERG, D., ZIELHOFER, C., BAHR, A. & RÖHL, U. (2010): Mississippi River discharge over the last ~560,000 years—indications from X-ray fluorescence core-scanning. – Palaeogeography Palaeoclimatology Palaeoecology, 298: 311-318.

LAERMANNS, H., KELTERBAUM, D., MAY, S.M., ELASHVILI, M., OPITZ, S., HÜLLE, D., RÖLKENS, VERHEUL, J., RIEDESEL, S. & BRÜCKNER, H. (2018a): Mid- to Late Holocene landscape changes in the Rioni Delta area (Kolkheti lowlands, W Georgia). – Quaternary International, 465: 85-98.

LAERMANNS, H., KIRKITADZE, G., MAY, S.M., KELTERBAUM, D., OPITZ, S., HEISTERKAMP, A., BASILAIA, G., ELASHVILI, M. & BRÜCKNER, H. (2018b): Bronze Age settlement mounds on the Colchian plain at the Black Sea coast of Georgia - a geoarchaeological perspective. – Geoarchaeology, 33 (4): 453-469.

LARIO, J., ZAZO, C., GOY, J.L., DABRIO, C.J., BORJA, F., SILVA, P.G., SIERRO, F., GONZÁLEZ, A., SOLER, V. & YILL, E. (2002): Changes in the sedimentation trends in SW Iberia Holocene estuaries (Spain). – Quaternary International, 93-94: 171-176.

LORDKIPANIDZE, D., JASHASHVILI, T., VEKUA, A., PONCE DE LEÓN, M., ZOLLIKOFER, C., RIGHTMIRE, G.P., PONTZER, H., FERRING, R., OMS, O., TAPPEN, M., BUKHSIANIDZE, M., AGUSTI, J., KAHLKE, R., KILADZE, G., MARTINEZ-NAVARRO, B., MOUSKHELISHVILI, A., NIORADZE, M. & ROOK, L. (2007): Postcranial evidence from early Homo from Dmanisi, Georgia. – Nature, 449: 305-310.

LORDKIPANIDZE, O. (1985): Das alte Kolchis und seine Beziehungen zur griechischen Welt vom 6. zum 4. Jh. v. Chr. – In: SCHULLER, W. (Ed.): XENIA – 49 pp.; Konstanzer Althistorische Vorträge und Forschungen 14, (Kontanz).

LORDKIPANIDZE, O. (1991): Archäologie in Georgien. Von der Altsteinzeit zum Mittelalter. – 349 pp.; Weinheim (VCH Verlagsgesellschaft mbH).

MARRINER, N. & MORHANGE, C. (2007): Geoscience of ancient Mediterranean harbours. – Earth-Science Reviews, 80: 137-194.

MARRINER, N., MORHANGE, C. & GOIRAN, J.P. (2010): Coastal and ancient harbour geoarchaeology. – Geology Today, 26 (1): 21-27.

MARTIN-PUERTAS, C., VALERO-GARCÉS, B., MATA, M.P., MORENO, A., GIRALT, S., MARTINEZ-RUIZ, F. & JIMENÉZ-ESPEJO, F. (2011): Geochemical processes in a Mediterranean lake: a high-resolution study of the last 4,000 years in Zoñar Lake, southern Spain. – Journal of Paleolimnology, 46: 405-421.

MEYERS, P. A., & TERANES, J.L. (2001): Sediment organic matter. In: W.M. LAST & J.P. SMOL (Eds.), Tracking Environmental Change Using Lake Sediments, Dordrecht, Kluver Academic Publishers, pp. 239–269.

MIRON, A. & ORTHMANN, W. (1995): Unterwegs zum Goldenen Vlies - archäologische Funde aus Georgien. 342 pp.; Saarbrücken (Museum für Vor- und Frühgeschichte Saarbrücken).

MITCHELL, J. & WESTAWAY, R. (1999): Chronology of Neogene and Quaternary uplift and magmatism in the Caucasus: constraints from K-Ar dating of volcanism in Armenia. – Tectonophysics, 304: 157-186.

NIKOLAISHVILI, D.A., ELIZARBARASHVILI, N. & MELADZE, G.G. (2015): Evaluation of degree of landscape's anthropogenic transformation (landscapes of Georgia). – Procedia Social and Behavioral Sciences, 19: 547-555.

NORTH, C.P. & DAVIDSON, S.K. (2012): Unconfined alluvial flow processes: recognition and interpretation of their deposits, and the significance for palaeogeographic reconstruction. – Earth Science Reviews, 111: 199- 223.

OKROSTSVARIDZE, A., GAGNIDZE, N. & AKIMIDZE, K. (2016): A modern field investigation of the mythical "gold sands" of the ancient Colchis Kingdom and "Golden Fleece" phenomena, – Quaternary International, 409: 61-69.

OONK, S., SLOMP, C.P. & HUISMAN, D.J. (2009): Geochemistry as an aid in archaeological prospection and site interpretation: Current issues and research directions. – Archaeological Prospection, 16: 35-51.

PAVLOPOULOS, K., KARKANAS, P., TRIANTAPHYLLOU, M., KARYMBALIS, E., TSOUROU, T. & PALYVOS, N. (2006): Paleoenvironmental evolution of the coastal plain of Marathon, Greece, during the Late Holocene: Depositional environment, climate, and sea level changes. – Journal of Coastal Research, 22 (2): 424- 438.

PIRAZZOLI, P.A. (1996): Sea-level Changes. The Last 20,000 Years. – Wiley and Sons, Chichester.

RAYFIELD, D. (2013): Edge of Empires: A History of Georgia. – 512 pp. London (Reaktion Books).

REILINGER, R., REILINGER, R., MCCLUSKY, S., VERNANT, P., LAWRENCE, S., ERGINTAV, S., CAKMAK, R., OZENER, H., KADIROV, F., GULIEV, I., STEPANYAN, R., NADARIYA, M., HAHUBIA, G., MAHMOUD, S., SAKR, K., ARRAJEHI, A., PARADISSIS, D., AL-AYDRUS, A., PRILEPIN, M., GUSEVA, T., EVREN, E., DMITROTSA, A., FILIKOV, S. V., GOMEZ, F., AL-GHAZZI, R. & KARAM, G. (2006): GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions. – Journal of Geophysical Research, 111: 405-411.

REIMER, P.J., BARD, E., BAYLISS, A., BECK, J.W., BLACKWELL, P.G., BRONK RAMSEY, C., BUCK, C.E., CHENG, H., EDWARDS, R.L., FRIEDRICH, M., GROOTES, P.M., GUILDERSON, T.P., HAFLIDASON, H., HAJDAS, I., HATTÉ, C., HEATON, T.J., HOGG, A.G., HUGHEN, K.A., KAISER, K.F., KROMER, B., MANNING, S.W., NIU, M., REIMER, R.W., RICHARDS, D.A., SCOTT, E.M., SOUTHON, J.R., TURNEY, C. & VAN DER PLICHT, J. (2013): InterCal13 and Marine 13 radiocarbon age calibration curves 0-50,000 years cal BP. – Radiocarbon, 55: 1869-1887.

RYAN, W.B.F. (2007): Status of the Black Sea Flood Hypothesis. – In: YANKO-HOMBACH, V., GILBERT, A.S., PANIN, N., & DOLUKHANOV, P.M. (Eds.), The Black Sea Flood Question, Dordrecht, Springer, pp. 63-88.

SADZRADZE, V., DAVLIANIDZE, R. & MURVANIDZE, B. (1999): Archaeological investigation of Supsa terminal and adjacent area. – Pipeline Archaeology, 1: 104-115.

SENS, U. 2009. Kulturkontakt an der östlichen Schwarzmeerküste. – In: BERTEMES, F. & A. FURTWÄNGLER (Eds.): 252 pp.; Schriften des Zentrums für Archäologie und Kulturgeschichte des Schwarzmeerraumes, 15, Stuttgart (Beier & Beran).

SOSSON, M., ROLLAND, Y., MÜLLER, C., DANELIAN, T., MEKONYAN, R., KEKELIA, S., ADAMIA, S., BABAZADEH, V., KANGARLI, T., AVAGYAN, A., GALOYAN, G. & MOSAR, J. (2010): Subduction, obduction and collision in the Lesser Caucasus (Armenia, Azerbaijan, Georgia) - new insights. – Geological Society, London Special Publications, 340: 329-352.

STOCK, F., PINT, A., HOREJS, B., LADSTÄTTER, S. & BRÜCKNER, H. (2013): In search of the harbours - New evidence of Late Roman and Byzantine harbours of Ephesus. – Quaternary International, 312: 57-69.

STOCK, F., KERSCHNER, M., KRAFT, J.C., PINT, A., FRENZEL, P. & BRÜCKNER, H. (2014): The palaeogeographies of Ephesos (Turkey), its harbours, and the Artemision – a geoarchaeological reconstruction for the timespan 1500 – 300 BC. – Zeitschrift für Geomorphologie, 58 (Suppl. 2): 33-66.

STOCK, F., KNIPPING, M., PINT, A., LADSTÄTTER, S., DELILE, H., HEISS, A., LAERMANNS, H., MITCHELL, P., PLOYER, R., STESKAL, M., THANHEISER, U., URZ, R., WENNRICH, V. & BRÜCKNER, H. (2016): Human impact on Holocene sediment dynamics in the Eastern Mediterranean - the example of the Roman harbour of Ephesus. – Earth Surface Processes and Landforms, 41: 980-996.

STUIVER, M. & REIMER, P. (1993): Extended ^{14}C data base and revised Calib 3.0 ^{14}C age calibration program. – Radiocarbon, 35: 215-230.

TÖRNQVIST, T.E., WALLACE, D.J., STORMS, J.E.A., WALLINGA, J., DAM, R.L., BLAAUW, M., DERKSEN, M.S., KLERKS, C.J.W., MEIJNEKEN, C. & SNIJDERS, E.M.A. (2008). Mississippi Delta subsidence primarily caused by compaction of Holocene strata: – Nature Geoscience, 1: 173-176.

TURNEY, C., CANTI, M., BRANCH, N., & CLARK, P. (2005): Environmental archaeology: theoretical and practical approaches. – Routledge, London.

VÖTT, A. (2007): Relative sea level changes and regional tectonic evolution of seven coastal areas in NW Greece since the mid-Holocene. – Quaternary Science Reviews, 26: 894-919.

VÖTT, A., SCHRIEVER, A., HANDL, M., & BRÜCKNER, H. (2007): Holocene palaeogeographies of the central Acheloos River delta (NW Greece) in the vicinity of the ancient seaport Oiniadai. – Geodinamica Acta, 20: 241-256.

YILMAZ, A., ADAMIA, S. & YILMAZ, H. (2013): Comparisons of the suture zones along a geotraverse from the Scythian Platform to the Arabian Platform. – Geoscience Frontiers, 5 (6): 855-875.

Chapter 5

5 Discussion

This research project deals with environmental changes and the Holocene palaeogeography of the coastal areas of the Colchian plain, and their interactions with human societies on the Black Sea shore of Georgia. Based on detailed investigations that were conducted (Chapters 2-4), the initial working hypotheses and research goals presented in Chapter 1.3. shall be discussed in this section. Furthermore, preliminary results of palynological research (Appendix A) carried out in the study area will also be included in this chapter.

5.1 Significant landscape and environmental changes during the Holocene

Reconstructing the Holocene evolution of the coastline and its hinterland, and deciphering the processes driving these changes, is of great importance for our understanding of the Colchian region. Therefore, geo-bio-archives were used to probe palaeoenvironmental changes.

Since the deceleration and stabilization of sea-level rise sediment supply due to long-shore drift and fluvial input has become the major factor driving coastline evolution (Anthony et al. 2014). Within this context, significant coastal changes have occurred. Hence, the major focus was to detect shallow marine or littoral sediments in the drill cores in order to reconstruct such changes. Although we assumed an initial shallow marine facies (at least of an open bay) in two of our sediment cores (KUL 7 and KUL 12, north of the Rioni, Area B, Chapter 2) it was eventually disproved by the palynological analyses of Suzanne Leroy (Appendix A). No dynocysts were found and therefore a marine influence is very unlikely. In addition, the relatively fine-grained sediments indicated standing water bodies and quiescent depositional conditions and thus the existence of a coastal barrier seaward, i.e. west of the drilling points already ca. 6000 cal BC. Consequently, the palaeo-barrier was located at a maximum distance of approx. 3 km to the east of the beach ridges of the modern coast.

