Human–environment interactions in the environs of the Late Bronze Age enclosure Corneşti-Iarcuri, western Romania

Doctoral thesis

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Preface

This doctoral thesis is completed at the Institute of Geographical Sciences, in the Department of Earth Sciences of the Freie Universität Berlin and within the doctoral program "Landscape Archaeology and Architecture" of the Berlin Graduate School of Ancient Studies. The research project is affiliated to the subproject A-6-8 "Distribution of ceramics in the large settlement of Corneşti-Iarcuri and its settlement history" within the Research Area A "Spatial Environment and Conceptual Design" of the Excellence Cluster (EXC 264) Topoi – The Formation and Transformation of Space and Knowledge in Ancient Civilizations. Moreover, this project is closely linked to the archaeological research project „Untersuchungen zu den Siedlungsstrukturen und zur Chronologie der spätbronzezeitlichen Befestigung von Corneşti-Iarcuri im rumänischen Banat", performed under the responsibility of Rüdiger Krause (Frankfurt am Main) and Matthias Wemhoff (Berlin) in cooperation with Anthony Harding (Exeter) and Alexandru Szentmiklosi (Timişoara), funded by the German Research Foundation (DFG) (WE4596/5-1). This doctoral thesis is a cumulative dissertation that comprises four peer-review papers. Therefore, it cannot in all cases be prevented that repetitions of texts and figures occur. All papers deal with different aspects of landscape development and human–environment interactions in the environs of Corneşti-Iarcuri. Different approaches from the fields of geoarchaeology and landscape archaeology are applied using methods from geomorphology, morphometry, geochronology, sedimentology and geochemistry and -physics, in combination with the findings achieved from archaeological methods such as excavations and systematic field walking, and complemented with historical data sources.

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Abstract

This doctoral thesis focuses on human–environment interactions in the environs of the Late Bronze Age enclosure Corneşti-Iarcuri – the largest known settlement of European prehistory. Varying interactions among humans and the environment are considered on different spatial and temporal scales aiming to enhance our understanding of their impacts on the Holocene development of the landscape in the surroundings of Corneşti-Iarcuri and in which ways they were involved in the formation of the respective archaeological context. Moreover, this thesis aims at exemplifying how the integration of results from the disciplines of archaeology and geography can be achieved successfully. It is demonstrated that through the application of geoarchaeological and landscape archaeological approaches the point of view of a hitherto purely archaeological research at Corneşti-Iarcuri is extended.

Corneşti-Iarcuri is located in the region of the Romanian Banat at the southern rim of the loess-covered, undulating plains of the Vinga Plain, c. 20 km north of the city of Timişoara. The region is characterized by fertile soils like Chernozems and Phaeozems, intensive arable farming and a moderate temperate climate with mean annual precipitation of 550 mm.

The findings that contribute to enhance our understanding of the impact of past and present-day human–environment interactions on the landscape development and on the formation of the archaeological context in the area of Corneşti-Iarcuri as well as the illustration of the integration of disciplinary results are presented in four case studies. They demonstrate that extensive parts of the high plain are affected by an intensification of wind-driven soil erosion that is induced by plowing of the arable fields and causes the ongoing lowering of the surface since historic times. The surface lowering in combination with plowing has a considerable impact on the preservation of the archaeological record, because the destructive impact of the plow continuously reaches greater depths affecting the systemic context of the cultural remains or may even cause its complete destruction. In specific locations on the high plains hollow ways are identified that mainly formed during the Late Bronze Age as a consequence of trampling along frequently used footpaths, i.e. connecting settlements or leading through the gates of the enclosure. The trampling-induced compaction of the surface leads to reduced infiltration capacity and accelerated surface runoff finally facilitating the formation of path-oriented gullies. As these hollow ways ultimately form part of the archaeological context they provide first evidence of how people moved through the built-up area of Corneşti-Iarcuri and the adjacent landscape and how their regular movement transformed the landscape in the Late Bronze Age. The process of integrating disciplinary results is illustrated applying a conceptual model that also considers possible feedbacks back into the disciplines. The model exemplifies that close cooperation and intellectual exchange among the disciplines of archaeology and geography leads to the development of new hypotheses that are subsequently integrated into more holistic and rigorous interdisciplinary interpretations.

Zusammenfassung

Die vorliegende Dissertation untersucht Mensch-Umwelt-Interaktionen in der Umgebung der spätbronzezeitlichen Befestigungsanlage Corneşti-Iarcuri – der größten Siedlung der Europäischen Prähistorie. Dabei werden verschiedene Arten von Mensch-Umwelt-Interaktionen auf unterschiedlichen räumlichen und zeitlichen Ebenen berücksichtigt. Das Ziel ist die Verbesserung des Verständnisses in, welchem Maße diese Interaktionen Einfluss auf die holozäne Landschaftsentwicklung im Umland von Corneşti-Iarcuri hatten und in welcher Weise sie an der Herausbildung des archäologischen Kontexts beteiligt sind. Darüber hinaus soll eine Möglichkeit zur erfolgreichen Einbindung von archäologischen und geographischen Ergebnissen veranschaulicht werden. Es wird gezeigt, dass die Nutzung geoarchäologischer und landschaftsarchäologischer Ansätze die Sichtweise der bisher rein archäologischen Forschung erweitert.

Corneşti-Iarcuri liegt in der Region des rumänischen Banats, am südlichen Rand der welligen und mit Löss bedeckten Ebenen der Vinga Plain, etwa 20 km nördlich der Stadt Timişoara. Die Region ist durch fruchtbare Böden, wie etwa Chernozeme und Phaeozeme, intensiven Ackerbau und ein gemäßigtes Klima mit mittleren Jahresniederschlägen von 550 mm gekennzeichnet.

Die Erkenntnisse, die einerseits ein verbessertes Verständnis der Einflüsse vergangener und gegenwärtiger Mensch-Umwelt-Interaktionen auf die Entwicklung der Landschaft und die Herausbildung des archäologischen Kontexts im Umland von Corneşti-Iarcuri ermöglichen und andererseits die Einbindung disziplinärer Forschungsergebnisse veranschaulichen, werden in vier Fallstudien präsentiert. Die Untersuchungsergebnisse zeigen, dass weite Teile der Ebene von einer Intensivierung windinduzierter Bodenerosion betroffen sind. Diese wird durch das Pflügen der Ackerflächen verursacht und hat seit historischen Zeiten die kontinuierliche Abtragung der Oberfläche zur Folge. Die Kombination aus Oberflächenabtrag und Pflugtätigkeit hat einen erheblichen Einfluss auf die Erhaltung der archäologischen Zeugnisse, denn die zerstörerische Wirkung des Pflügens erreicht kontinuierlich größere Tiefen und gefährdet daher den systemischen Kontext der kulturellen Überreste; bis hin zu ihrer vollständigen Zerstörung. An einigen Stellen auf den Ebenen konnten Hohlwege identifiziert werden, die vornehmlich während der Spätbronzezeit durch das häufige Beschreiten der Wege, wie etwa zwischen einzelnen Siedlungen oder durch Tore der Befestigungsanlage hindurch, entstanden sind. Die durch das Beschreiten verursachte Kompaktion der Oberfläche führt zu verringerter Infiltrationskapazität und beschleunigtem Oberflächenabfluss und ermöglicht so die Entwicklung von Gullies. Da es sich bei diesen Hohlwegen letztlich um einen Teil des archäologischen Kontexts handelt, geben sie einen ersten Hinweis, wie sich die Menschen innerhalb der bebauten Flächen von Corneşti-Iarcuri und durch die angrenzende Landschaft bewegt haben und in welcher Weise die regelmäßige Nutzung von Wegen in dieser Zeit die Landschaft verändert hat. Der Prozess zur Einbildung disziplinärer Ergebnisse wird anhand eines konzeptionellen Modells veranschaulicht, dass auch mögliche Rückkopplungen zurück in die Disziplinen berücksichtigt. Das Modell zeigt, dass die enge Kooperation und der intellektuelle Austausch zwischen Archäologie und Geographie zur Entwicklung neuer Hypothesen führen, die nachfolgend in holistischeren und präziseren interdisziplinären Interpretationen münden.