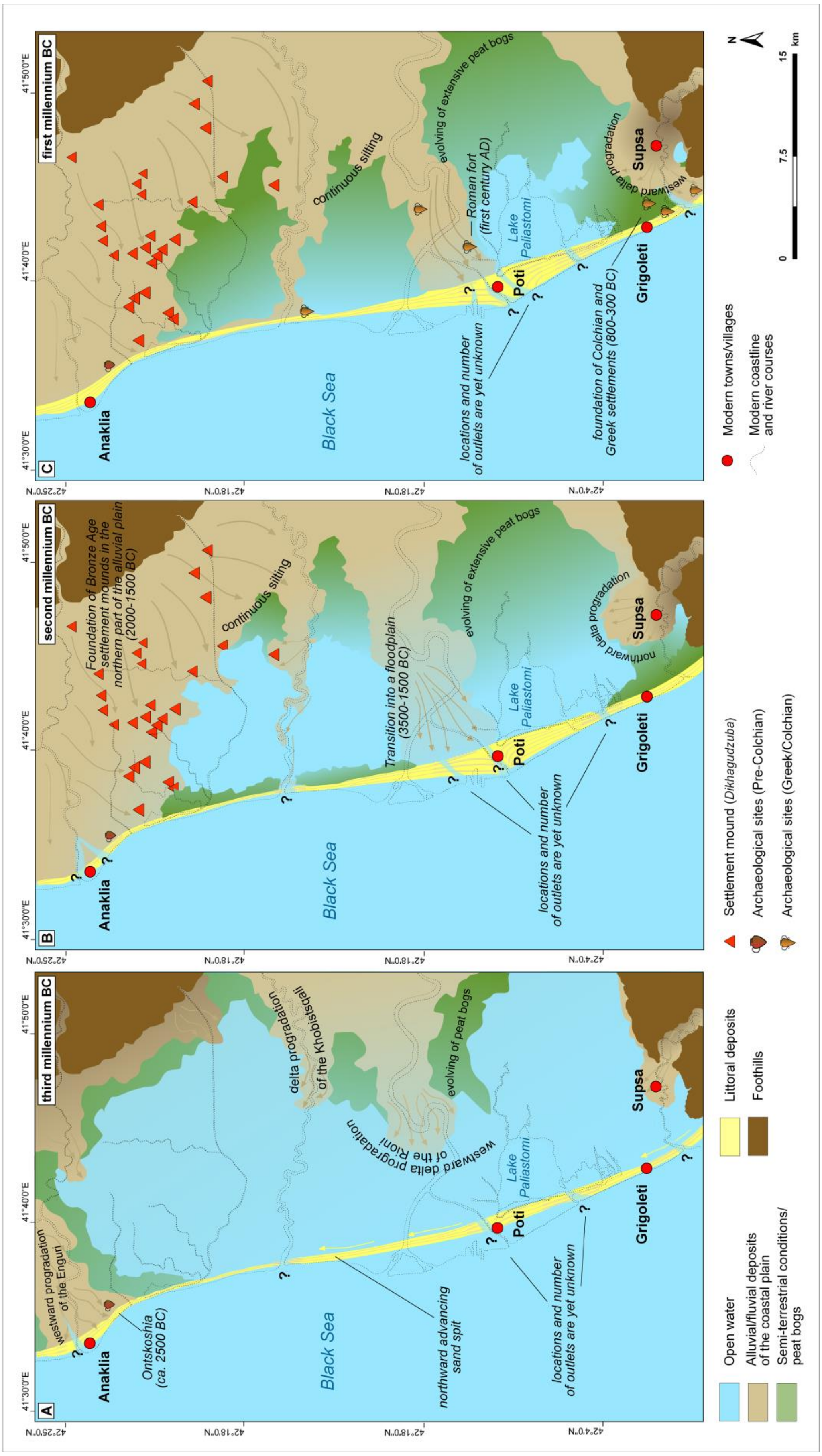

Fig. 5.1: Palaeoenvironmental evolution of the research area since 3000 BC (based on: ASTER Shaded Model, own design 2017)

This coincides with the radiocarbon dating of sediment core KUL 3, situated on the oldest of the recent beach ridges, which proves that, at least since ~1500 BC, coarse littoral sands had been deposited there. IRSL-ages of the top of beach ridges show that they have been stable for at least 1000 years, also indicating a constant topography on a smaller scale (Chapter 2). Additional indications of a "stable" coastline are the mid-3rd millennium BC sites of Ontskoshia, close to Anaklia (Area A, Janelidze & Tatashidze 2010) and Ispani, close to Kobuleti further south which were built in back barrier locations, 1-2 km from the present shoreline (Connor et al. 2007, de Klerk et al. 2009). The situation may be comparable to the Curonian Spit (Baltic Sea), where also longshore drift caused the evolution of a sand barrier, and the absence of significant tides allowed a formation without intersections by openings (Zhamoida et al. 2009, Žaromskis & Gulbinskasas 2010) known e.g. from the barrier islands of the North Sea (Bungenstock & Schäfer 2009).

The palaeogeography of the alluvial plain has changed significantly. Following the maximum ingression of the sea, within the context of the reconnection between the Mediterranean and the Black Sea around 5500 BC (Pitman & Ryan 1998), an alluvial plain started to evolve due to the progradation of the river deltas, in this case primarily the Rioni and its tributaries. Such processes where fluvial sediment supply fills embayments thus leading to a continued progradation of the shoreline are well documented in the Mediterranean, e.g. the Küçük Menderes, Büyük Menderes and Karamenderes in the Aegean Sea (Kraft et al. 2003, Brückner 2005, Brückner et al. 2002, Anthony et al., 2014; Stock et al. 2013, 2016) and also for the Caspian Sea (Kazancı et al. 2004, Naderi Beni et al. 2013, Haghani et al. 2015).

We have demonstrated that, since ~3500 BC, alluvial sediments of the Rioni and the adjacent rivers reached the study area and started infilling the vast lagoon(s). For the northern part of the research area (Area A), the existence of an alluvial floodplain can be stated since at least the 3rd millennium BC. In other parts of the lowlands, this shift took place significantly later, e.g. between ~1500 and ~350 cal BC along the lower Rioni where on the northern branch huge swamp areas with relict lakes prevailed (Area B, Chapter 2). South of the Rioni, Lake Paliastomi still gives an impression of what the former lagoons may have looked like. On the southern edge of the research area where the Supsa fan formed a special morphology some relict lagoons prevailed until at least the 1st millennium BC (Area C, Chapter 4). The granulometric results of the sediments from the surroundings of the Supsa fan indicate that even there the largest proportion of the sediment is supplied by the Rioni. This leads to the conclusion that its annual sediment load is twenty times higher than the load of the Supsa (Berkun et al. 2015).

The available palynological data indicate an overall warm and humid climate throughout the last six millennia (Connor et al. 2007); however, several stages and slight changes are detectable. For instance, during the Sub-Boreal climate optimum, lasting from 1850 to 1400 BC, high temperatures and precipitations were reconstructed (Kvavadze & Connor 2005, Arslanov et al. 2007). Although our own preliminary palynological investigations only cover the second half of the 5th millennium BC (between 4533-4366 cal BC and 4036-3804 cal BC), the elucidated conditions are largely similar (Fig. A.1, Appendix A). The pollen that were preserved in the fine grained lagoonal deposits indicate open alder and birch forests with some hornbeam and hazel, species that still dominate the landscape today. In addition to this, high frequencies of *Cyperaceae* sedge-pollen reveal that reed areas and swamps covered extensive parts as well. Within that time span a trend towards slightly drier conditions is documented, which is shown by an increasing proportion of arbol pollen and a decrease of non-arbol pollen.

However, even if there were certain variations in the region's climate, it can be stated that the general conditions remained similar during the late Holocene (Connor et al. 2007, de Klerk et al. 2009). The humid climate and the swampy conditions are also described by several ancient authors who provide important descriptions of the Colchian landscape during the Greek and Roman periods (de Klerk et al. 2009). For example Hippocrates (~460 – ~370 BC) and Strabo (64/63 BC – AD 24) both reported that the climate was hot and humid and that the surroundings of Phasis and the Rioni consisted of marshy forests with swamps, where people used boats to travel (cf., Jouanna 1996, de Klerk et al. 2009, Gamkrelidze, 2012).

5.2 Holocene sea-level curve of the Black Sea coast of Georgia

Based on five sediment cores and 22 samples, two curves could be established from the area between the Rioni and Khobistskali and the surroundings of the Supsa fan. The relationship of each dated sample to the respective palaeo sea level allows for an approximation of the relative sea-level position for each data point, thus allowing us to probe the general trends in relative sea level. To obtain reliable information on this topic, it is necessary to consider the different depositional facies of the dated material.

Eight samples were taken from peat layers. Due to the proximity to the coast and the existence of vast peat bogs in the research area today, it can be assumed that they represent paralic peat layers. These layers are directly related to the back-barrier groundwater table, and therefore also to the local relative sea level (Pirazzoli 1991, Vött 2007). Despite a vertical error range of ~0.5 m which must be assumed (Pirazzoli 1996, Behre 2003), they are considered to be good sea-level indicators.

Three samples derive from lagoonal deposits. This material was deposited below the former local sea level. Due to the subsequent peat growth and the very shallow bathymetry of the coastal margin Black Sea in western Georgia, a deposition close to the lagoonal water table is most likely. Hence these samples represent minimum values of the sea-level position at a certain time. We assume rather shallow lagoonal conditions and a deposition close to the lagoonal water, since subsequently peat evolved.

Another set of ten samples was taken from alluvial facies that can be related to the deposition of overbank fine-grained sediments on the floodplain. They derive from areas that are located above the former local sea level. At present, the dry floodplain shows maximum elevations of ~3 m and therefore represents a maximum sea level position.

Based on these assumptions it was possible to reconstruct local relative sea-level trends for the Kulevi and Supsa areas (Areas B & C). In Area B around Kulevi and the Rioni delta, our data indicate a local relative sea level at ~-9 to -10 m ca. 6000 cal BC. In the course of the subsequent sea-level rise it reached a level between ~-7 and -3 m ca. 3500 cal BC. With a gradual decelerated rise until 2000-1500 cal BC, a sea level of ~3-2 m below its present position was reached. Then the water table rose gradually and slowly until today's level.

A similar trend was reconstructed for the Supsa area (Area C). In this area, we assume a local RSL of ~-10 to -8 m for a time span between 4000 and 3500 cal BC. During the 1st millennium BC, a gradual but relatively steep rise from -5 to -3/-2 m is assumed. Afterwards the rise decelerated and is similar to the one of the Rioni/Kulevi area.

Though the two curves show very similar trends and are comparable for the last 1500 years, the differences prior to 1 BC/AD are obvious. While in the Kulevi area the accelerated rise from ~-5 to ~-2 m took place between 4000 and 1500 cal BC, a similar trend is assumed for the Supsa area some time later, between 1000 and 1 cal BC/AD. Nevertheless, the two curves need not to be harmonised, since they originate from different sites and may have been influenced by different local effects. For example, it needs to be considered that the region is subject to subsidence (tectonic subsidence and/or compaction) due to its location in a back-arc marginal extensional basin between the Caucasus ridges (Yılmaz et al., 2013). Although the high subsidence rates of 2-6 mm/a suggested by Gamkrelidze (1998) are probably overestimated, local tectonics must be considered as an important factor. Thus, the proximity of the Supsa area to the Adjara-Trialeti Thrust Belt (ATTB) (Adamia et al.

2011, Forte et al. 2014) with a horizontal offset of 2 mm/a (Avdeev & Niemi 2011, Yılmaz et al. 2013) may also have caused the vertical offset, which would be a possible explanation for the different courses of the Kulevi and Supsa RSL-curves.

However, it is obvious that the relative local sea-level rise can be considered as one of the most important factors of the landscape change of coastal Georgia. The coastline evolution and the shoreline position depend strongly on stable sea-level conditions. The evolution of the deltas that deliver their sediments to the sea is also dependent on stable conditions (Brückner et al. 2005). Therefore, the time of the silting of great parts of the former coastal lagoon is in accordance with the time of the deceleration of the relative sea-level rise between 3500 and 1500 cal BC.

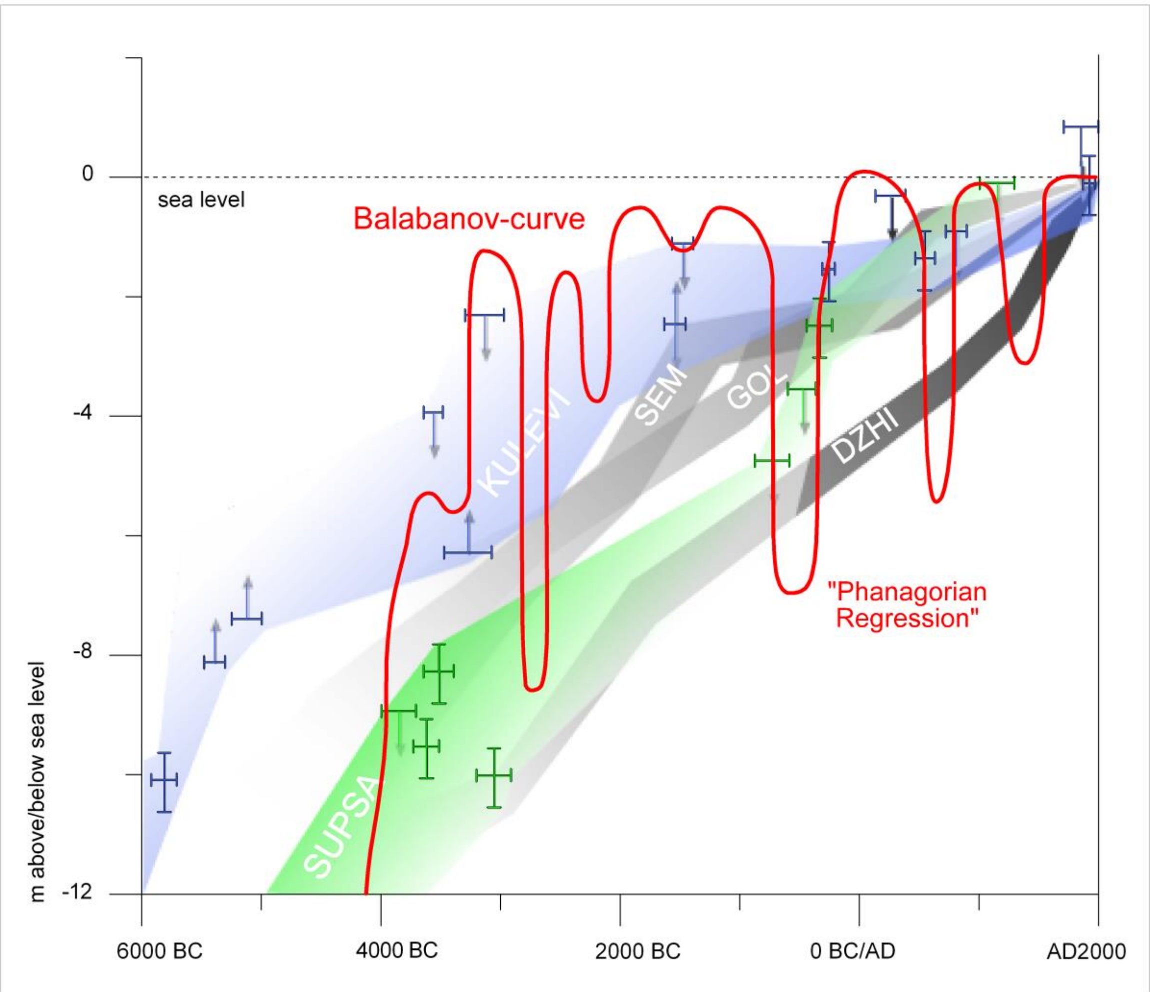

Fig. 5.2: Sea-level curves of the surroundings of the Rioni delta and the Kulevi swamps (KULEVI, in blue) and the Supsa area (SUPSA, in green) with indicated radiocarbon ages (in corresponding colours). Further comparison is given to other RSL curves by Balabanov (2007, 2009) and from the sites of the north-eastern Black Sea, e.g., SEM = Semebratnee (Brückner et al. 2010), GOL = Golobitskaya (Kelterbaum et al. 2011), and DZHI = Dschiginka (Fouache et al. 2012), all on Taman Peninsula in SW Russia. Own design 2017.

5.3 Evaluation of the RSL evolution in the context of the Black Sea curve debate

The new RSL data are an important contribution to the ongoing debate on how sea level in the Black Sea has developed during the Holocene, whether its course is oscillating (Balabanov 2007, 2009) or continuously rising (cf. Hiscott et al. 2002; Giosan et al. 2009, Brückner et al. 2010, Fouache et al. 2012). However, some of the sea-level indicators used here and the radiocarbon dating method in general contain several uncertainties (Brückner et al. 2010), and the reconstructed curves should be considered with caution due to limited reliable information on tectonics and subsidence rates (cf. Chapter 5.1; Gamkrelidze 1998, Adamia et al. 2011). Nevertheless, correlations between our data and data from research on the Taman Peninsula (SW Russia) are obvious. Compared with the RSL curves from the sites of Semebratnee (Brückner et al. 2010), Golobitskaya (Kelterbaum et al. 2011), and Dschiginka (Fouache et al. 2012) our curves *grosso modo* show similar trends (Fig. 5.2). In particular, when compared to the RSL curves of Semebratnee and Golobitskaya for the last ~3000 years. After 2000 cal BC, the estimates of the Supsa area fit better than the curve of the Kulevi area, although the representation of the small number of samples must not be neglected. However, the general trend of the RSL curves from the Georgian coast closely mirrors those of the Taman peninsula in addition to other RSL models of the Eastern Mediterranean (Vött 2007, Vött et al. 2007, Brückner et al. 2010). The differences are most probably the result of local tectonic settings of the Colchian coast (Fouache et al. 2012).

The crucial question of significant oscillations during the last 6000 years as postulated in the so-called Balabanov-curve (Balabanov 2009) and several other publications (e.g., Martin et al. 2007, Martin & Yanko-Hombach 2011, Bolikhovskaya et al. 2017; see also Chapter 1.1.1) must be rejected on the basis of this data. Though the number of age estimates is small, there are no hints for any significant regressions. Even if it is argued that data from the Supsa area indicate a steep rise during the 1st millennium BC, which coincides with the Balabanov-curve, there is no evidence of any antecedent regressions in sea level. A correlation of the Kulevi-curve with the Balabanov-curve (Fig. 5.2) for the antecedent period is not possible due to both the reasons explained above (Chapter 5.2) and the continuous course of the Kulevi-curve.

Another strong argument against the major periods of falling sea-levels proposed by the Balabanov-curve is the stable position of the coastline. It would definitely have been affected regressions of the Black Sea. In fact, there is neither an evidence for coastline displacement or drowned palaeo-coasts in our sediment cores nor is there any convincing field evidence mentioned in the literature.

Furthermore, there is no archaeological evidence for an event such as the so-called Phanagorian Regression. The settlements in the Supsa area (Chapter 4) and close to Ureki and Anaklia (Miron & Orthmann 1995, Gamkrelidze 2012) were found in back barrier positions close to the coastline; therefore, they contradict such a regression as well. However, while we cannot entirely exclude the possibility of small-scaled RSL-variations (Leorri et al. 2006, Dzhanelidze 2007, Erginal et al. 2013) due to the mentioned uncertainties (Chapter 5.1), which would nevertheless be unlikely considering data from the Mediterranean; we definitely deny any regressions in the scale of the so-called Phanagorian regression as presented in the Balabanov curve for the research area of this study (cf. Chapter 1.1.1).

5.4 Human occupation – the Colchian settlement mounds

Of the sparse Bronze Age (or older) settlement remains in the Colchian plain the *Dikhagudzuba* settlement mounds may not be the oldest, but they are definitely the best preserved. Compared to the older sites of Ispani (Tsetskhladze 1999, Papuashvili & Papuashvili 2014), and Ontskoshia (Janelidze & Tatashidze 2010) that were covered by sediment, the mounds' massive shape prevailed over several millennia to date. They are, therefore, of special geoarchaeological interest to investigate the occupation history and possible dependencies on distinct landscapes changes.

Firstly, similar patterns on the mounds' location were identified. Almost all known settlement mounds are located on the fertile coastal plain between the two rivers Enguri and Khobistskali. While a few are isolated, the majority is located in proximity to each other, some are separated by just a few hundred metres, which indicates a relatively dense occupation. The three investigated settlement mounds (*Ergeta 1, Orulu 1* and *Orulu 2*; Chapter 3) were founded on slightly elevated natural locations, on top of fine-grained alluvial deposits with fine fluvial-sand intercalations below. Furthermore, remains of circular surrounding ditches or moats were discovered. Whether they were built for defensive or drainage purposes (or both) is unclear (see Parkinson et al. 2004, Parkinson & Duffy 2007, Gauss et al. 2013); however, humid conditions with standing water bodies during their building period evoke drainage. This assumption coincides with our research in Area B (Chapter 2) and the data of for example, Kvavadze & Connor (2005), Arslanov et al. (2007), Connor et al. (2007), and de Klerk et al. (2009). A rising groundwater table, attributed to the sea-level evolution of the Black Sea (Chapters 2, 5.2 & 5.3, and, e.g., Giosan et al. 2006, Brückner et al. 2010, Fouache et al. 2012) might also have affected the conditions for settling in the marshlands of the plain, since drainage was needed around the settlement mounds. Such swampy conditions are further attested by many historical sources, e.g., in Hippocrates' treaty *On the*

Airs, Waters, and Places (Jouanna, 1996), in the *Anabasis* of Xenophon (cf. Dan 2014, 2016) and in reports of Strabo etc. where warm and humid conditions are stated (Lordkipanidze 1991, Tsetskhladze 1997, Sens 2009).

Secondly, all investigated mounds are of similar size. Using the Structure-from-Motion techniques (SfM) (Westoby et al. 2012), the ground size of mound *Ergeta 1* was estimated to be ~1240 m^2 with a volume of ~4200 m^3. The two mounds in Orulu are of similar dimensions. This is rather small as compared to other dwelling forms all over Europe (see Chapter 3 & 5.5) where constructed mounds and tells, for example, reach ground sizes between 3600 m^2 in Flanders (Ervynck et al. 2012) to more than 20000 m^2 in Thessaly (Runnels et al. 2009).

Thirdly, all investigated Colchian settlement mounds consist of the alluvial fines of the surrounding area, which has been proven by the granulometric and geochemical analyses. Anthropogenic layers could be differentiated by several parameters, e.g. poorer sorting and increased metal and phosphorus content (Guyard et al. 2007, Corella et al. 2012, Nicosia et al. 2013, Miller et al. 2014) reflecting an increased human influence. This applies both to the settlement mounds themselves, as well as to their direct surroundings, where high phosphorus contents indicate cattle breeding (Corella et al. 2012) and disturbed stratification hints at the use as farmland our housing areas. This supports a local anthropogenic fingerprint on the alluvial environs starting with the foundation of the settlement mounds.

5.5 A chronostratigraphy of the Colchian settlement mounds

The initial formation of the three investigated settlement mounds can be dated to the beginning (*Orulu 1* & *Orulu 2*) and the middle (*Ergeta 1*) of the 2^{nd} millennium, coinciding with the local Early to Middle Bronze Age (Figs. 1.6 & 3.11), which supports archaeological assumptions (Lordkipanidze 1991, Greppin, 1991). The relatively late occurrence of settlement mounds in Western Georgia, as compared to eastern Georgia (Hansen et al. 2007) and other regions, i.e. Anatolia (Çilingiroğlu et al. 2012, Horejs 2012) or the Balkans (Parkinson & Gyucha 2012), can be explained by the late transformation of the area from a lagoon to a floodplain and, thus, the late accessibility. However, earlier occupation and later abandonment due to co-seismic subsidence and/or sea-level rise and subsequent burial by deltaic sediments, e.g. in the case of Ispani (Tsetskhladze 1999, Papuashvili & Papuashvili 2014) and Ontskoshia (Janelidze & Tatashidze 2010) can, however, not be excluded (cf., Hassan 2010, Carozza et al. 2011).

The possibility of subsidence and sea-level rise emphasizes the central question whether the settlement mounds are cumulative or constructed forms. The answer is closely related to the mounds' stratigraphy. While overlapping ages from different layers of the mounds *Orulu 2* and *Ergeta 1* indicate that these two mounds were built during one phase, at *Orulu 1* there is a gap of ~470-800 years between the two dated layers. The short time of accumulation (even in the case of *Orulu 1*) contradicts the nature of formation of tells with their successive accumulation over the long term due to the disintegration of air-dried loam bricks.

Considering the warm and humid climate and the swampy conditions at the time mounds' erection (Chapter 5.1; cf. Arslanov et al. 2007, Connor et al. 2007, de Klerk et al. 2009), the construction of circular moats and the rather short accumulation phase of *Ergeta 1* and *Orulu 2*, an intentional construction of the mounds seems most likely. Possible flood events, and the limited accessibility of the swampland, may have necessitated (artificially) elevated settlement spots and explains the late occupation, even if alluvial deposits indicate an earlier transformation into a floodplain. These special characteristics can eventually be attributed to local cultural expressions, but probably also due to adaptation strategies to the natural circumstances given on the Colchian plain.

Thus, although we can determine the chronology of the mounds' construction, representing maximum ages of occupation, it is rather difficult to constrain the duration of their activity. The limited number of ^{14}C ages does not allow a particular differentiation of consecutive construction or occupation phases, nor the identification of their abandonment. Archaeological investigations and a greater number of reliable age estimates would help to decipher the exact chronostratigraphy of the mounds.

Chapter 6

6 Conclusion and Outlook

This palaeogeographical and geoarchaeological study provides new insights into the Holocene landscape evolution, sea-level changes, occupation history and human-environment interactions on the Black Sea coast of Georgia. Based on a variety of methods, e.g., vibracores, sediment trenches, remote sensing techniques, ^{14}C and IRSL dating methods as well as geochemical and granulometric analyses, detailed information on the chronostratigraphy of this region was gained.

During the Mid and Late Holocene, the study area was subject to considerable landscape changes. The evolution of a spit system, which was located close to the modern coastline, separated vast lagoons from the open sea ~6000 cal BC. Continuous sediment supply, provided by the rivers of the Colchian plain, and by the Rioni with its high and widespread sediment load in particular, transformed great parts of the area into a swampy alluvial plain, which was dominated by extensive wetlands covered by peat bogs, reed areas and open alder and hazel forests. This transformation took place between 3500 and 1500 cal BC; several large water bodies have persisted through to present, such as Lake Paliastomi. Nowadays, a substantial part is still occupied by wetlands and open waters, despite the fact that since the early 20th century wetlands were systematically transformed into farmland.

The sedimentation patterns that triggered this landscape change are closely related to another important driving factor, the Holocene sea-level rise (Brückner 2005, Marriner et al. 2010). Though our data do not cover the reconnection between the Black Sea and the Mediterranean, it was possible to reconstruct first preliminary local RSL trends for the areas north of the Rioni delta and around the Supsa fan. While in the former case, a sea level of ~-9 to -10 m is indicated for around 6000 cal BC, in the latter the same level is assumed for ~4000 cal BC. These differences may be to the result of local tectonics; they preclude a synthesis of both curves (Fig. 5.2). However, thereafter the sea-level courses subsequently rise continuously and decelerate within the 2nd to 1st millennium BC. For the last 2000 years their trends correlate closely.

In any case, both curves do not show evidence for RSL regressions as postulated, e.g. in the Balabanov-curve. Our results contradict the hypothesis of an oscillating sea-level rise (e.g. Balabanov 2007, 2009); instead they support the reconstruction of a continuous rise as proposed, e.g. by Giosan et al. (2006), Brückner et al. (2010), Kelterbaum et al. (2011), Fouache et al. (2012).

We have elucidated the landscape change from open lagoons to an alluvial floodplain. Settlement mounds had been constructed since the early 2nd millennium BC on the Colchian plain. This proves the existence of stable settlements there at least since that time. This confirms archaeological implications of their Bronze Age origin, which match with other sites at the coast, e.g. Ontskoshia (Janelidze & Tatashidze 2010). Though establishing a precise chronostratigraphy of these mounds remains challenging, our results suggest an intentional accumulation of the mounds within a short time. However, this may be seen as an adaptation strategy to the natural conditions, namely swampy but fertile wetlands. Compared to anthropogenic dwelling forms (tells or constructed mounds) of other regions, the settlement mounds of the Colchian plain stand out with their grouped occurrence, small size and relatively young age.

The region's geo-bio-archives offer many opportunities for further investigations on the Holocene landscape evolution and geoarchaeology along the Black Sea coast of Georgia. In particular, the controversially debated local RSL evolution should be studied further in detail. In the context of the debate on the postglacial sea-level rise of the Black Sea, a high-resolution analysis with precise and well-dated sea-level indicators would contribute important information from this so far neglected part of the Pontus region. In addition, an extended chronostratigraphic framework covering the Early Holocene would provide further information, not only about the Holocene transgression, but also on the chronology of the reconnection of the Mediterranean and the Black Sea.

Western Georgia is of special interest with regards to its vegetation evolution during the Holocene. In particular, it stands out due to its protected location compared to other Pontic regions that allowed thermopile species to survive during glacial periods. Several publications on the vegetation history exist (e.g. Kvavadze & Connor 2005, Connor et al. 2007), a high-resolution record covering the whole Holocene is, however, still lacking.