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1. Introduction

The Late Bronze Age enclosure Corneşti-Iarcuri is the largest known settlement of European prehistory and, to date, the largest ground monument in Europe. The enclosure consists of four earth-filled wooden ramparts that have a total length of more than 33 km and surround an area of c. 17.6 km² (Szentmiklosi et al., 2011; Heeb et al., 2015). Corneşti-Iarcuri is located at the eastern edge of the Great Hungarian Plain in western Romania, c. 20 km north of the modern city of Timişoara. It was erected in the landscape of the southern Vinga Plain that is characterized by loess-covered, undulating plains and fertile Chernozem and Phaeozem soils, which are intensively used for arable farming. The present-day climate is moderate temperate with mean annual precipitation of 550 mm (Grigoraş et al., 2004; Sherwood, 2013; cf. chapter 3). The ongoing investigation of Corneşti-Iarcuri with modern archaeological methods provides new insights regarding the construction of the ramparts, their dimensions and chronology as well as regarding the settlement history in the built-up area within the ramparts (Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2011; Heeb et al., 2012; Heeb et al., 2014; Heeb et al., 2015; Balarie et al., 2016; cf. chapter 3). While the archaeological data basis for Corneşti-Iarcuri grows since 2007, studies applying geoarchaeological or landscape archaeological approaches and aim to investigate the Holocene human–environment interactions are scarce. To date, for the wider surroundings of Corneşti-Iarcuri only two studies, one geoarchaeological (Sherwood, 2013) and one landscape archaeological (Meyer et al., 2016), have been conducted (cf. chapter 2).

The exemplified need for research in the field of human–environment interactions for the environs of Corneşti-Iarcuri is taken into account by presenting four studies that apply geoarchaeological and landscape archaeological approaches. The superordinate goals of this thesis are to close the gap of

i) how past and present-day human–environment interactions have shaped the landscape (considered in chapter 5.1.-5.3.),

ii) in which ways past and present-day human–environment interactions were involved in the formation of the archaeological context (considered in chapter 5.1.-5.3.) and

iii) how – in an interdisciplinary research context – the integration of results from the disciplines of archaeology and geography can be achieved successfully (considered in chapter 5.4.).

The presented geoarchaeological and landscape archaeological studies are among the first ones for the environs of Corneşti-Iarcuri extending the point of view of a hitherto purely archaeological research.

In general, the study of human–environment interactions often plays a major role in geoarchaeological and landscape archaeological approaches as it provides the opportunity to enhance the understanding of the development of landscapes and societies (cf. chapter 2). However, due to substantial differences among the approaches of geoarchaeology and landscape archaeology (French, 2003; Legler, 2012; Meier, 2012; Engel and Brückner, 2014), e.g. the understanding of the term landscape, it is necessary to discuss both approaches in detail and to set the presented studies into this context.

Varying aspects of human–environment interactions on different spatial and temporal scales in the surroundings of the archaeological site Corneşti-Iarcuri are considered by applying either a geoarchaeological or a landscape archaeological approach. The presented cumulative doctoral thesis contains the following four case studies (chapter 5):

Estimation of wind-driven soil erosion of a loess-like sediment and its implications for the occurrence of archaeological surface and subsurface finds – An example from the environs of Corneşti-Iarcuri, western Romania (chapter 5.1.).
Nykamp, M., Knitter, D., Timár, G., Krause, J., Heeb, B.S., Szentmiklosi, A., Schütt, B., 2017b. Journal of Archaeological Science: Reports 12, 601-612. *Own contribution: 90 %.*

This study aims i) to record the landscape development and estimate the soil erosion-induced lowering of the surface in historic times, ii) to deduce the minimum penetration depth required by archaeological structures to ensure their preservation and iii) to discuss the combined impact of soil erosion and plowing on the preservation of cultural remains.

Linking hydrological anomalies to archaeological evidences – identification of Late Bronze Age pathways at the fortification enclosure Iarcuri in western Romania (chapter 5.2.).
Nykamp, M., Heeb, B.S., Knitter, D., Krause, J., Krause, R., Szentmiklosi, A., Schütt, B., 2015. eTopoi. Journal for Ancient Studies, Special Volume 4, 77-92. *Own contribution: 75 %.*

This study aims i) to relate morpho-hydrological relief anomalies with archaeological findings, ii) to uncover their spatial concurrence and iii) to discuss the Late Bronze Age formation of the relief anomalies as hollow ways due to reduced infiltration capacity and accelerated surface runoff as a consequence of the repeated passage of humans causing compaction.

Holocene sediment dynamics in the environs of the fortification enclosure of Corneşti-Iarcuri in the Romanian Banat (chapter 5.3.).
Nykamp, M., Hoelzmann, P., Heeb, B.S., Szentmiklosi, A., Schütt B., 2016. Quaternary International 415, 190-203. *Own contribution: 85 %.*

This study aims i) to identify periods of spatio-temporal variations of Holocene morphodynamics in the built-up area of Corneşti-Iarcuri, ii) to combine the geoscientific results with archaeological evidences of the development of the Copper Age to Late Bronze Age settlement landscape and iii) to discuss the kind and degree of Copper Age to Late Bronze Age human impact on the development of the landscape.

A landscape archaeological approach to link human activities to past landscape change in the built-up area of the Late Bronze Age enclosure Corneşti-Iarcuri, western Romania (chapter 5.4.).
Nykamp, M., Knitter, D., Heeb, B.S., Szentmiklosi, A., Krause, R., Schütt, B., 2017a. eTopoi. Journal for Ancient Studies 6, 1-15. *Own contribution: 80 %.*

This study aims i) to illustrate the process of integration of disciplinary results using a conceptual model, ii) to show how integration can lead to a more holistic and rigorous interdisciplinary interpretation and iii) to emphasize the importance of close cooperation and intellectual exchange among the disciplines of archaeology and geography, the joint development of new hypotheses and their interdisciplinary interpretation.

The results of the four case studies are achieved applying a wide variety of geoscientific methods on multi-proxy data sets (chapter 4) and using well-established concepts from the field of physical geography. The presented findings contribute to enhance our general understanding of Corneşti-Iarcuri; especially the understanding of past and present-day human–environment interactions regarding their impacts on the Holocene development of the landscape and their influences on the formation of the archaeological context is improved and the successful integration of disciplinary results is exemplified. In particular, the findings provide an explanation for different archaeological observations (cf. chapter 5.1.) such as the blurring of structures in the magnetograms (Heeb et al., 2015) or the ongoing destruction of the archaeological remains (Szentmiklosi et al., 2011) and yield first evidence of how Late Bronze Age people moved through the enclosed area and the adjacent landscape and how their regular movement transformed the landscape at this time (cf. chapter 5.2.-5.3.). Moreover, the process of intellectual exchange among the disciplines of archaeology and geography is illustrated with a conceptual model (cf. chapter 5.4.) that allows the integration of disciplinary results, the development of new hypotheses and the successful achievement of interdisciplinary interpretations.

2. State of the art

2.1. Human–environment interactions and the approaches of geoarchaeology and landscape archaeology

The research studies that are published in four peer-reviewed journal articles (Nykamp et al., 2015; Nykamp et al., 2016; Nykamp et al., 2017a; Nykamp et al., 2017b; chapter 5) and joined in this cumulative doctoral thesis were conducted in the tension field of *human–environment interactions*. The studies apply geoscientific methods (chapter 4) and adopt either of the approaches of *geoarchaeology* or *landscape archaeology*.

The complex and reciprocal interactions between the natural environment and the humans living in it have a major influence on the development of landscapes and societies (Moran and Brondízio, 2013; Ostrom, 2013; Goman, 2014). Salisbury and Bácsmegi (2013) state that "[…] humans and environments interact, and they do so in a dynamic and reciprocal fashion. Everything people do affects the environment, whilst everything the environment "does" affects people, and this is a continuous process of co-adaption, or mutual change and adjustment" (Salisbury and Bácsmegi, 2013, p. 145).

Human–environment interactions are frequently a research object of studies, which are conducted – among other fields of research – within the framework of geoarchaeological (Gladfelter, 1977; Butzer, 1982; French, 2003; Fuchs and Zöller, 2006; Goldberg and Macphail, 2006; Beach et al., 2008; Bebermeier and Schütt, 2011; Wilson, 2011; Diskin et al., 2013; Engel and Brückner, 2014; Kluiving, 2015; Kluiving et al., 2015) and landscape archaeological approaches (Gramsch, 2003; Wilkinson, 2003; Zimmermann et al., 2004; Zimmermann et al., 2009; Hu, 2011; Kluiving and Guttmann-Bond, 2012; Kluiving et al., 2012; Legler, 2012; Bebermeier et al., 2013; Zimmermann, 2014; Kluiving, 2015; Knitter et al., 2015). The eligibility of geoarchaeological and landscape archaeological approaches to reconstruct past human–environment interactions is rather high. Lohmann (2009) even uses the terms geoarchaeology and landscape archaeology synonymously and emphasizes their strong connection to the term human–environment interactions. However, the understanding of these approaches, their definitions and practical applications as well as the expected outcomes differ significantly (Rapp and Hill, 2006; Kluiving et al., 2012; Meier, 2012). Moreover, the fact that these approaches are often used in various disciplines of natural and social sciences and humanities (Pollard, 1999; Kluiving et al., 2012) further complicates the task of giving clear definitions.