To fill the gaps on the RSL evolution and the Holocene vegetation history we are planning a study of a 48 m long sediment core, which was retrieved by a drilling company in the course of a pilot-survey for a highway construction along the Georgian coast. The detailed sampling will enable us to refine the existing resolution of the postglacial sea-level rise, extend the age ranges of the region's sedimentation pattern and so-far known vegetation history. A grant application will be submitted to the German Research Council (DFG).

Excavating the settlement mounds would clarify their stratigraphy and yield precise data on their occupation phases as well as their abandonment. Together with detailed knowledge about coastline changes, river dislocations and the RSL evolution in general and, palaeo-geographical surveys within the city of Poti and the surroundings of the Rioni delta in particular, could render important new information about the settlement history of the Colchis region. It might also give hints about the still lost city of Phasis. As shown in this PhD thesis, these topics and their interdependencies can best be addressed with the interdisciplinary research approach of geoarchaeology and palaeogeography.

Chapter 7

7 References

ADAMIA, S., MUMLADZE, T., SADRADZE, N., TSERETELI, E., TSERETELI, N. & VARAZANASHVILI, O. (2008): Late Cenozoic Tectonics and Geodynamis of Georgia (SW Caucasus) – Georgian International Journal of Science and Technology, 1 (1): 77-107.

ADAMIA, S., ZAKARIADZE, G., CHKHOTUA, T., SADRADZE, N., TSERETELI, N., CHABUKIANI, A. & GVENTSADZE, A. (2011): Geology of the Caucasus: A Review. – Turkish Journal of Earth Sciences, 20: 489-544.

AKSU, A.E., HISCOTT, R.N. & YASAR, D. (1999): Oscillating Quaternary water levels of the Marmara Sea and vigorous outflow into the Aegean sea from the Marmar-Black sea drainage corridor. – Marine Geology, 153: 275-302.

AKSU, A.E., HISCOTT, R.N., MUDIE, P.J., ROCHON, A., KAMINSKI, M.A., ABRAJANO, T. & YASAR, D. (2002): Persistent holocene outflow from the Black Sea to the eastern Mediterranean contradicts Noah's flood hypothesis. – GSA Today, 12 (5): 4-10.

ANTHONY, E.J., MARRINER, N. & MORHANGE, C. (2014): Human influence and the changing geomorphology of Mediterranean deltas and coasts over the last 6000 years: From progradation to destruction phase? – Earth-Science Reviews, 139: 336-361.

ARSLANOV, K.A., DOLUKHANOV, P.M. & GEI, N.A. (2007): Climate, Black Sea levels and human settlements in Caucasus Littoral 50,000-9,000 BP. – Quaternary International, 167-168: 121-127.

AVDEEV, B. & NIEMI, N.A. (2011): Rapid Pliocene exhumation of the central Greater Caucasus constrained by low-temperature thermochronometry, – Tectonics, 30 (TC2009): 1-16.

BALABANOV, I.P. (1984): Change in the wave regime of the Black Sea in the Late Holocene. Izvestiia AN SSSR, Seriia Geograficheskaiia, 5: 70-81 (in Russian).

BALABANOV, I.P. (2007): Holocene sea-level changes of the Black Sea. – In: YANKO-HOMBACH, V., GILBERT, A.S., PANIN, N. & P. DOLUKHANOV (Eds.): The Black Sea Flood question: Changes in coastline, climate and human settlement. – Springer, Dordrecht: pp. 711-730.

BALABANOV, I.P. (2009): Paleogeographical Background to Modern Natural Condition of the Caucasus Littoral Holocene Terraces and Their Long-term Development Forecast. – Dalnauka, Moscow-Vladivostok.

BALLARD, R.D., COLEMAN, D.F. & ROSENBERG, G.D. (2000): Further evidence of abrupt Holocene drowning of the Black Sea shelf. – Marine Geology, 170: 253–261.

BARALIS, A., DEVILLERS, B., MARRINER, N., MORHANGE, C. & HERMARY, A. (2011): Coastal geoarchaeology of Apollonia Pontica (Bulgaria). – Mediterranée, 117: 103-109.

BARSCH, H., BILLWITZ, K. & BORK, H. (2000): Arbeitsmethoden in der Physiogeographie und Geoökologie. – Klett-Perthes, Gotha.

BAZHENOV, M.L. & BURTMAN, V.S. (2002): Eocene paleomagnetism of the Caucasus (southwest Georgia): oroclinal bedding in the Arabian syntaxis. – Tectonophysics, 344: 247-259.

BEHRE, K.-E. (2003): Eine neue Meeresspiegelkurve für die südliche Nordsee. Transgressionen und Regressionen in den letzten 10.000 Jahren. – Probleme der Küstenforschung im südlichen Nordseegebiet, 28: 9-63.

BENNETT, K. (2007): Psimpoll and pscomb programs for pand analysis (version 4.27). Available at: http://www.chrono.qub.ac.uk/ psimpoll/psimpoll.html (accessed 16 January 2015).

BERKUN, M., ARAS, E. & AKDEMIR, U. (2015): Water runoff, sediment transport and related impacts in the southeastern Black Sea rivers. – Environmental Engineering and Management Journal, 14 (4): 781-791.

BLAAUW, M. & CHRISTEN, J.C. (2011): Flexible Paleoclimate Age-Depth Models Using an Autoregressive Gamma Process. – Bayesian Analysis, 6 (3): 457-474.

BLOTT, S.J. & PYE, K. (2001): Technical communication, GRADISTAT: A grain size distribution and statistics package for the analysis of unconsolidated sediments. – Earth Surface Processes and Landforms, 26: 1237-1248.

BOGGS, S. (2006): Principles of Sedimentology and Stratigraphy. – Pearson Prentice Hall, New Jersey.

BOLIKHOVSKAYA, N.S., POROTOV, A.V., RICHARDS, K., KAITAMBA, M.D., FAUSTOV, S.S. & KOROTAEV, V.N. (2017): Detailed reconstructions of Holocene climate and environmental changes in the Taman Peninsula (Kuban River delta region) and their correlation with rapid sea-level fluctuations of the Black Sea. – Quaternary International (2017), DOI: 10.1016/j.quaint. 2017.08.013.

BOX, E.O., FUJIWARA, K., NAKHUTSRISHVILI, G., ZAZANASHVILI, N., LIEBERMANN, R.J. & MIYAWAKI, A. (2000): Vegetation and Landscape of Georgia (Caucasus) as a Basis for Landscape Restoration. – Bulletin of the Institute of Environmental Science and Technology, Yokohama National University, 26: 69-102.

BRAUND, D. (1994): Georgia in Antiquity. A history of Colchis and Transcaucasian Iberia 550 BC-AD 562. – Clarendon Press, Oxford.

BRÜCKNER, H. (2005): Holocene shoreline displacements and their consequences for human societies: the example of Ephesus in western Turkey. – Zeitschrift f. Geomorphologie, 137: 11-22.

BRÜCKNER, H., MÜLLENHOFF, M., HANDL, M. & VAN DER BORG, K. (2002): Holocene landscape evolution of the Büyük Menderes alluvial plain in the environs of Myous and Priene (Western Anatolia, Turkey). – Zeitschrift für Geomorphologie, 127: 47-65.

BRÜCKNER, H., VÖTT, A., SCHRIEFER, A. & HANDL, M. (2005): Holocene delta progradation in the eastern Medterranean – case studies in their historical context. – Méditerranée, 1.2: 95-106.

BRÜCKNER, H., MÜLLENHOFF, M., GEHRELS, R., HERDA, A., KNIPPING, M. & VÖTT, A. (2006): From archipelago to floodplain - geographical and ecological changes in Miletus and its environs during the past six millennia (Western Anatolia, Turkey). – Zeitschrift für Geomorphologie, 142: 63-83.

BRÜCKNER, H., KELTERBAUM, D., MARUNCHAK, O., POROTOV, A. & VÖTT, A. (2010): The Holocene sea level story since 7500 BP - lessons from the Eastern Mediterranean, the Black and the Azov Seas. – Quaternary International, 255: 160-179.

BRÜCKNER, H. & GERLACH, R. (2011): Geoarchäologie - von der Vergangenheit in die Zukunft. – In: GEBHARDT, H., GLASER, R., RADTKE, U. & REUBER, P. (Eds.): Geographie – Physische Geographie und Humangeographie. – Spektrum-Verlag, Heidelberg: pp. 1179-1186.

BRÜCKNER, H., HERDA, A., MÜLLENHOFF, M., RABBEL, W. & STÜMPEL, H. (2014): On the Lion Harbour and other Harbours in Miletos: recent historical, archaeological, sedimentological and geophysical research. – Proceedings of the Danish Institute at Athens (PDIA), 7: 49-103.

BUNGENSTOCK, F. & SCHÄFER, A. (2009): The Holocene relative sea-level curve for the tidal basin of the barrier island Langeoog, German Bight, Southern North Sea. – Gobal and Planetary Change, 66 (1-2): 34-51.

BURKE, A., EBERT, D., CARDILLE, J. & DAUTH, D. (2008): Paleoethology as a tool for the development of archaeological models of land-use: the Crimean Middle Palaeolithic. – Journal of Archaeological Science, 35: 894-904.

CAROZZA, J.M., MICU, C., MIHEIL, F. & CAROZZA, L. (2012): Landscape change and archaeological settlements in the lower Danube valley and delta from early Neolithic to Chalcolithic time: A review. – Quaternary International, 261: 21-31.

CARTER, J.C., CRAWFORD, M., LEHMAN, P., NIKOLAENKO, G. & TRELOGAN, J. (2000): The Chora of Chersonesos in Crimea, Ukraine. – American Journal of Archaeology, 104 (4): 707-741.

CHEPALYGA, A.L. (1984): Inlands sea basins. In: VELICHKO, A.A., WRIGHT, H.E. & BARNOSKY, C.W. (Eds.), Late Quaternary Environments of the Soviet Union. – University of Minnesota Press, Minneapolis: pp. 237-240.

CHEPALYGA, A.L. (2002): The Black Sea. – In: VELICHKO, A.A. (Ed.): Dynamics of Terrestrial Landscape Components and Inner Marine Basins of Northern Eurasia during the Last 130,000 years. – GEOS, Moscow, pp. 170-182 (in Russian).

CHEPALYGA, A.L. (2007): The late glacial great flood in the Ponto-Caspian basin. – In: YANKO-HOMBACH, V., GILBERT, A.S., PANIN, N. & DOLUKHANOV, P.M. (Eds.), The Black Sea Flood Question. – Springer, Dordrecht: pp. 119-148.

ÇILINGIROĞLU, A., ÇEVIK, Ö. & ÇILINGIROĞLU, Ç. (2012): Ulucak Höyük. Towards Understanding the Early Farming Communities of Middle West Anatolia: The Contribution of Ulucak. – In: ÖZDOĞAN, M. BAŞGELEN, M. & KUNIHOLM, P. (Eds.): The Neolithic in Turkey, – Archaeology and Art Publications, Istanbul, 4 pp. 139-175.

CLARK, P.U. & MIX, A.C. (2002): Ice sheets and sea level of the Last Glacial Maximum. – Quaternary Science Reviews, 21: 1-7.

CLARK, P.U., DYKE, A.S., SHAKUN, J.D., CARLSON, A.E., CLARK, J., WOHLFARTH, B., MITROVICA, J.X., HOSTELER, S.W. & MARSHALL MCCABE, A. (2009): The Last Glacial Maximum. – Science, 325: 710-714.

CONNOR, S., THOMAS, I. & KVAVADZE, E. (2007): A 5600-yr history of changing vegetation, seal levels and human impacts from the Black Sea coast of Georgia. – The Holocene, 17 (1): 25-26.

CORDOVA, C., GERASIMENKO, N.P., LEHMAN, P. & KLIUKIN, A. (2011): Late Pleistociene and Holocene paleoenvironments of Crimea: Pollen, soils, geomorphology, and geoarchaeology. – The Geological Society of America, Special Paper, 473: 133-164.

CORDOVA, C. (2016): Crimea and the Black Sea – An environmental history. – I.B. Tauris & Co. Ltd., London, New York.

CORELLA, J., BRAUER, A., MANGILI, C., RULL, V., VEGAS-VILARRÚBIA, T., MORELLÓN, M. & VALERO-GARCÉS, B. (2012): The 1.5-ka varved record of Lake Montcortès (southern Pyrenees, NE Spain). – Quaternary Research, 78: 323-332.

COUWENBERG, J. & JOOSTEN, H. (2005): Self-organization in raised bog patterning: the origin of microtope zonation and mesotope diversity. – Journal of Ecology, 93: 1238-1248.

CROUDACE, I.W., RINDBY, A. & ROTHWELL, R.G. (2006): ITRAX: description and evaluation of a new multi-function X-ray core scanner. – Geological Society London Special Publication, 267: 51-63.

DAN, A. (2014): Xenophon’s Anabasis and the common Greek mental modelling of spaces. – In: GEUS, K. & THIERING, M. (Eds.): Features of Common Sense Geography: Implicit Knowledge Structures in Ancient Geographical Texts. – LIT Verlag, Münster: pp. 157-198.

DAN, A. (2016): The rivers called Phasis. – Ancient West and East, 15: 245-277.

DE KLERK, P., HABERL, A., KAFFKE, A., KREBS, M., MATCHUTADZE, I., MINKE, M., SCHULZ, J. & JOOSTEN, H. (2009): Vegetation history and environmental development since ca 6000 cal yr BP in and around Ispani 2 (Kolkheti lowlands, Georgia). – Quaternary Science Reviews, 28: 890-910.

DELILE, H., MAZZINI, I. BLICHERT-TOFT, J., ARNAUD-GODET, F., SALOMON, F. & ALBARÈDE, F. (2014): Geochemical investigation of a sediment core from the Trajan basin at Portus, the harbor of ancient Rome. – Quaternary Science Reviews, 87: 34-45.

DENK, T., FROTZLER, N. & DAVITASHVILI, N. (2000): Vegetational patterns and distribution of relict taxa in humid temperate forests and wetlands of Georgia (Transcaucasia). – Biological Journal of the Linnean Society, 72: 287-332.

DHONT, D. & CHOROWICZ, J. (2006): Review of the neotectonics of the Eastern Turkish-Armenian Plateau by geomorphic analysis of digital elevation model imagery, – International Journal of Earth Sciences, 95: 34-49.