It is beyond the scope of this chapter to give a conceptual and textual in-depth discussion of these approaches and their disciplinary developments, however, it is necessary to define the basic terminology, introduce the applied approaches and set the context for the case studies (chapter 6).

An uniform definition of geoarchaeology does not exist; however, the differences among the individual definitions are small (Gerlach, 2003; Fuchs and Zöller, 2006). Rapp and Hill (2006) give a rather broad definition of geoarchaeology that is generally widely accepted (Fuchs and Zöller, 2006). They state that "[…] *geoarchaeology* refers to the application of any earth-science concept, technique, or knowledge base to the study of artifacts and processes involved in the creation of the archaeological record" (Rapp and Hill, 2006, p. 1, italic in the original).

Other scholars put emphasize on the participating disciplines such as geomorphology, sedimentology, pedology and geoecology, as being particularly essential for geoarchaeological research (Gladfelter, 1977; Pollard, 1999; French, 2003; Gerlach, 2003; Fuchs and Zöller, 2006; Beach at al., 2008).

Gladfelter (1977), for example, states that "*the contribution[s] of the earth sciences, particularly geomorphology and sedimentary petrography, to the interpretation and environmental reconstruction of archaeological contexts is called geoarchaeology*" (Gladfelter, 1977, p. 519, italic in the original). French (2003) is even more explicit, stating that "geoarchaeology is the combined study of archaeological and geomorphological records and the recognition of how natural and human-induced processes alter landscapes. The main aim of geoarchaeology is to construct integrated models of human-environmental systems and to interrogate the nature, sequence and causes of human versus natural impacts on the landscape" (French, 2003, p. 3). Thus, on the one hand French (2003), just like Gladfelter (1977), highlights the important role of geomorphology in geoarchaeological studies. On the other hand, French (2003) emphasizes human–environment interactions as being the main aim of geoarchaeological research. Fuchs and Zöller (2006) and Bebermeier and Schütt (2011) argue, in contrast to e.g. French (2003) or Rapp and Hill (2006) who associate geoarchaeology with the discipline of archaeology, that geoarchaeology is deeply rooted in geomorphology. Following the definition of applied geomorphology by Ahnert (2003) its main aim is to study geomorphic forms and formation processes that are created or triggered by humans ("[…] Vom Menschen geschaffene oder beeinflusste Formen und Formungsvorgänge" (Ahnert, 2003, p.421)). Exactly this issue, the study of the human impact on otherwise natural geomorphic systems, is one of the core competences of geomorphology (Ahnert, 2003).

An important point is missing in the aforementioned definitions of geoarchaeology. In their definition of geoarchaeology Engel and Brückner (2014) include the value of studying diagnostic cultural findings from Quaternary stratigraphies as being often an even more precise age constraint than any radiometric dating technique. Accordingly, for them *"geoarchaeology is the science that studies geo-bio-archives in an archaeological context by also considering historical and archaeological data sources in its syntheses. It mainly applies geosciences tools in order to reconstruct the evolution and use of former landscapes and ecosystems, with special regard to the interactions between humans and their environment"* (Engel and Brückner, 2014, p. 1, italic in the original).

Geoarchaeology is understood in this thesis as the application of earth-science methods and concepts in combination with historical and archaeological records to study the development of landscapes aiming at uncovering past and present-day natural and human-induced processes that are involved in the formation of the archaeological context. Geomorphology plays a prominent role in geoarchaeology, not only because it provides valuable methodological toolkits and theoretical concepts to the study of human–environment interactions, but also because the study of the human impact on otherwise natural geomorphic systems is one of its core competences (adapted according to Gladfelter, 1977;

Ahnert, 2003; French, 2003; Fuchs and Zöller, 2006; Rapp and Hill, 2006; Bebermeier and Schütt, 2011; Engel and Brückner, 2014).

Just as in the case of geoarchaeology, many different definitions of landscape archaeology are used in the literature. Wilkinson (2003) uses the working definition: "Landscape archaeology is concerned with the analysis of the cultural landscape through time. This entails the recording and dating of cultural factors that remain as well as their interpretation in terms of social, economic, and environmental factors. It is assumed that the "natural landscape" has been reorganized either consciously or subconsciously for a variety of religious, economic, social, political, environmental, or symbolic purposes" (Wilkinson, 2003, pp. 3-4). This definition focuses on the diachronic study of cultural remains and their interpretation regarding social, economic and environmental factors. Also, other societal factors such as religious, political and symbolic purposes as reasons for the reorganization of the landscape are included.

A definition of landscape archaeology that not only considers the interactions between humans and their environment, but also includes human–human interactions, is given by Kluiving and Guttmann-Bond (2012). They define landscape archaeology as "[…] the science of material traces of past peoples within the context of their interactions with the wider natural and social environment they inhabited" (Kluiving and Guttmann-Bond, 2012, p. 15). Regarding its focus, Kluiving et al. (2012) emphasize that "[…] the focus of landscape archaeology should be on the reconstruction of spatial environments and their shaping by humans as they adapt to the natural environment during settlement. This includes analyzing the interrelationships between natural conditions and modes of adaption with a focus on the formation of space (Schütt and Meyer, 2011), including the social construction of space (Meier, [in press] 2012)" (Kluiving et al., 2012, p. 5, citations in the original).

The following definition by David and Thomas (2008) more explicitly puts the people to the focus of landscape archaeology. "Landscape archaeology is an archaeology of how people visualized the world and how they engaged with one another across space, how they chose to manipulate their surroundings or how they were subliminally affected to do things by way of their locational circumstances. It concerns the intentional and the unintentional, the physical and the spiritual, human agency and the subliminal" (David and Thomas, 2008, p. 38).

Landscape archaeology is understood in this thesis as the study of cultural remains and their interpretation regarding economic, socio-cultural and environmental reasons that have caused the intentional or unintentional modification of the landscape. Societal developments and human–environment interactions are equally considered to reconstruct the spatial environment including the formation of space and its social construction (adapted according to Wilkinson, 2003; David and Thomas, 2008; Schütt and Meyer, 2011; Kluiving and Guttmann-Bond, 2012; Kluiving et al., 2012; Meier, 2012).

The discussion of the aforementioned definitions clearly shows that, indeed, geoarchaeology and landscape archaeology have much in common. Both approaches frequently aim to answer questions regarding human–environment interactions and include the cooperation of earth-sciences and archaeology. However, a synonymous use (Lohmann, 2009) should be avoided, because of substantial differences among both approaches. One of these differences is the understanding of the term landscape and the role humans play in it. In the context of geoarchaeology the understanding of landscape is based upon the dichotomy of humans and nature into two entities. Humans are merely seen as objects; as another factor of the investigated system. These two entities reciprocally influence each other and their mutual impacts can be quantified using scientific methods (Ahnert, 2003; French, 2003; Engel and Brückner, 2014). The understanding of landscape in the context of landscape archaeology is fundamentally different. In this context landscape is not only a physical phenomenon that is modified by human intervention for various economic and socio-cultural purposes, but also the social construction of space. Humans are not merely seen as a factor of the investigated system, but as ideational actors that not simply react to environmental conditions. Thus, the perception of the people that inhabited a landscape must be considered and as a result its characteristics are less quantifiable. Moreover, due to the task of investigating how landscape was constructed by the inhabiting people landscape archaeology allows to assess which particular environmental factors were considered important (Anschuetz et al., 2001; Gramsch, 2003; Legler, 2012; Meier, 2012; Knitter et al., 2015; Popa and Knitter, 2016). Anschuetz et al. (2001) uses four interrelated premises to define landscape in the context of landscape archaeology: first, landscapes and the natural environment are not synonymous; landscapes are the synthetic product of interactions among people and the natural environment, structured and organized by cultural systems. Second, landscapes are cultural products; physical spaces are transformed into meaningful places by the daily activities, beliefs and values of communities. Third, landscapes are the setting for all activities of a community; they are not only constructs of human populations, but they are the environment in which these populations survive and sustain themselves. Fourth, landscapes are dynamic constructions; each community and each generation assigns its own cognitive map to the human world of interwoven morphology, arrangement, and coherent meaning (Anschuetz et al., 2001).

Fundamental to the understanding of geoarchaeology and landscape archaeology is the understanding of the term landscape and the role humans play in it. The term landscape has two primary meanings that are relevant for this thesis: first, landscape is understood as a geographically delimited area whose natural factors can be investigated using scientific methods. This implies the division between humans as the acting characters and the nature as the object into two entities, who interact and thus, reciprocally influence each other. Second, landscape is understood as a social construct of an area which owes its existence to the human assignment of meaning and which needs to be investigated hermeneutically. In this context humans create space themselves and thus, they are part of their surroundings (Kluiving et al., 2012; Legler, 2012; Meier, 2012; Knitter et al., 2015). Combining these two meanings, landscape should be understood as a physical phenomenon that is modified by economical and socio-cultural utilization, which causes its constant transformation and which is followed by a changing perception and the assignment of a new meaning. It is neither only an economically developed natural environment nor only a socially constructed cultural environment (Gramsch, 2003; Legler, 2012). In its third meaning landscape is used as an aesthetic term for a sensually perceived detail of a territory by one or more observers (Legler, 2012). However, this third meaning is not considered in this thesis.

Another difference is that geoarchaeology is mostly regarded to be multidisciplinary (French, 2003; Gerlach, 2003; Fuchs and Zöller, 2006; Goldberg and Macphail, 2006; Diskin et al., 2013); even though some scholars, e.g. Wilson (2011) or Engel and Brückner (2014), underline its interdisciplinary character. Thus, the disciplinary exchange usually happens on the results level (Meier, 2012). Landscape archaeology, by contrast, is regarded to be purely interdisciplinary (Kluiving and Guttmann-Bond, 2012; Kluiving et al., 2012; Bebermeier et al., 2013), thus, the disciplinary exchange already starts at the very beginning, i.e. the level of jointly negotiated questions and jointly designed close cooperation and also considers the presuppositions of the participating disciplines (Meier, 2012; Knitter et al., 2015). Moreover, the term landscape by itself is transdisciplinary and thus offers more than the opportunity to simply combine disciplinary results to achieve a multidisciplinary interpretation; it offers the possibility to perform interdisciplinary research (Meier and Tillessen, 2011; Legler, 2012; Meier, 2012). Kluiving et al. (2012), in this regard, argue that landscape archaeology can be considered as a "new interdisciplinary discipline" (Kluiving et al., 2012, p. 5) that formed through multidisciplinary research and Wilkinson (2003) concludes that "[...] one major advantage of landscape archaeology is that it does and should contain both cultural and physical components. Thus it should truly be an integrative discipline" (Wilkinson, 2003, p. 10).

2.2. Prehistoric and historic human–environment interactions in the area of the eastern Great Hungarian Plain

Apart from one geoarchaeological case study (Fig. 1) in the environs of Corneşti-Iarcuri (Sherwood, 2013) geoarchaeological research has not been conducted so far in the wider surroundings of Corneşti-Iarcuri. In her study Sherwood (2013) uses soil augerings and macroscopic soil descriptions to provide new possibilities to interpret the anomalies of the magnetic prospections from the built-up area of Corneşti-Iarcuri to identify different types of archaeological features, e.g. hearths or buildings. According to her soil descriptions Calcic Chernozems prevail in the study area showing calcrete horizons of varying development stages at depths ranging between c. 50 and 110 cm. The secondary precipitated carbonates have a low magnetic susceptibility and thus, their subsurface distribution, surface proximity and development stages affect the results of the magnetic prospections that were conducted with a cesium-magnetometer (Sherwood, 2013). Generally, the magnetic anomalies are interpreted as follows: high contrast anomalies are regarded to represent burnt archaeological deposits while areas where archaeological deposits are thought to be absent are characterized by low contrast anomalies. The results of her study show that besides this general interpretation of the magnetometer results other explanations for high and low contrast anomalies must be considered in areas with prevailing Calcic Chernozems. High contrast anomalies can be the results of e.g. linear erosion, which have cut into the calcareous horizons and the subsequent deposition of decalcified material from the surroundings backfilling the erosion form. In other cases archaeological deposits can produce low contrast anomalies due to the absence of burning (Sherwood, 2013).

Beyond the geoarchaeological study of Sherwood (2013) Meyer et al. (2016) most recently published first results of their landscape archaeological study on ceramic characterization in the built-up area of Corneşti-Iarcuri and within its regional surroundings (Fig. 1). The study applies archaeometric methods, e.g. analyses of chemical and physical ceramic properties, on a local and on a regional scale. On the local scale the intra-site ceramic characteristics, encompassing the two settlement phases from the Middle and Late Bronze Age, allow the investigation of production continuity and the distribution of products from different workshops within the site. The regional approach allows to identify the type and intensity of pottery exchange in the wider surrounding of Corneşti-Iarcuri (Meyer et al., 2016). The results of Middle and Late Bronze Age ceramic analyses show that pottery in the built-up area of Corneşti-Iarcuri was made from non-calcareous clays that were colored by iron compounds and fired at 700 to 800 °C using the same pottery manufacturing technology during both periods. The variety of used clays point to the presence of many local workshops during both periods, too. However, the significant differences among the characteristics of the raw materials used in the Middle Bronze Age compared to those used in the Late Bronze Age indicate no on-site continuity in the use of raw materials (Meyer et al., 2016). The results of the regional analyses of Late Bronze Age ceramics show that the majority of the material found at each site represents local products that were not exchanged, while regionally exchanged products are characterized by the same material that was found at each of the studied sites (Meyer et al., 2016).

In the area of the eastern Great Hungarian Plain a wide variety of studies (Fig. 1) dealing with different aspects of human–environment interactions have been conducted applying approaches from the fields of geoarchaeology or landscape archaeology, respectively. The time periods covered in these studies range from the Early Neolithic to the most recent historic past, whereby only the studies covering prehistoric periods use geoarchaeological or landscape archaeological approaches. The topics covered in these studies include the human impact on the Holocene vegetation development (Gardner, 2002; Feurdean et al., 2012; Magyari et al., 2012; Salisbury et al., 2013), the Neolithic and Copper Age animal use (Hoekman-Sites and Giblin, 2012), the reconstruction of the palaeohydrology and its implications on the distribution of Neolithic to Bronze Age settlements (Gyucha et al., 2011; Gyucha et al., 2013) and the localization of activity zones within Neolithic and Copper Age settlements (Salisbury, 2013) as well as the effects of the large-scale 19th century river regulation works on the alteration of channel morphology and flood occurrence (Sipos et al., 2007; Kiss et al., 2008; Kiss et al., 2011).

Feurdean et al. (2012) compile sedimentary charcoal records from eleven sites in Hungary and Romania (Fig. 1) to document the trends and pattern of biomass burning in the Carpathian region during the last 15,000 years. Four distinct temporal phases have been distinguished: 1) the end of the glacial and late glacial period (15,000-11,700 cal. BP) with low burning of biomass, 2) the Early Holocene period (11,700-8000 cal. BP) with the highest burning of biomass and regionally homogeneous trends in fire activity, 3) the Mid to Late Holocene period (8000-1000 cal. BP) with generally low burning of biomass and regionally heterogeneous trends in fire activity, and 4) the period of the last 1000 years with a marked increase of biomass burning (Feurdean et al., 2012). Late glacial and Holocene climate conditions are, due to their effects on vegetation productivity and fuel availability, most probable the main driving force behind the trends in fire activity in the studied region. However, with the beginning of the Neolithic anthropogenic biomass burning becomes evident and from c. 5500 cal. BP the human impact in the lowland areas markedly altered the natural trends of fire activity leading to the regionally heterogeneous trend during the Mid to Late Holocene period (Feurdean et al., 2012).