DUBOIS DE MONTPÉREUX, F. (1842): Reise um den Kaucasus, zu den Tscherkessen, Abchasen, nach Kolchis, Georgien, Armenien und in die Krim. – Darmstadt.

DURCAN, J.A., KING G.E. & DULLER G.A.T. (2015): DRAC: Dose rate and age calculator for trapped charge dating. – Quaternary Geochronology, 28: 54-61.

DZHANELIDZE, Z.C. (2007): The amplitude of Phanagorian regression of Black sea. – In: Problems of the coastal zone management and sustainable development. – Abstracts XXII International Coastal conference, Gelendjik (Russia): 327-328.

EPPELBAUM, L. & KHESIN, B. (2012): Geophysical Studies in the Caucasus. – Lecture Notes in Earth System Sciences. Springer, Berlin, Heidelberg.

ERGINAL, A.E., EKINCI, Y.L., DEMIRCI, A., BOZCU, M., OZTURK, M.Z., AVCIGLU, M. & OZTURA, E. (2013): First record of beachrock on Black Sea coast of Turkey: Implications for Late Holocene sea-level fluctuations. – Sedimentary Geology, 294: 294-302.

ERVYNCK, A., DECKERS, P., LENTACKER, A., TYS, D. & VAN NEER, W. (2012): 'Leffinge-Oude Werf': the first archaeozoological collection from a terp se lement in coastal Flanders. – In: D.C.M. Raemaekers, E. Esser, R.C.G.M. Lauwerier & J.T. Zeiler (Eds.): A Bouquet of Archaeozoological Studies. Essays in Honour of Wietske Prummel (Groningen Archaeological Studies 21). – Barkhuis/Groningen University Library, Groningen.

FÄHNRICH, H. (2010): Geschichte Georgiens. Handbuch der Orientalistik, Bd. 21. Leiden.

FILIPOVA-MARINOVA, M., (2007): Archaeological and paleontological evidence of climate dynamics, sea-level change, and coastline migration in the Bulgarian sector of the circum-Pontic region. – In: YANKO-HOMBACH, V., GILBERT, A.S., PANIN, N. & DOLUKHANOV, P. (Eds.): The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement – Springer, Dordrecht, pp. 453-481.

FLAUX, C., ROUCHET, P., POPOVA, T., STERNBERG, M., GUIBAL, F., TALON, B., BARALIS, A., PANAYOTOVA, K., MORHANGE, C. & RIAPOV, A.V. (2016): An Early Bronze Age pile-dwelling settlement of discovered in Alepu lagoon (municipality of Sozopol, department of Burgas), Bulgaria. – Mediterranée, 126: 57-70.

FLAUX, C., EL-ASSAL, M., SHAALAN, C., MARRINER, N., MORHANGE, C., TORAB, M. GOIRAN, J.P. & EMPEREUR, J.Y. (2017): Geoarchaeology of Portus Mareoticus: Ancient Aleandria's lake harbour (Nile Delta, Egypt) – Journal of Archaeological Science: Reports, 13: 669-681.

FOLK, R.L. & WARD, W.C. (1957): Brazos river bar: A study in the significance of grain size parameters. – Journal of Sedimentary Petrology, 27: 3-26.

FORTE, A., COWGILL, E. & WHIPPLE, K.X. (2014): Transition from a singly vergent to doubly vergent wedge in a young orogeny. The Greater Caucasus. Tectonics, 33: 2077-2101.

FOUACHE, E., KELTERBAUM, D., BRÜCKNER, H., LERICOLAIS, G., POROTOV, A. & DIKAREV, V. (2012): The Late Holocene evolution of the Black Sea – a critical view on the so-called Phanagorian regression. – Quaternary International, 266: 162-174.

GABUNIA, L., VEKUA, A., LORDKIPANIDZE, D., SWISHER, C.C., FERRING, R., JUSTUS, A., NIORADZE, M., TVALCHRELIDZE, M., ANTÓN, S.C., BOSINSKI, G., JÖRIS, O., LUMLE, M.A., MAJSURADZE, G. & MOUSKHELISHVILI, A. (2000): Earliest Pleistocene Hominid Cranial Remains from Dmanisi, Republic of Georgia: Taxonomy, Geological, Setting, and Age. – Science, 288: 1019-1025.

GAMKRELIDZE, G. (1992): Hydroarchaeology in the Georgian Republic (the Colchian Littoral). – The International Journal of Nautical Archaeology, 21: 101-109.

GAMKRELIDZE, G. (1998): Stress Vector Orientations and Movement of the Earth's Crust of Territory of Georgia and the Neotectonic Stage. – Bulletin of the Georgian Academy of Science, 158: 284-287.

GAMKRELIDZE, G. (2012): Researches in the Iberia-Colchology (History and archaeology of ancient Georgia). – Georgian National Museum, Tbilisi.

GAUSS, R.K., BÁTORA, J., NOWACZINSKI, E., RASSMANN, K. & SCHUKRAFT, G. (2013): The Early Bronze Age settlement of Fidvár, Vráble (Slovakia): Reconstructing prehistoric settlement patterns using portable XRF. – Journal of Archaeological Science, 40: 2942-2960.

GEORGIEVSKI, G. & STANEV, E. (2006): Paleo-evolution of the Black Sea watershed: sea level and water transport through the Bosporus Straits as an indicator of the Lateglacial-Holocene transition. – Climate Dynamics, 26: 641-644.

GIOSAN, L., DONNELLY, J.P., FILIP, F., OVEJANU, I., VESPREMEANU-STROE, A., VESPREMEANU, E. & DULLER, G.A:T. (2006): Young Danube delta documents stable Black Sea level since the middle Holocene: Morphodynamic, paleogeographic, and archaeological implications. – Geology, 34: 757-760.

GIOSAN, L., FILIP, F. & CONSTANTINESCU, S. (2009): Was the Black Sea catastrophically flooded in the early Holocene? – Quaternary Science Reviews, 28: 1-6.

GOIRAN, J.P., SALOMON, F., MAZZINI, I., BRAVARD, J.P., PLEUGER, E., VITTORI, C., BOETTO, G., CHRISTIANSEN, J., ARNAUD, P., PELLEGRINO, A., PEPE, C. & SADORI, L. (2014): Geoarchaeology confirms location of the ancient harbour basin of Ostia (Italy). – Journal of Archaeological Science, 41: 389-398.

GREPPIN, D. (1991): Some effects of the Hurro-Urartian people and their languages upon the earliest Armenians. – Journal of the American Oriental Society, 111.4: 720-730.

GUYARD, H., CHAPRON, E., ST-ONGE, G., ANSELMETTI, F., ARNAUD, F., MAGAND, O., FRANCUS, P. & MÉLIÈRES, M.-A. (2007): High-altitude varve records of abrupt environmental changes and mining activity over the last 4000 years in the Western French Alps (Lake Bramant, Grandes Rousses Massif). – Quaternary Sciences Reviews, 26: 2644-2660.

HAGHANI, S., LEROY, S., KHDIR, S., KABIRI, K., BENI, A.N. & LAHIJANI, H.A.K. (2015): An early 'Little Ice Age' brackish water invasion along the south coast of the Caspian Sea (sediment of Langarud wetland) and its wider impacts on environment and people. – The Holocene, 26: 3-16.

HANSEN, S., MIRTSKHULAVA, G. & BASTERT-LAMPRICHS, K. (2007): Aruchlo: Neolithic Settlement Mound in the Caucasus. – Neo-Lithics, 1/07: 13-18.

HASSAN, F.A (1986): Holocene lakes and prehistoric settlements of the Western Faiyum, Egypt. – Journal of Archaeological Science, 13 (5): 483-501.

HASSAN, F.A. (2010): The dynamics of the riverine civilization: A geoarchaeological perspective on the Nile Valley, Egypt. – World Archaeology, 29 (1): 51-74.

HEIRI, O., LOTTER, A. & LEMCKE, G. (2001): Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. – Journal of Paleolimnology, 25: 101-110.

HISCOTT, R.N., AKSU, A.E., YAŞAR, D., KAMINSKI, M.A., MUDIE, P.J., KOSTYLEV, V.E., MACDONALD, J.C., ISLER, F.I. & LORD, A.R. (2002): Deltas south of the Bosphorus Strait record persistent Black Sea outflow to the Marmara Sea since 10 ka. – Marine Geology, 190: 95-118.

HOREJS, B. (2012): Çukuriçi Höyük - A Neolithic and Bronze Age settlement in the region of Ephesos. – In: Özdoğan, M., Başgelen, N. & Kuniholm, P. (Eds.): The Neolithic in Turkey, 4 – Archaeology and Art Publications, Istanbul: pp. 117-131.

IVANOVA, E.V., MURDMAA, I.O., CHEPALYGA, A.L., CRONIN, T.M., PASECHNIK, I.V., LEVCHENKO, O.V., HOWE, S.S., MANUSHKINA, A.V. & PLATONOVA, E.A. (2007): Holocene sea-level oscillations and environmental changes on the Eastern Black Sea shelf. – Palaeogeography, Palaeoclimatology, Palaeoecology, 246: 228-259.

JANELIDZE, Z. & TATASHIDZE, Z. (2010). Palaeogeographical interpretation of archaeological sites of swamps of the Black Sea coast of Georgia. – Bulletin of the Georgian National Academy of Sciences, 4: 159-161.

JOOSTEN, H., KAFFKE, A. & MATCHUTADZE, I. (2003): The mires of the Kolkheti lowlands (Georgia). – IMCG Newsletter, 2003/3: 19-23.

JOUANNA, J. (1996): Hippocrate 2.2. Airs, eaux, lieux. – Les Belles Lettres, Paris.

KAZANCI, N., GULBADAZDEH, T., LEROY, S.A.G. & ILERI, Ö. (2004): Sedimentary and environmental characteristics of the Gilan-Mazenderan plain, northern Iran: influence of long- and short-term Caspian water level fluctuations on geomorphology. – Journal of Marine Systems, 46: 145-168.

KEHL, M., BUROW, C., HILGERS, A., NAVAZO, M., PASTOORS, A., WENIGER, G.C., WOOD, R. & JORDA PARDO, J.F. (2013): Late Neanderthals at Jarama VI (central Iberia)? Quaternary Research, 80: 218-234.

KELTERBAUM, D., BRÜCKNER, H., POROTOV, A., SCHLOTZHAUER, U. & ZHURAVLEV, D. (2011): Geoarchaeology of Taman Peninsula (SW Russia) – the example of the ancient Greek settlement of Golubitskaya 2. – Die Erde, 142 (3): 235-258.

KELTERBAUM, D., BRÜCKNER, H., DIKAREV, V., GERHARD, S., PINT, A. POROTOV, A. & Zin'ko, V. (2012): Palaeogeographic changes at Lake Chokrak on the Kerch Peninsula, Ukraine, during the Mid and Late Holocene. – Geoarchaeology, 27 (3): 206-219.

KOHL, P. (2001): Migrations and Cultural diffusions in the later Prehistory of the Caucasus. In: EICHMANN, R. & PARZINGER, H. (Eds.), Migration und Kulturtransfer. Der Wandel vorder- und zentralasiatischer Kulturen im Umbruch vom 2. zum 1. vorchristlichen Jahrtausend (= Kolloquien zur Vor- und Frühgeschichte. Bd. 6). – Akten des internationalen Kolloquiums, Berlin, 23. bis 26. November 1999. – Habelt, Bonn.

KORENJAK, M. (2003): Die Welt-Rundreise eines anonymen griechischen Autors ("Pseudo-Skymnos"). – Georg Olms Verlag, Hildesheim.

KOROTAEV, G., OGUZ, T., NIKIFOROV, A. & KOBLINSKY, C. (2003): Seasonal, interannual, and mesoscale variability of the Black Sea upper layer circulation derived from altimeter data. – Journal of Geophysical Research, 108 (C4): 19.1-19.15.

KOSCHELENKO, G.A. & KUSNETSOW, V.D. (1998): Greek Colonisation of the Bosporus. – In: TSETSKHLADZE, G. (Ed.): The Greek Colonisation of the Black Sea Area. Historical Interpretation of Archaeology. – Steiner, Stuttgart: pp: 249-263.

KRAFT, J.C., RAPP, G., KAYAN, İ. & LUCE, J.V. (2003): Harbor areas at ancient Troy: Sedimentology and geomorphology complement Homer's Iliad. – Geology 31, (2): 163-166.

KVAVADZE, E.V. & CONNOR, S. (2005): *Zelkova carpinifolia* (Pallas) K. Koch in Holocene sediments of Georgia – an indicator of climatic optima. – Review of Palaeobotany and Palynology, 133: 69-89.

KVINIKADZE, M., KUPARADZE, D. & PATARIDZE, D. (2014): Geo-Environmental Peculiarities of the Territory of Colchis and Rioni River basin area (West Georgia, Caucasus). – Standard Global Journal of Geology and Explorational Research, 2 (2): 35-43.

LAERMANNS, H., KELTERBAUM, D., MAY, S.M., ELASHVILI, M., OPITZ, S., HÜLLE, D., RÖLKENS, J., VERHEUL, J., RIEDESEL, S. & BRÜCKNER, H. (2017a): Mid- to Late Holocene landscape changes in the Rioni Delta area (Kolkheti lowlands, W Georgia). – Quaternary International, DOI: 10.1016/ j.quaint.2016.12.037.

LAERMANNS, H., KIRKITADZE, G., MAY, S.M., KELTERBAUM, D., OPITZ, S., HEISTERKAMP, A., BASILAIA, G., ELASHVILI, M. & BRÜCKNER, H. (2017b): Bronze Age settlement mounds on the Colchian plain at the Black Sea coast of Georgia - a geoarchaeological perspective. – Geoarchaeology. DOI: 10.1002/gea.21670.

LAMBECK, K. & PURCELL, A. (2005): Sea-level change in the Mediterranean Sea since the LGM: model predictions for tectonically stable areas. – Quaternary Science Reviews, 24: 1969-1988.