The study of Gardner (2002) combines palynology and charcoal analyses with geophysical and -chemical sediment analyses to infer the Holocene vegetation development and the human impact on it for the northeastern part of the Great Hungarian Plain, northeast Hungary (Fig. 1). The results show that the vegetation at the beginning of the Holocene rapidly developed from a parkland environment dominated by coniferous and broadleaved taxa to a deciduous broadleaved forest. From c. 8200 cal. BP onwards fluctuations of the forest composition occurred at short timescales, which are attributed to Neolithic and Copper Age forest use, such as coppicing or pollarding (Gardner, 2002). After c. 5200 cal. BP the controlled forest use presumably ceased and the forest recovery continued until c. 3700 cal. BP. Major forest clearings occurred only after c. 2000 cal. BP accompanied by the spread of open-ground herbaceous vegetation. However, the results of the geophysical and -chemical sediment analyses indicate landscape stability since the beginning of the Holocene suggesting that the vegetation changes in the catchment were of insufficient intensity to initiate soil erosion (Gardner, 2002).

While studying the same part of the eastern Great Hungarian Plain (Fig. 1) as Gardner (2002) Magyari et al. (2012) temporally focus on the Neolithic to Early Copper Age human impact on the vegetation and its implications for subsidence practices disproving the hypothesis of Willis and Bennett (1994), who state that there was little human impact by farmers on the environment of southeast Europe until the Bronze Age. Their interdisciplinary study integrates archaeology and palaeobotany combining results of pollen analyses and well-dated surface artifact scatters obtained by systematic field walking (Magyari et al., 2012). For the Early Neolithic small-scale agriculture is documented and signs of an expanding scale of mixed farming is evident during the Middle Neolithic. Strong evidence for extensive landscape alterations and enhanced pasturing exist for the Late Neolithic and Early Copper Age (Magyari et al., 2012). The Middle Neolithic and the Early Copper Age occupation phases match well among the complementing data sets from pollen analyses and archaeological artifact scatters. However, considerable mismatches appear for the Early and Late Neolithic occupation phases where pollen data point to episodic woodland clearances, but the archaeological record so far provides no evidence for occupation. Suggestions to explain the discrepancy among the two records include the burial of hitherto undetected sites or the Late Mesolithic human impact on the vegetation for the Early Neolithic case and the seasonal use of the meadows by people living in dispersed homesteads or in a hitherto undetected medium-sized site for the Late Neolithic case (Magyari et al., 2012). The comparison with other well-dated pollen records from eastern Hungary shows several similarities regarding the practiced land use. While the evidence for Early to Middle Neolithic coppicing is not very strong the evidence for Late Neolithic pastoralism and associated woodland clearance is more intensive (Magyari et al., 2012).

Further south than the studies of Gardner (2002) and Magyari et al. (2012), in the area of the Körös Basin (Fig. 1; Fig. 3), north of the Mureş alluvial fan, Salisbury et al. (2013) applies pollen analyses to reconstruct the local vegetation history and the human impact on it since the Neolithic. In agreement with other studies (Gardner, 2002; Magyari et al., 2012) their results show that the human impact on the local vegetation, which consisted of a patchy wooded steppe until the Neolithic, is evident including proofs for cultivated plants and forest clearance (Salisbury et al., 2013). The human impact on the local vegetation increased throughout the Late Neolithic and Copper Age culminating in the Late Copper Age and Early Bronze Age when extensive deforestation occurred (Salisbury et al., 2013).

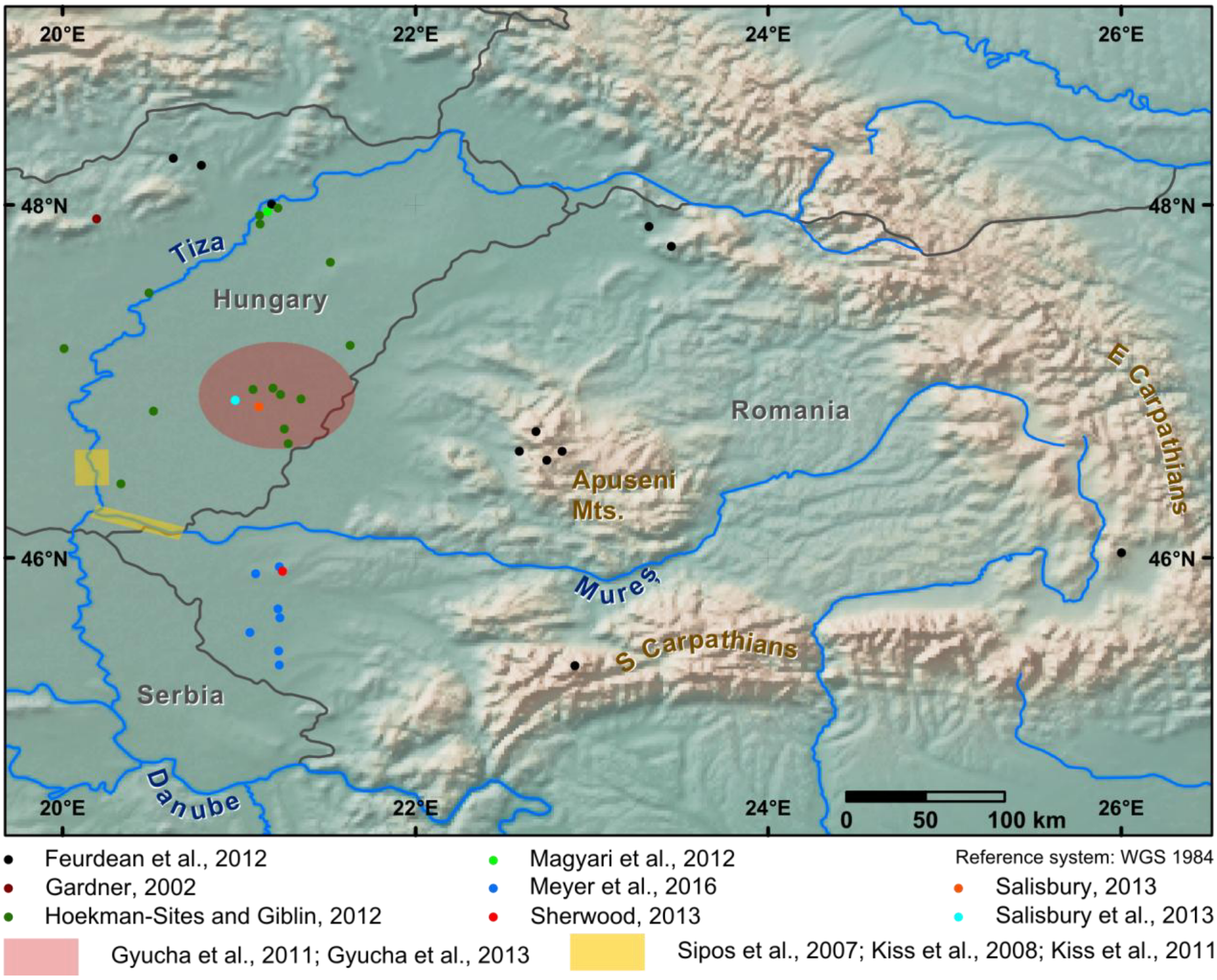

Fig. 1. Study site locations of the case studies cited in the text (vector line and raster data from Natural Earth Data, 2014).

The major shifts of settlement patterns, subsidence strategies, ceramic style, trade patterns and mortuary practice that occurred during the Late Neolithic and the Copper Age (5000-2700 cal. BCE) in the area of the Great Hungarian Plain (Fig. 1) is addressed in the study of Hoekman-Sites and Giblin (2012) applying isotope and pottery-based residue analyses combined with the evaluation of previously published faunal data. The study temporally focuses on the transition of the Late Neolithic to the Early Copper Age at c. 4500 cal. BCE and spatially covers the area of east Hungary aiming to answer the questions whether the herding mobility increased and if products of domesticated animals became more important. Both questions relate to the subsidence strategy of the local people and can provide explanations for the shift from the large nucleated tell settlements of the Late Neolithic to the more dispersed and ephemeral flat sites of the Copper Age (Hoekman-Sites and Giblin, 2012). The presented strontium isotopes show no larger shifts in herding practice at the beginning of the Copper Age and no increased herd mobility, thus the hypothesis of settlement dispersal due to increased herd mobility is rebutted. Carbon and nitrogen isotopes as well as the results of the residue analyses of pottery indicate that the diet was primarily based on terrestrial plants and animals and that animal protein was an important component of the diet from the Late Neolithic onwards (Hoekman-Sites and Giblin, 2012). The residue analyses of pottery from the Middle and Late Copper Age show more animal fats compared to preceding periods indicating an increased use of animal products in the Middle Copper Age. The presented results demonstrate that the significant cultural shifts at the beginning of the Copper Age in the eastern Great Hungarian Plain cannot be fully explained by an increased reliance on domesticated animals (Hoekman-Sites and Giblin, 2012).