LEORRI, E., MARTIN, R. & MCLAUGHLIN, P. (2006): Holocene environmental and parasequence development of the St. Jones Estuary, Delaware (USA): foraminiferal proxies of natural climatic and anthropogenic change. – Palaeogeography, Palaeoclimatology, Palaeoecology, 241 (3-4): 590-607.

LERICOLAIS, G., POPESCU, I., GUICHARD, F., POPESCU, S.-M. & MANOLAKAKIS, L. (2007): Water level fluctuations in the Black Sea since the Last glacial maximum. – In: YANKO-HOMBACH, V., GILBERT, A.S., PANIN, N., DOLUKHANOV, P.M. (Eds.), The Black Sea Flood Question. – Springer, Dordrecht: pp. 437-452.

LERICOLAIS, G., BULOIS, C., GILLET, H. & GUICHARD, F. (2009): High frequency sea-level fluctuations recorded in the Black Sea since the LGM. – Global and Planetary Change, 66: 65-75.

LEROY, S.A.G., KAKROODI, A.A., KROONENBERG, S., LHIJANI, H.K., ALIMOHAMMADIAN, H. & NIGRAOV, A. (2013): Holocene vegetation history and sea level changes in the SE corner of the Caspian Sea: relevance to SW Asia climate. – Quaternary Science Reviews, 70: 28-47.

LICHELI, V. (2016): Geoarchaeology of Phasis, Mediterranée, 126: 119-128.

LINSTÄDTER. J. & KEHL, M. (2012): Holocene archaeological sequence and sedimentological processes at Ifri Oudadane, NE Morocco. – Journal of Archaeological Science, 39: 3306-3323.

LISETSKII, F.N., STOLBA, V. & PICHURA, V.I. (2017): Late Holocene palaeoenvironments of Southern Crimea: Soils, soil-climate relationship and human impact. – The Holocene, DOI:10.1177/0959683617708.

LORDKIPANIDZE, D., JASHASHVILI, T., VEKUA, A., PONCE DE LEÓN, M., ZOLLIKOFER, C., RIGHTMIRE, G.P., PONTZER, H., FERRING, R., OMS, O., TAPPEN, M., BUKHSIANIDZE, M., AGUSTI, J., KAHLKE, R., KILADZE, G., MARTINEZ-NAVARRO, B., MOUSKHELISHVILI, A., NIORADZE, M. & ROOK, L. (2007): Postcranial evidence from early *Homo* from Dmanisi, Georgia. – Nature, 449: 305-310.

LORDKIPANIDZE, O. (1991): Archäologie in Georgien: Von der Altsteinzeit zum Mittelalter. – VCH Verlagsgesellschaft mbH, Weinheim.

LORDKIPANIDZE, O. (2000): Phasis: The river and city in Colchis. Geographica Historica. – Steiner, Stuttgart.

MAMULADZE, S., KARASIEWICZ-SZCZYPIORSKI, R., SHALIKADZE, T., SURMANIDZE, N. & KAKHIDZE, E. (2014): Interim report on the Polish – Georgian excavation of a Roman fort in Gonio (Apsaros) in 2014. – Polish Archaeology in the Mediterranean, 25: 533-552.

MARRINER, N. & MORHANGE, C. (2006): The ‘Ancient Harbour Parasequence’: anthropogenic forcing of the stratigraphic highstand record. – Sedimentary Geology, 186 (1-2): 13-17.

MARRINER, N. & MORHANGE, C. (2007): Geoscience of ancient Mediterranean harbours. – Earth-Science Reviews, 80: 137-194.

MARRINER, N., MORHANGE, C. & GOIRAN, J.P. (2010): Coastal and ancient harbour geoarchaeology. – Geology Today, 26 (1): 21-27.

MARTIN, R.E., LEORRI, E. & MCLAUGHLIN, P.P. (2007): Holocene sea-level and climate change in the Black Sea: multiple marine incursions and freshwater discharge events. – Quaternary International, 167: 61-72.

MARTIN, R.E. & YANK-HOMBACH, V. (2011): Rapid Holocene sea-level and climate change in the Black Sea: An evaluation of the Balabanov sea-level curve. – In: Buynevich, I.V., Yanko-Hombach, V., Gilbert, A.S. & Martin, R.E. (Eds.): Geology and Geoarchaeology of the Black Sea Region: Beyond the Flood Hypothesis: Geological Society of America Special Paper, 473: 51-58.

MESSAGER, E., LORDKIPANIDZE, D., KVAVADZE, E., FERRING, C.R. & VOINCHET, P. (2009): Palaeoenvironmental reconstruction of Dmanisi site (Georgia) based on palaeobotanical data. – Quaternary International, 223-224: 20-27.

MESSAGER, E., LEBRETON, V., MARQUER, L., RUSSO-ERMOLLI, E., ORAIN, R., RENAULT-MISKOVSKY, J., LORDKIPANIDZE, D., DESPRIÉE, J., PERETTO, C. & ARZARELLO, M. (2011): Palaeoenvironments of early hominins in temperate and Mediterranean Eurasia: new palaeobotanical data from Palaeolithic key-sites and synchronous natural sequences. – Quaternary Science Reviews, 30: 1439-1447.

MEYERS, P.A. & TERANES, J.L. (2001): Sediment organic matter. – In: LAST, W.M. & SMOL, J.P. (Eds.): Tracking Environmental Change Using Lake Sediments. – Kluver Academic Publishers, Dordrecht: pp. 239-269.

MILLER, H., CROUDACE, I.W., BULL, J.M., COTTERILL, C.J., DIX, J.K. & TAYLOR, R.N. (2014). Sediment lake record of anthropogenic and natural inputs to Windermere (English Lake District) using double-spike lead isotopes, radiochronology, and sediment microanalysis. – Environmental Science & Technology, 48: 7254-7263.

MIRON, A. & ORTHMANN, W. (1995): Unterwegs zum Goldenen Vlies - archäologische Funde aus Georgien. – Museum für Vor- und Frühgeschichte Saarbrücken, Saarbrücken.

MITCHELL, J. & WESTAWAY, R. (1999): Chronology of Neogene and Quaternary uplift and magmatism in the Caucasus: constraints from K-Ar dating of volcanism in Armenia. – Tectonophysics, 304: 157-186.

MORHANGE, C. (2005): Relative sea-level changes in Marseille's ancient harbors (France) during the Late Holocene. – Zeitschrift f. Geomorphologie, 137 (Supplement): 23-28.

MURRAY, A.S. & WINTLE, A.G. (2000): Luminescence dating of quartz using an improved single aliquot regenerative-dose protocol. – Radiation Measurements, 32: 57-73.

MURRAY, A.S. & WINTLE, A.G. (2003): The single aliquot regenerative dose protocol: potential for improvements in reliability. – Radiation Measurements, 37: 377-381.

NADERI BENI, A., LAHIJANI, H., MUSSAVI HARAMI, R., LEROY, S.A.G., SHAH-HOSSEINI, M., KABIRI, K. & TAVAKOLI, V. (2013): Development of spit-lagoon complexes in response to Little Ice Age rapid sea-level changes in the central Guilan coast, South Caspian Sea, Iran. – Geomorphology, 187: 11-26.

NAKHUTSRISHVILI, G.S. (1999): The vegetation of Georgia (Caucasus) – Braun-Blanquetia, 15: 1-68.

NARIMANIDZE, E. & BRÜCKNER, H. (1999): Survey on metal contamination of agricultural soils in Georgia. – Land Degradation and Development, 10: 467-488.

NEVESSKY, E.N. (1970): Holocene history of the coastal shelf zone of the USSR of useful minerals. – Quaternaria, 12: 78-88.

NICOSIA, C., LANGOHR, R., CARMONA GONZÁLEZ, P., GÓMEZ BELLARD, C., MODRALL, E.B., RUÍZ PÉREZ, J.M. & VAN DOMMELEN, P. (2013): Land use history and site formation processes at the Punic site of Pauli Stincus in West Central Sardinia. – Geoarchaeology, 28: 373-393.

NIKOLAISHVILI, D.A., ELIZARBARASHVILI, N. & MELADZE, G.G. (2011): Evaluation of degree of landscape's anthropogenic transformation (landscapes of Georgia). – Procedia Social and Behavioral Sciences, 19: 547-555.

OGNJANOVA-RUMENOVA, N. (2008): Palaeoenvironment and archaeology: the use of diatom analysis in archaeology. – In: KOSTOV, R.I., GAYDARSKA, B. & GUROVA, M. (Eds.): Geoarchaeology and Archaeomineroalogy. – St. Ivan Rilski, Sofia: pp. 291-294.

OKROSTSVARIDZE, A., GAGNIDZE, N. & AKIMIDZE, K. (2016): A modern field investigation of the mythical "gold sands" of the ancient Colchis Kingdom and "Golden Fleece" phenomena, – Quaternary International, 409: 61-69.

OONK, S., SLOMP, C.P. & HUISMAN, D.J. (2009): Geochemistry as an aid in archaeological prospection and site interpretation: Current issues and research directions. – Archaeological Prospection, 16: 35-51.

OSTROVSKY, A.B., IZMAYLOV, Y.A., BALABANOV, I.P., SKIBA, S.I., SKRYABINA, N.G., ARSLANOV, S.A., GEY, N.A. & SUPRUNOVA, N.I. (1977): New data on the paleohydrological regime of the Black Sea in the Upper Pleistocene and Holocene – In: KAPLIN, P.A. & SHCHERBAKOV, F.A. (Eds.): Pleistocene Paleogeography and Sediments of the Southern Seas of the USSR – Nauka, Moscow: pp. 131-140 (in Russian).

PANIN, N. & POPESCU, I. (2007): The northwestern Black Bea: climatic and sea-level changes in the Upper Quaternary. – In: YANKO-HOMBACH V., GILBERT, A.S., PANIN, N. & DOLUKHANOV, P.M. (Eds.): The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement. – Springer, New York: pp. 387-404.

PAPUASHVILI, R. & PAPUASHVILI, I. (2014): Kolchian Lowland in the Context of the Black Sea Palaeo-regime (In III-I millennium B.C.). – Mtsignobari, Tbilisi (in Georgian).

PARKINSON, W.A., GYUCHA, A., YERKES, R.W., HARDY, M. & MORRIS, M. (2004): Settlement reorganization at the end of the Neolithic in Central Europe: Recent research in the Körös River Valley, southeastern Hungary. – Journal of Eurasian Prehistory, 2: 57-73.

PARKINSON, W.A. & DUFFY, P.R. (2007): Fortifications and enclosures in European Prehistory: A cross-cultural perspective. – Journal of Archaeological Research, 15: 97-141.

PARKINSON, W.A. & GYUCHA, A. (2012): Tells in Perspective: Long-Term Patterns of Settlement Nucleation and Dispersal in Central and Southeast Europe. – In: HOFFMANN, R., MOETZ, F.-K. & MÜLLER, J. (Eds.): Tells: Social and Environmental Space – Universitätsforschungen zur prähistorischen Archäologie – Habelt, Bonn: pp. 105-116.

PINT, A., SEELIGER, M., FRENZEL, P., FEUSER, S., ERKUL, E., BERNDT, C., KLEIN, C., PIRSON, F. & BRÜCKNER, H. (2015): The environs of Elaia's ancient open harbour - a reconstruction based on microfaunal evidence. – Journal of Archaeological Science, 54: 340-355.

PIRAZZOLI, P.A. (1991): World atlas of Holocene sea-level changes. – Elsevier Oceanography Series, 58, Amsterdam, London, New York, Tokyo.

PIRAZZOLI, P.A. (1996): Sea-level Changes. The Last 20,000 Years. – Wiley and Sons, Chichester.

PITMAN, W.C. & RYAN, W.B.F. (1998): Noah's flood. The new scientific Discoveries about the event that changed history. – Simon and Schuster, New York.

PLONTKE-LÜNING, A. (2007): Apsaros, Apsyrtos, Andreas, Mathata. Heroentranditionen im politischen Kontext. – Journal Phasis, 10 (1-12): 125-134.

POROTOV, A. (2007): Relative sea-level changes and submersion of archaeological sites along the northern shoreline of the Black Sea. – Mediterranée, 108 (1): 29-36.

PREOTEASA, L., VESPREMEANU-STROE, A., HANGANU, D, KATONA, O. & TIMAR-GABOR, A. (2013): Coastal changes from open coast to present lagoon system in Histria region (Danube delta). – In: CONLEY, D.C., MASSELINK, G., RUSSELL, P.E. & O'HARE, T.J. (Eds.): Proceedings 12th International Coastal Symposium (Plymouth, England), Journal of Coastal Research, Special Issue, 65: 564-569,

RAYFIELD, D. (2013): Edge of Empires: A History of Georgia. – Reaktion Books, London.

REIMER, P.J., BARD, E., BAYLISS, A., BECK, J.W., BLACKWELL, P.G., BRONK RAMSEY, C., BUCK, C.E., CHENG, H., EDWARDS, R.L., FRIEDRICH, M., GROOTES, P.M., GUILDERSON, T.P., HAFLIDASON, H., HAJDAS, I., HATTÉ, C., HEATON, T.J., HOGG, A.G., HUGHEN, K.A., KAISER, K.F., KROMER, B., MANNING, S.W., NIU, M., REIMER, R.W., RICHARDS, D.A., SCOTT, E.M., SOUTHON, J.R., TURNEY, C. & VAN DER PLICHT, J. (2013): InterCal13 and Marine 13 radiocarbon age calibration curves 0-50,000 years cal BP. – Radiocarbon, 55: 1869-1887.

RÖHRIG, E. (1991): Deciduous forests of the Near East. In: RÖHRIG, E. & B. ULRICH (Eds.): Temperate deciduous forests. – Ecosystems of the world, 7: 527-537.

ROMANESCU, G. (2013): Geoarchaeology of the ancient and medieval Danube Delta: Modelling environmental and historical changes. A review. – Quaternary International, 293: 231-244.

ROMANESCU, G. (2014): The catchment area of the Milesian colony of Histria, within the Razim-Sinoie lagoon complex (Romania): hydrogeomorphologic, economic and geopolitical implications. – Area, 46.3: 320-327.