The studies of Gyucha et al. (2011) and Gyucha et al. (2013) also aim to explain the changes in settlement patterns that occurred in the area of the Körös Basin (Fig. 1; Fig. 3) between the Neolithic and the Bronze Age. The studies link settlement distributions with hydrologic data prior to the river regulation works that were carried out since the second half of the 18th and intensified in the early 19th century to clarify whether the distribution of the settlements and major shifts in settlement patterns can be explained by a combination of climatic, hydrological and subsistence factors (Gyucha et al., 2011; Gyucha et al., 2013). The data set overlay of maps from the Military Survey of the Habsburg Empire (1764-1915), modern topographic maps, aerial photographs, soil maps and the extensive archaeological survey (Hungarian Archaeological Topography) reveals that the water courses in the Körös Basin were generally in the same position between c. 5000 cal. BCE and the period immediately prior to the river regulation works. They argue that the maps from the First and Second Military Survey of the Habsburg Empire therefore provide a reliable picture of the prehistoric hydrology (Gyucha et al., 2011). The results of Gyucha et al. (2013) suggest that the changes in settlement patterns and organization that occurred between the Neolithic and the Bronze Age in the Körös Basin were determined by a combination of environmental factors, social concerns and cultural preferences. On the regional scale the distribution of the settlements was strongly influenced by hydrological features such as the location of the water courses. However, hydrological changes were not strong enough to explain the changes of the settlement patterns (Gyucha et al., 2013).

Salisbury (2013) applies multi-element sediment geochemistry as an intra-site prospection method at small, flat Late Neolithic and Early Copper Age settlements in the Körös Basin (Fig. 1; Fig. 3) to study the spatial organization of settlements. The study aims at reconstructing the internal spatial organization at small farmsteads and comparing these farmsteads diachronically. The results reveal that the different activities within small settlements, e.g. cooking or food preparation, the use of a midden or the trampling around a house, cause particular signatures that can be successfully analyzed applying multi-element geochemistry and multivariate statistics (Salisbury, 2013). Based on his results Salisbury (2013) assumes long-term cultural traditions in the location of activity zones within small Late Neolithic and Early Copper Age farmsteads and concludes that the continuity in the location of activity zones provided a kind of safety net in times of significant social change that occurred at the transition from the Late Neolithic to the Early Copper Age (Salisbury, 2013).

Studies focusing on human–environment interactions in the historic past in the area of the Great Hungarian Plain (Fig. 1) often deal with the river regulation works that were intensively carried out from the beginning of the 19th century. The regional hydrology is strongly affected by the large-scale human impact causing the alteration of the channel morphology, accelerated overbank accumulation and an increased frequency and magnitude of floods (Sipos et al., 2007; Kiss et al., 2008; Kiss et al., 2011). Prior to the river regulation works the course of the Tiza river was highly sinuous, but during the 19th century c. half of its course was altered by meander cutoffs. The meander cutoffs caused a reduction of total channel length and sinuosity of c. 35 %, while the length of the straight channel sections and the channel slope doubled. As a consequence the incision of the Tiza totals up to 3.8 m in the time period between c. 1890 and 1929 resulting in a better flood conductivity (Sipos et al., 2007; Kiss et al., 2008). Besides the planimetric changes of the channel morphology also the channel width decreased and channel depth increased due to the regulation works (Kiss et al., 2008). In order to prevent the channels from lateral migration the river management of the 1920s carried out bank stabilization measures including the confinement of the up to 100 km wide floodplains by artificial levees. These floodplains, artificially confined to c. 0.5-4 km, experience increased overbank sedimentation that caused a substantial rise in floodplain levels during the last century and increased flood hazards (Kiss et al., 2008; Kiss et al., 2011).

3. Study site

The archaeological site Corneşti-Iarcuri (Fig. 2) is located at the eastern edge of the Great Hungarian Plain, in the area of the Romanian Banat, c. 20 km north of the city of Timişoara (Fig. 3). With its four earth-filled wooden ramparts that enclose an area of 17.6 km² Corneşti-Iarcuri is the largest known prehistoric enclosure in Europe (Szentmiklosi et al., 2011; Heeb et al., 2015).

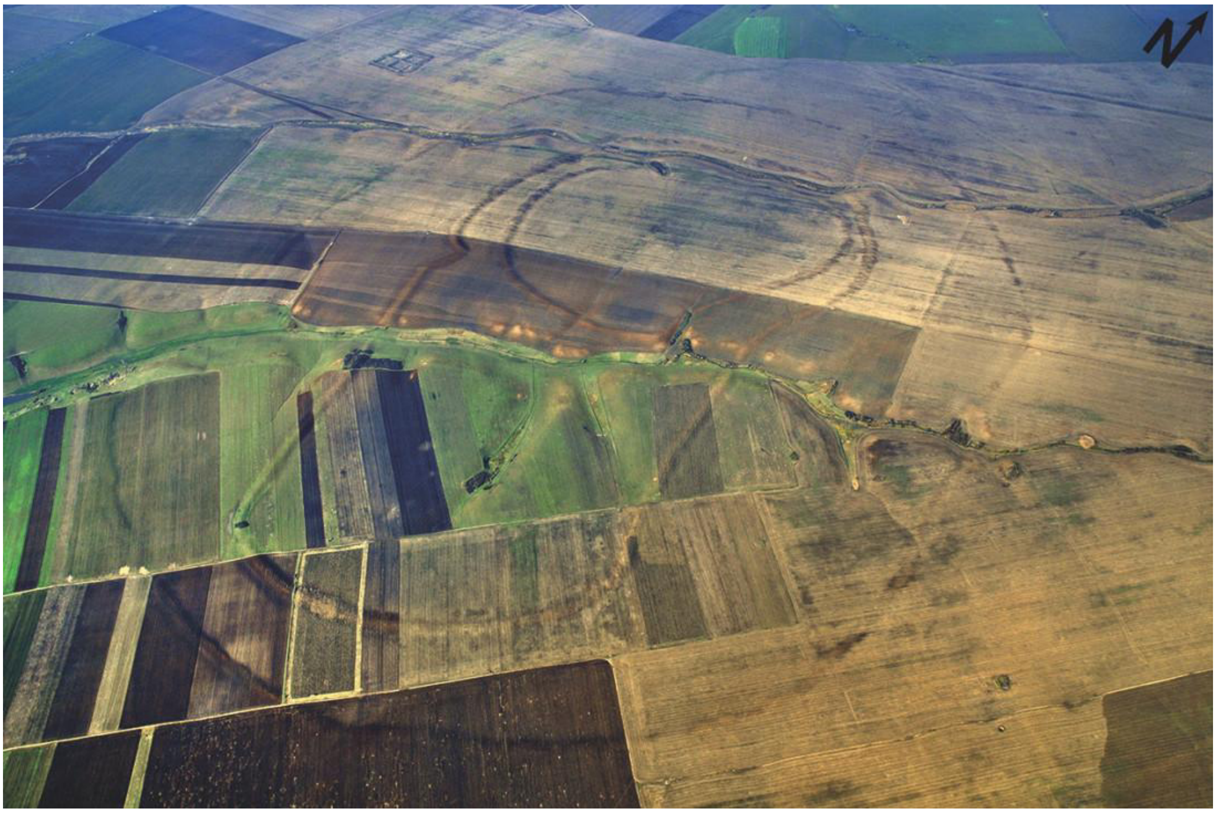

Fig. 2. Oblique aerial photograph of Corneşti-Iarcuri. The photograph gives an overview of the prevailing environment; the three innermost ramparts I-III are visible. The innermost rampart I (in the upper central part of the photograph) measures c. 1 km in diameter (Photograph taken by D. Baltat, Bucharest, 2009).

3.1. Environmental characteristics

3.1.1. Geological and geomorphological characteristics

The surface of the Great Hungarian Plain (GHP) is composed of Quaternary fluvial and aeolian sediments. It can be subdivided into wide alluvial plains and large alluvial fans that are often covered by loess or sand dunes (Lóczy et al., 2012). However, the formation of the Mureş alluvial fan in the eastern part of the Great Hungarian Plain dates back to the Late Pliocene, around 3.5-3.2 million years ago (Borsy, 1990). The Mureş alluvial fan represents one of the most extensive landscape features (c. 10.000 km²) in the region of the eastern Great Hungarian Plain (Fig. 3; Urdea et al., 2012; Kiss et al., 2012; Kiss et al., 2014).The Mureş river, which deposited the sediments of the Mureş alluvial fan, has a total length of

769 km and drains a catchment area of about 30.000 km² that is mainly located in the Transylvanian Basin and the Eastern and Southern Carpathians (Katona et al., 2012; Urdea et al., 2012).

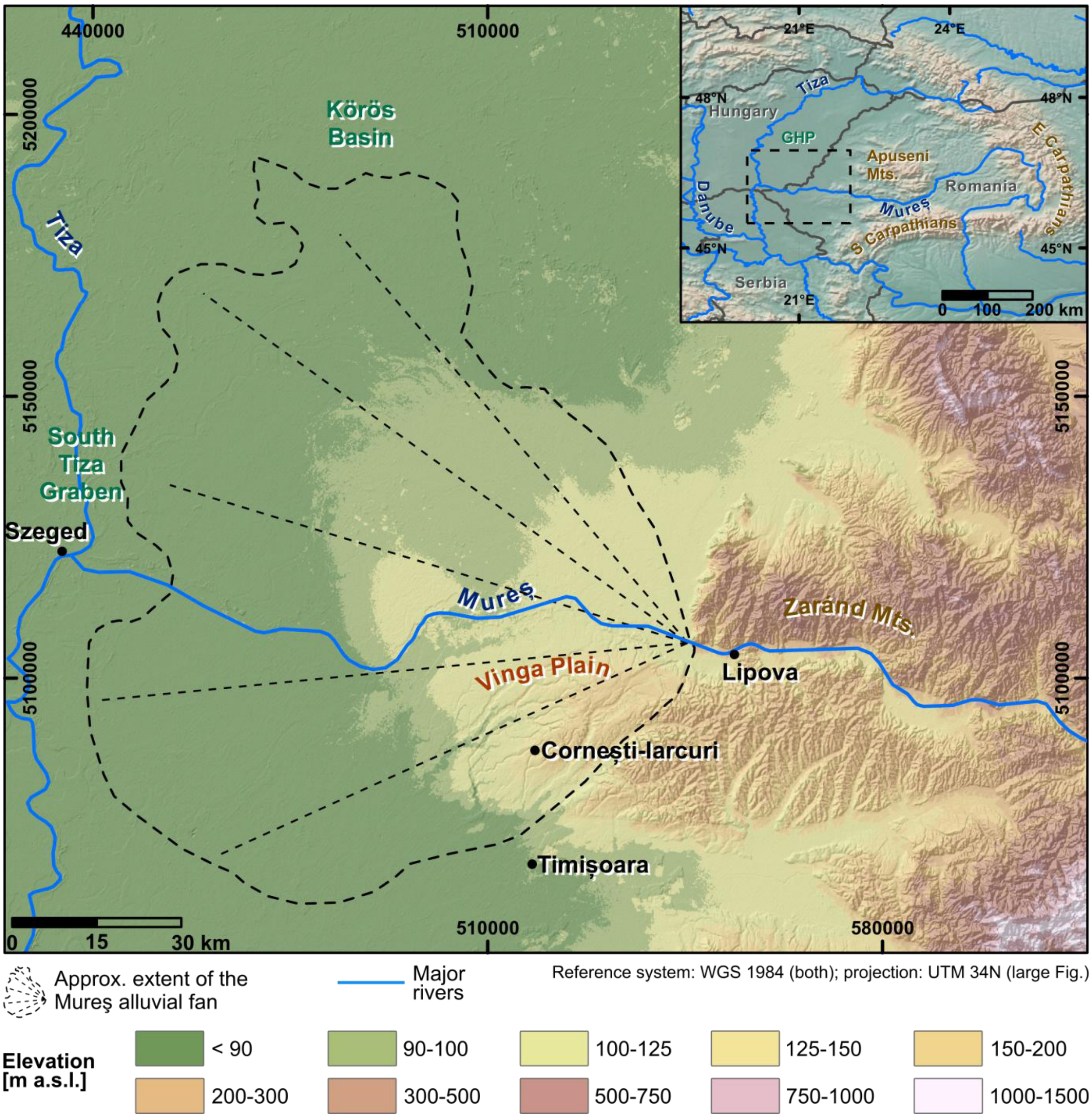

Fig. 3. Overview map of the study area showing the location of Corneşti-Iarcuri in its regional (main figure) and its supra-regional (upper right) context (vector line and raster data of upper right figure from Natural Earth Data, 2014; elevation based on SRTM data according to Jarvis et al., 2008; extent of the Mureş alluvial fan modified after Kiss et al., 2014; locations of the South Tiza Graben and the Körös Basin according to Kiss et al., 2015 and Nádor et al., 2011).

The tectonic activities in the area of the Pannonian Basin considerably influenced the formation of the alluvial fans in the area of the Great Hungarian Plain. Even though the entire Pannonian Basin subsides during the Quaternary, some areas sank with lower velocities and thus formed relative uplifts. Areas with highest Quaternary subsidence rates, such as the

South Tiza Graben or the Körös Basin (Fig. 3), sank as much as 300 to 700 m. In other parts of the basin, such as the eastern part of the Mureş alluvial fan, the subsidence rates were substantially lower (Mihăilă et al., 1987; Borsy, 1990; Kiss et al., 2012; Kiss et al., 2015). The Mureş river follows its east-west orientated valley between the Apuseni Mountains and the South Carpathians and enters the area of the unevenly subsiding Great Hungarian Plain after passing the Lipova Gorge (Fig. 3). Large amounts of gravel were deposited in the western piedmont area of the Zaránd Mountains. The distal parts of the Mureş alluvial fan are characterized by sandy, silty and clayey sediments that were deposited through frequent avulsions of the Mureş river (Borsy, 1990; Nádor, 2008; Urdea et al. 2012). From the apex at Lipova the deposits of the Mureş alluvial fan become thicker towards the distal parts in the west. The thickness of the Quaternary sequence in the east is about 100 m, while up to 500 to 700 m are reached in the west (Borsy, 1990; Nádor, 2008). The alternation of the Quaternary glacial and interglacial periods determined the amount and type of sediment transported by the Mureş river. During the dry and cold glacials coarse sediments were produced and low mean discharges prevailed whereas the warm and wet interglacials favored chemical weathering and created high mean discharges (Urdea et al., 2012).

Based on the subsurface distribution of different gravel-units three major development phases of the Mureş alluvial fan were reconstructed (Nádor, 2008). During the first phase the main flow direction was southwest coinciding with the alignment of the valleys from Zaránd Mountains. In the second phase the main flow direction shifted to the northwest due to the stronger subsidence of the Körös Basin that acted as the local base-level for the arriving floods. The third phase was marked by the development of the east-west course and the deposition of the youngest fan lobe (Nádor, 2008). Studies, most recently carried out to reconstruct the palaeohydrology of the Mureş alluvial fan successfully dated different phases of channel activity and developed a model of the alluvial fan evolution. According to the results of Kiss et al. (2012, 2014, 2015) the active channels shifted to the northern margin of the alluvial fan at the end of the Pleistocene (16.8-14.3 ka BP). The avulsions that took place in the Holocene caused major changes of the main flow direction. The active channels changed their direction to the southwestern margin of the alluvial fan around 8.5-5.3 ka BP and further to the north, to its axial position, around 2.6-1.1 ka BP (Kiss et al., 2015).

As a part of the eastern rim of the Great Hungarian Plain, located in the proximal position of the Mureş alluvial fan, the Vinga Plain is geologically built up of a mixture of Pleistocene and Holocene gravels, sand and clay. The eastern part of the Vinga Plain consists of Early and Middle Pleistocene sediments and the western part of Late Pleistocene sediments. Late Holocene sediments are present in the alluvial plains of the rivers (Fig. 4; Institutul Geologic, 1966; Mihăilă et al., 1987). The Vinga Plain is a part of the geomorphic unit of the west Romanian high piedmont plain that was formed by large coalescing lobes of the Mureş alluvial fan. It is surrounded by the piedmont hills in the east, the low piedmont plain in the west and south and the Holocene alluvial plain of the Mureş river in the north (Fig. 5; Badea et al., 1979; Mihăilă et al., 1987; Ianoş, 2002; Grigoraş et al., 2004; Micle et al., 2009).