ROMANESCU, G., BOURNEGRU, O., STOLERIU, C., MIHU-PINTILIE, A., NICU, C., ENEA, A. & STAN, C. (2014): The ancient legendary island of PEUCE - myth or reality? – Journal of Archaeological Science, 51: 521-535.

RUNNELS, C.R., PAYNE, C., RIFKIND, N.V., WHITE, C., WOLFF, N.O. & LEBLANC, S. (2009): Warfare in Neolithic Thessaly: A case study. Hesperia: – The Journal of the American School of Classical Studies at Athens, 78 (2): 165-194.

RYAN, W.B.F. (2007): Status of the Black Sea Flood Hypothesis. – In: Yanko-Hombach, V., Gilbert, A.S., Panin, N. & P.M. Dolukhanov (Eds.): The Black Sea Flood Question. – Springer, Dordrecht: pp. 63-88.

RYAN, W.B.F., PITMAN, W.C., MAJOR, C.O., SHIMKUS, K., MOSKALENKO, V., JONES, G.A., DIMITROV, P., GÖRÜR, N., SAKINÇ, M., SEYIR, H.I. & YÜCE, H. (1997): An abrupt drowning of the Black Sea shelf. – Marine Geology, 138: 119–126.

SADZRADZE, V., DAVLIANIDZE, R. & MURVANIDZE, B. (1999): Archaeological investigation of Supsa terminal and adjacent area. – Pipeline Archaeology, 1: 104-115.

SEELIGER, M., BARTZ, M., ERKUL, E., FEUSER, S., KELTERBAUM, D., KLEIN, C., PIRSON, F., VÖTT, A. & BRÜCKNER, H. (2013): Taken from the sea, reclaimed by the sea - The fate of the closed harbour of Elaia, the maritime satellite city of Pergamum (Turkey). – Quaternary International, 312: 70-83.

SEELIGER, M., BRILL, D., FEUSER, S., BARTZ, M., ERKUL, E., KELTERBAUM, D., VÖTT, A., KLEIN, C., PIRSON, F. & BRÜCKNER, H. (2014): Purpose and age of underwater walls in the Bay of Elaia (western Turkey) – a multidisciplinary approach. – Geoarchaeology, 29: 138-155.

SENS, U. (2009): Kulturkontakt an der östlichen Schwarzmeerküste. – In: Bertemes, F. & Furtwängler, A. (Eds.): Schriften des Zentrums für Archäologie und Kulturgeschichte des Schwarzmeerraumes, 15. – Beier & Beran, Stuttgart.

SOLIGO, R. & MYERS JAFFE, A. (2002): The economics of Pipeline Routes: The Conudrum of Oil Exports from Caspian Basin.– In: KALYUZHNOVA, Y., MYERS JAFFE, A., LYNCH, D. & SICKLES R. (Eds.): Energy in the Caspian Region: pp. 109-132.

SOTER, S. & KATSONOPOULOU, D. (2011): Submergence and Uplift of Settlements in the Area of Helike, Greece, from the Early Bronze Age to Late Antiquity – Geoarchaeology, 26 (4): 584-610.

STOCK, F., PINT, A., HOREJS, B., LADSTÄTTER, S. & BRÜCKNER, H. (2013): In search of the harbours - New evidence of Late Roman and Byzantine harbours of Ephesus. – Quaternary International, 312: 57-69.

STOCK, F., KNIPPING, M., PINT, A., LADSTÄTTER, S., DELILE, H., HEISS, A., LAERMANNS, H., MITCHELL, P., PLOYER, R., STESKAL, M., THANHEISER, U., URZ, R., WENNRICH, V. & BRÜCKNER, H. (2016): Human impact on Holocene sediment dynamics in the Eastern Mediterranean – the example of the Roman harbour of Ephesus. – Earth Surface Processes and Landforms, 41: 980-996.

STUIVER, M. & REIMER, P. (1993): Extended ^{14}C data base and revised calib 3.0 ^{14}C age calibration program. – Radiocarbon, 35: 215-230.

TARASOV, P.E., VOLKOVA, V.S., WEBB, T., III, GUIOT, J., ANDREEV, A.A., BEZUSKO, L.G., BEZUSKO, T.V., BYKOVA, G.V., DOROFEYUK, N.I., KVAVADZE, E.V., OPISOVA, I.M., PANOVA, N.K. & SEVASTYANOV, D.V. (2000): Last glacial maximum biomes reconstructed from pollen and plant macrofossil data from northern Eurasia. – Journal of Biogeography, 27: 609-620.

TSETSKHLADZE, G.R. (1997): How Greek colonists adapted their way of life to the conditions in Kolkhis. – In: FOSSEY, J.M. (Ed.): Proceedings of the first international conference on the archaeology and history of the Black Sea. pp. 121-136.

TSETSKHLADZE, G.R. (1999): Pichvnari and its Environs 6th c BC-4th c AD. – Presses Universitaires Franc-Comtoises, Paris.

TURNEY, C., CANTI, M., BRANCH, N. & CLARK, P. (2005): Environmental Archaeology: Theoretical and Practical Approaches. – Routledge, London.

VESPREMEANU-STROE, A., PREOTEASA, L., HANGANU, D., BROWN, A.G., BÎRZESCU, I., TOMS, P. & TIMAR-GABOR, A. (2013): The impact of the Late Holocene coastal changes on the rise and decay of the ancient city of Histria (southern Danube delta). – Quaternary International, 293: 245-256.

VOSKOBOINIKOV, V.M., ROTAR, M.F. & KONIKOV, E.G. (1982): Relationship between the rhythmic composition of thick Holocene layers of the Black Sea region lagoons and the oscillatory level regime of the Black Sea. – In: KAPLIN, P.A., KLIGE, R.K. & CHEPALYGA, A.L. (Eds.): Sea-Level Fluctuations. – Moscow State University, Moscow: pp. 264-274 (in Russian).

VÖTT, A. (2007): Relative sea level changes and regional tectonic evolution of seven coastal areas in NW Greece since the mid-Holocene. – Quaternary Science Reviews, 26: 894-919.

VÖTT, A. & BRÜCKNER, H. (2006): Versunkene Häfen im Mittelmeerraum. Antike Küstenstädte als Archive für die Kultur- und Umweltforschung. – Geographische Rundschau, 58 (4): 12-21.

VÖTT, A., SCHRIEVER, A., HANDL, M., & BRÜCKNER, H. (2007): Holocene palaeogeographies of the central Acheloos River delta (NW Greece) in the vicinity of the ancient seaport Oiniadai. – Geodinamica Acta, 20: 241-256.

WALLINGA, J., MURRAY, A. & WINTLE, A. (2000): The single-aliquot regenerative-dose (SAR) protocol applied to coarse-grain feldspar. – Radiation Measurements, 32: 529-533.

WESTOBY, M.J., BRASINGTON, J., GLASSER, N.F., HAMBREY, M.J., & REYNOLDS, J.M. (2012): 'Structure-from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications. – Geomorphology, 179: 300-314.

YANKO-HOMBACH, V., GILBERT, A.S. & DOLUKHANOV, P. (2007): Controversy over the great flood hypotheses in the Black Sea in light of geological, paleontological, and archaeological evidence. – Quaternary International, 167-168: 91-113.

YILMAZ, A., ADAMIA, S. & YILMAZ, H. (2013): Comparisons of the suture zones along a geotraverse from the Scythian Platform to the Arabian Platform. – Geoscience Frontiers, 5 (6): 855-875.

ŽAROMSKIS, R. & GULBINSKAS, S. (2010): Main patterns of coastal zone development of the Curonian Spit, Lithuania. – Baltica, 23 (2): 149-156.

ZHAMOIDA, V.A., RYABCHUCK, D.V., KROPATCHEV, Y.P., KURENNOY, D., BOLDYREV, V.L. & SIVKOV, V.V. (2009): Recent sedimentation processes in the coastal zone of the Curonian Spit (Kaliningrad region, Baltic Sea). – Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 160 (2): 143-157.

ZIELFHOFER, C., FAUST, D. & LINSTÄDTER, J. (2008): Late Pleistocene and Holocene alluvial archives in the Southwestern Mediterranean: Changes in fluvial dynamics and past human response. – Quaternary International, 181: 39-54.

Appendix A

Palynological, sedimentological and granulometrical analyses on sediment core KUL 13

In preparetion to submit a research proposel to the German research Council (DFG) the sediment core KUL 13 was palynologically, sedimentologically and granulometrically analysed in order to demonstrate its suitability for those investigations. We intend to continue our studies in Western Georgia to decipher the Holocene and Late Pleistocene vegetation history and sea-level evolution on analysing a 48 m-long sediment core that was drilled on the western shore of Lake Paliastomi.

The closed sediment core KUL 13 was taken from the same site as KUL 12 (Figure 2.1), which in turn was taken with open tubes, in the most accessible proximity of the centre of the swampland between the rivers Khobistskali and Rioni. It was drilled with one-meter-long inliners with an overlap of 20 cm to avoid compaction of the sediment material.

The samples were analysed for their grain size pattern according to the methods described in Chapter 2.3.2. The section between the maximum depth at 12.00 m and 10.40 m b.s. were analysed with an energy-dispersive X-ray fluorescence (XRF) Itrax Core Scanner (Cox Analytical Systems, Sweden; Croudace et al. 2006) equipped with a 1.9 kW chromium (Cr) X-ray tube set to a voltage and current of 30 kV and 30 mA. Measurements were conducted in 2 mm resolution within an exposure time of 20 seconds. Magnetic susceptibility (MagSus) measurements were performed three times for each sample using a Bartington MS2B sensor. Two samples were taken for radiocarbon dating and calibrated using CALIB 7.1 software and IntCal13 data set (Stuiver & Reimer 1993; Reimer et al. 2013).

For the palynological analysis a total number of 16 samples were taken. For sample processing (on average 1 ml) sodium pyrophosphate was added to avoid coagulation. In the next step, samples were treated with cold hydrochloric acid (10%) and cold hydrofluoric acid (32%), followed by a repeated addition of HCl in order to eliminate carbonates, quartz and fluorosilicate gels, respectively. Subsequently, the residual organic fraction was screened through 120 and 10 µm mesh sieves and mounted on glass slides in glycerol. *Lycopodium* tablets were added for concentration estimates and a light microscope at 400 × and at 1000 × magnifications was used for counting and identification of the palynomorphs. Percentages were calculated based on the terrestrial sum and the pollen diagram was plotted with the Psimpoll software, version 4.27 (Bennett 2007). A zonation

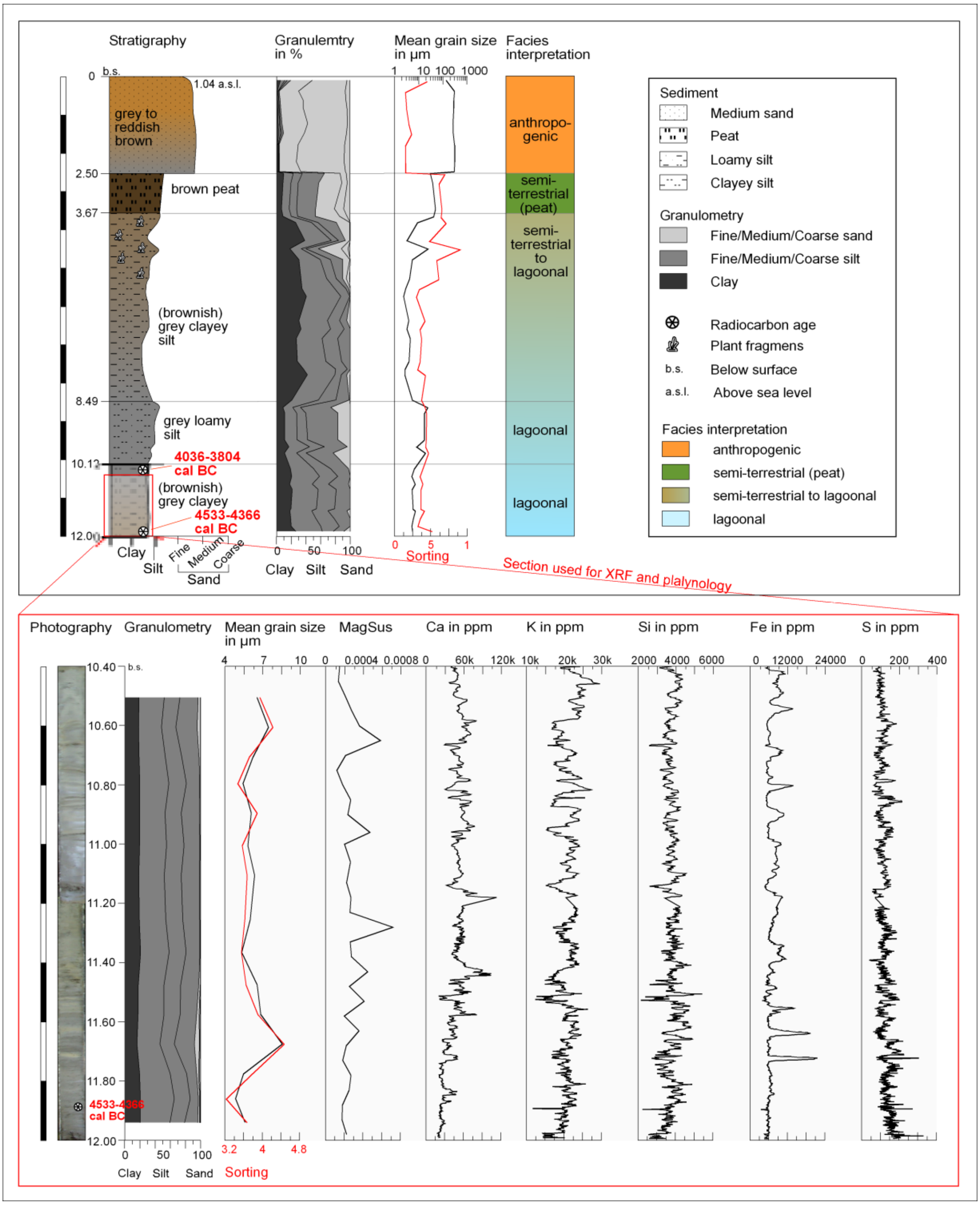

Fig. A.1: Facies interpretation, granulometry, geochemistry and ^{14}C age estimates of the sediment core KUL 13 (own design 2017).

by cluster analysis (CONISS) after square-root transformation was applied to the main terrestrial taxa.

From the maximum depth at 12 m to 3.67 m b.s. the sediment core consists of homogeneous silt with a high clay content. Only between 10.12 and 8.49 m b.s. and around 4.50 m b.s. the sand component rises slightly. The geochemical parameters from the investigated part between 12 m and 10.40 m b.s. indicate lagoonal conditions (cf. facies determination Chapter 2.5.1.3) that seem to prevail until the upper part of the silt layer. Between 3.67 m and 2.50 m b.s. peat layers with macroscopic plant remains can be found. Above those, homogenous coarse sand was accumulated in the course of the construction of the causeway.

The investigated part between 12 m and 10.40 m b.s. can be dated to the second half of the 5th millennium BC due to the two radiocarbon ages that were taken at 11.86 and 10.29 m b.s. indicating ages of 4533-4366 cal BC and 4036-3804 cal BC respectively. The pollen data implies warm and humid climate conditions for that time. Open forests prevailed in the surroundings of the lagoon which were dominated by alder *(Alnus)* as well as hornbeam *(Carpinus betulus)* and hazel *(Corylus)* with scattered Turkish pines *(Pinus eldarica)*, *Fagus* and deciduous oak *(Quercus deciduous)*. The high percentage of non-arbol pollen, especially sedges (*Cyperaceae*) and grasses *(Poaceae)*, indicate swampy conditions. Over the estimated time the latter decreased slightly while the percentage of arbol pollen increased, suggesting a trend to dryer conditions – although on a very limited scale.

These results confirm the prior outcome of investigations by Connor et al. (2007) and de Klerk et al. (2009) at the site of Ispani. Even though their studies cover a time span of ~5500 years they also assume warm and humid conditions. Future investigations (cf. Chapter 6) would extend and deepen our knowledge of the region's palynology.

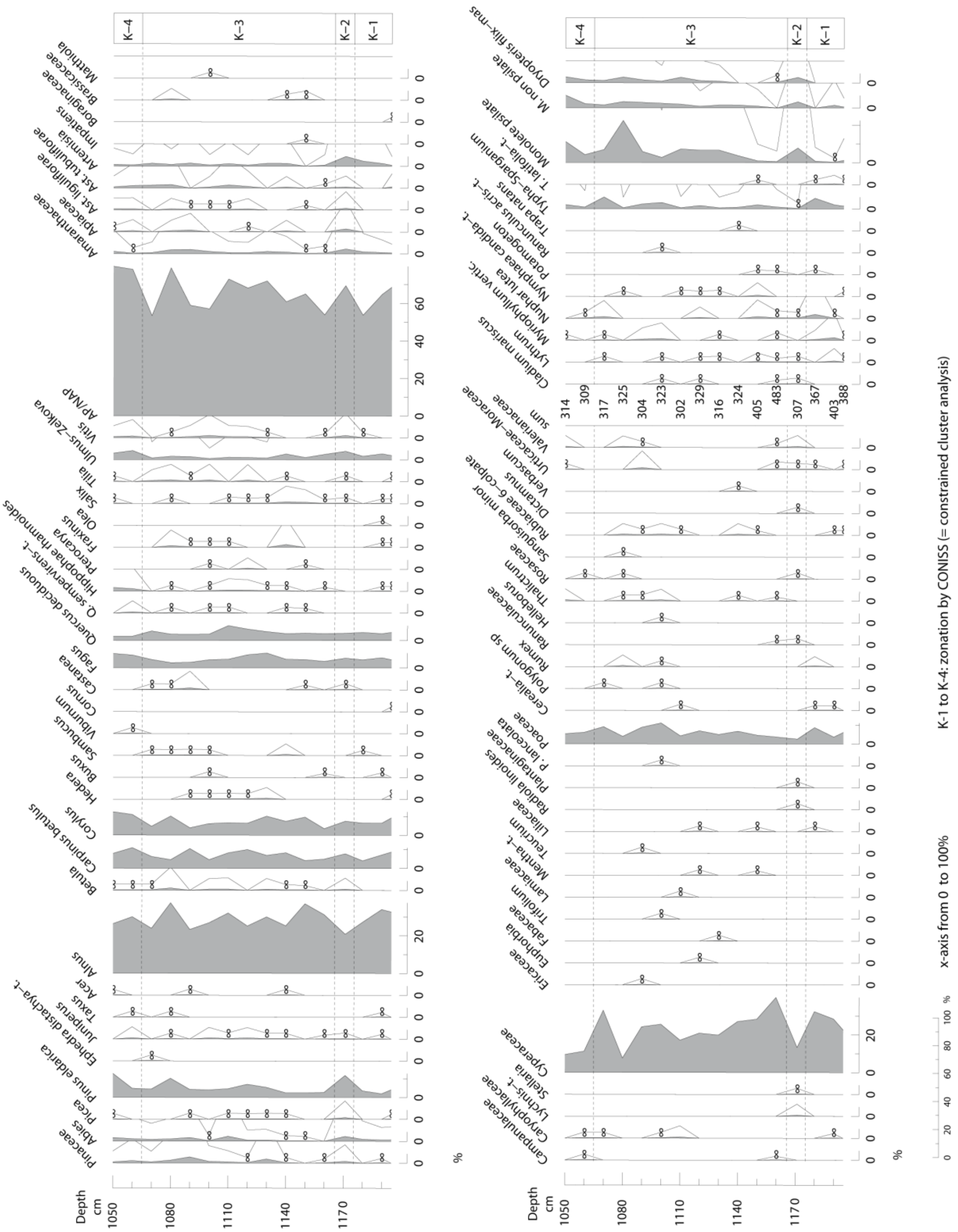

Fig. A.2A: Pollen analysis (part I), plotted with Psimpoll software, version 4.27 (Bennett 2007). The x-axes indicate the percentages of the single species. A zonation applied of the main terrestrial taxa was applied by cluster analysis (CONISS) (analysis and design: S. Leroy, 2017).

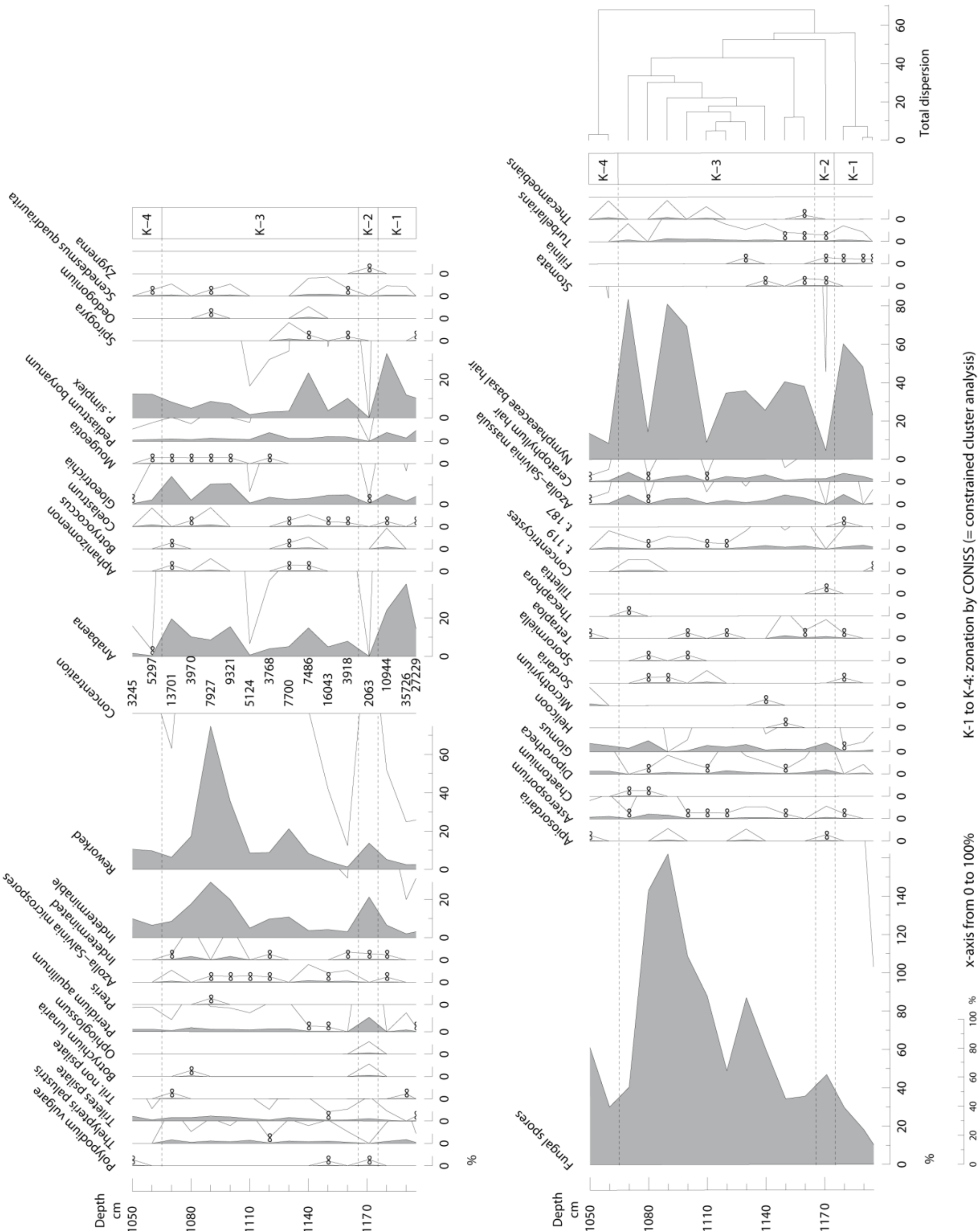

Fig. A.2B: Pollen analysis (part I), plotted with Psimpoll software, version 4.27 (Bennett 2007). The x-axes indicate the percentages of the single species. A zonation applied of the main terrestrial taxa was applied by cluster analysis (CONISS) (analysis and design: S. Leroy, 2017).

Paper contribution

LAERMANNS, H., KELTERBAUM, D., MAY, S.M., ELASHVILI, M., OPITZ, S., HÜLLE, D., RÖLKENS, J., VERHEUL, J., RIEDESEL, S. & BRÜCKNER, H. (2017): Mid- to Late Holocene landscape changes in the Rioni Delta area (Kolkheti lowlands, W Georgia). *Quaternary International*. DOI: 10.1016/j.quaint.2016.12.037

Geländearbeit: 75 %
Erhebung der Daten im Labor: 85 %
Auswertung und Interpretation: 75 %
Verfassen der Publikation: 65 %

LAERMANNS, H., KIRKITADZE, G., MAY, S.M., KELTERBAUM, D., OPITZ, S., HEISTERKAMP, A., BASILAIA, G., ELASHVILI, M. & BRÜCKNER, H. (2017): Bronze Age settlement mounds on the Colchian plain at the Black Sea coast of Georgia – a geoarchaeological perspective. *Geoarchaeology*. DOI:10.1002/gea.21670

Geländearbeit: 90 %
Erhebung der Daten im Labor: 80 %
Auswertung und Interpretation: 70 %
Verfassen der Publikation: 75 %

LAERMANNS, H., MAY, S.M., KELTERBAUM D., KIRKITADZE, G., OPITZ S., NAVROZASHVILI, L., ELASHVILI, M. & BRÜCKNER, H. (*submitted*): Coastal lowland and floodplain evolution along the lower reach of the Supsa River (Western Georgia). *Eiszeitalter und Gegenwart.*

Geländearbeit: 75 %
Erhebung der Daten im Labor: 80 %
Auswertung und Interpretation: 80 %
Verfassen der Publikation: 65 %

Erklärung

Ich versichere, dass ich die von mir vorgelegte Dissertation selbständig angefertigt, die benutzten Quellen und Hilfsmittel vollständig angegeben und die Stellen der Arbeit − einschließlich Tabellen, Karten und Abbildungen −, die anderen Werken im Wortlaut oder dem Sinn nach entnommen sind, in jedem Einzelfall als Entlehnung kenntlich gemacht habe; dass diese Dissertation noch keiner anderen Fakultät oder Universität zur Prüfung vorgelegen hat; dass sie − abgesehen von unten angegebenen Teilpublikationen − noch nicht veröffentlicht worden ist, sowie, dass ich eine solche Veröffentlichung vor Abschluss des Promotionsverfahrens nicht vornehmen werde. Die Bestimmungen der Promotionsordnung sind mir bekannt. Die von mir vorgelegte Dissertation ist von Prof. Dr. H. Brückner betreut worden.

Nachfolgend genannte Teilpublikationen liegen vor:

1. LAERMANNS, H., KELTERBAUM, D., MAY, S.M., ELASHVILI, M., OPITZ, S., HÜLLE, D., RÖLKENS, J., VERHEUL, J., RIEDESEL, S. & BRÜCKNER, H. (2017): Mid- to Late Holocene landscape changes in the Rioni Delta area (Kolkheti lowlands, W Georgia). *Quaternary International, 465: 85-98*. DOI: 10.1016/j.quaint.2016.12.037.
2. LAERMANNS, H., KIRKITADZE, G., MAY, S.M., KELTERBAUM, D., OPITZ, S., HEISTERKAMP, A., BASILAIA, G., ELASHVILI, M. & BRÜCKNER, H. (2017). Bronze Age settlement mounds on the Colchian plain at the Black Sea coast of Georgia – a geoarchaeological perspective. *Geoarchaeology, 33 (4): 453-469*. DOI:10.1002/gea.21670.
3. LAERMANNS, H., MAY, S.M., KELTERBAUM D., KIRKITADZE, G., OPITZ S., NAVROZASHVILI, L., ELASHVILI, M. & BRÜCKNER, H. (*submitted*): Coastal lowland and floodplain evolution along the lower reach of the Supsa River (Western Georgia). *Eiszeitalter und Gegenwart.*

Köln, den _____________

____

(Hannes Laermanns)