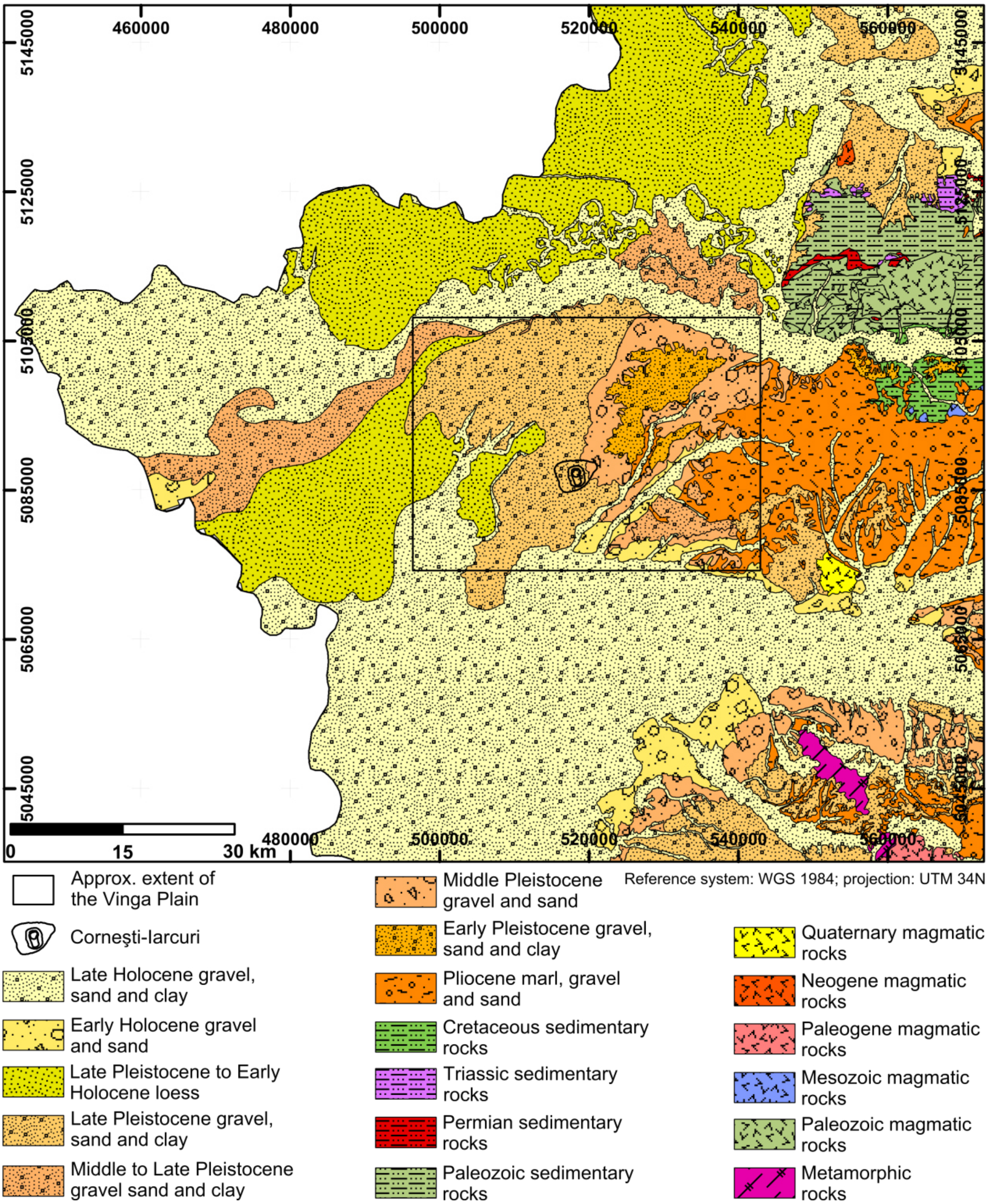

Fig. 4. Geological map of western Romania (modified after Institutul Geologic, 1966; extent of the Vinga Plain according to Grigoraş et al., 2004).

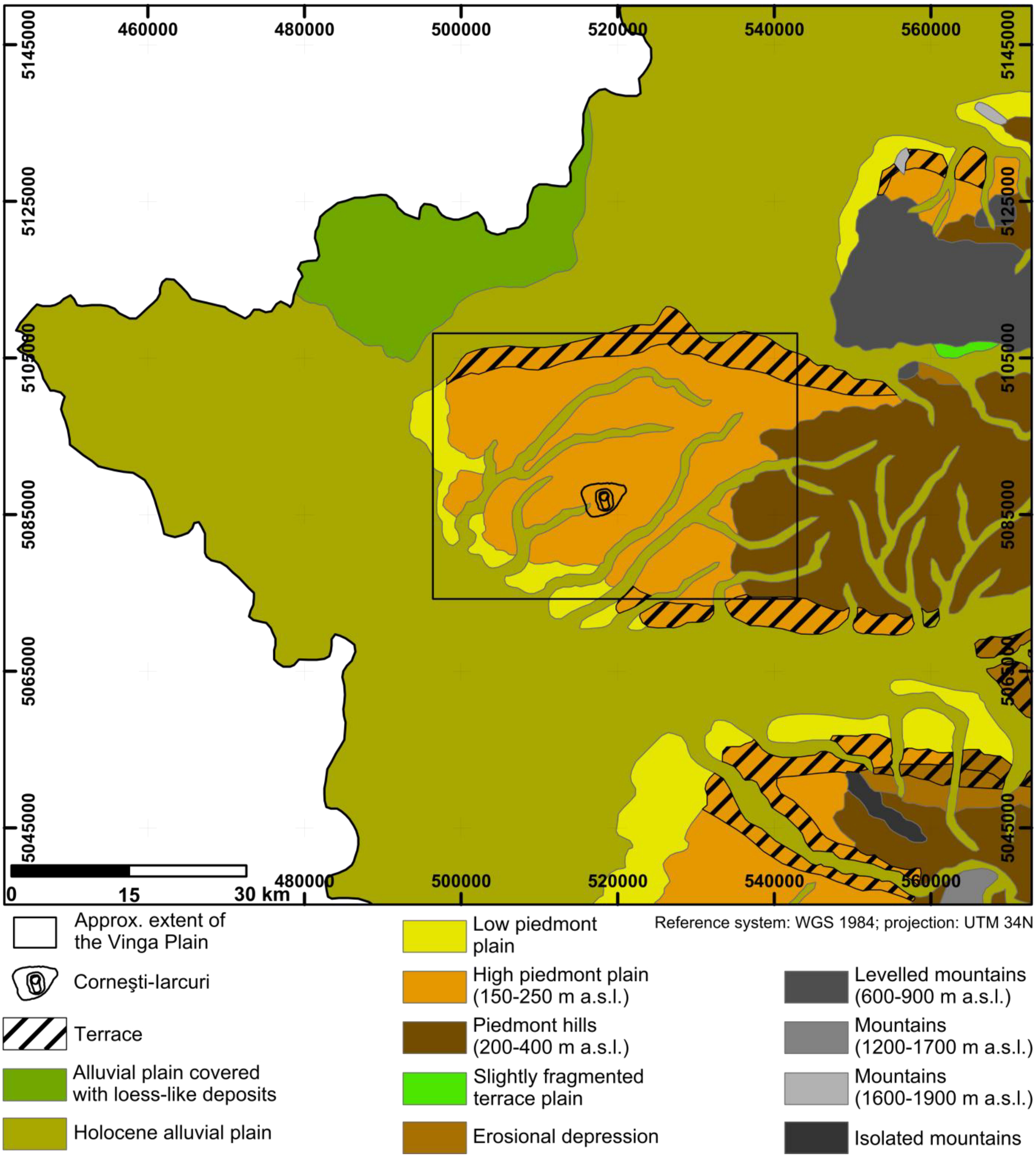

Fig. 5. Geomorphologic units in western Romania (modified after Badea et al., 1979; extent of the Vinga Plain according to Grigoraş et al., 2004).

During the Pleistocene extensive parts of the Great Hungarian Plain were covered by loess and alluvial loess (Borsy, 1990; Haase et al., 2007). This also holds true for the surface of the Vinga Plain that was widely covered with loess and loess-like deposits (Fig. 6; Mihăilă et al., 1987; Grigoraş et al., 2004; Haase et al., 2007). However, the reported thickness of the deposits is debated: Grigoraş et al. (2004) report loess and loess-like deposits on the Vinga Plain that reach a thickness of 10-30 m. The European Loess Map by Haase et al. (2007), by contrast, shows loess deposits of less than 2 m thickness only for the central and western part of the Vinga Plain (Fig. 6).

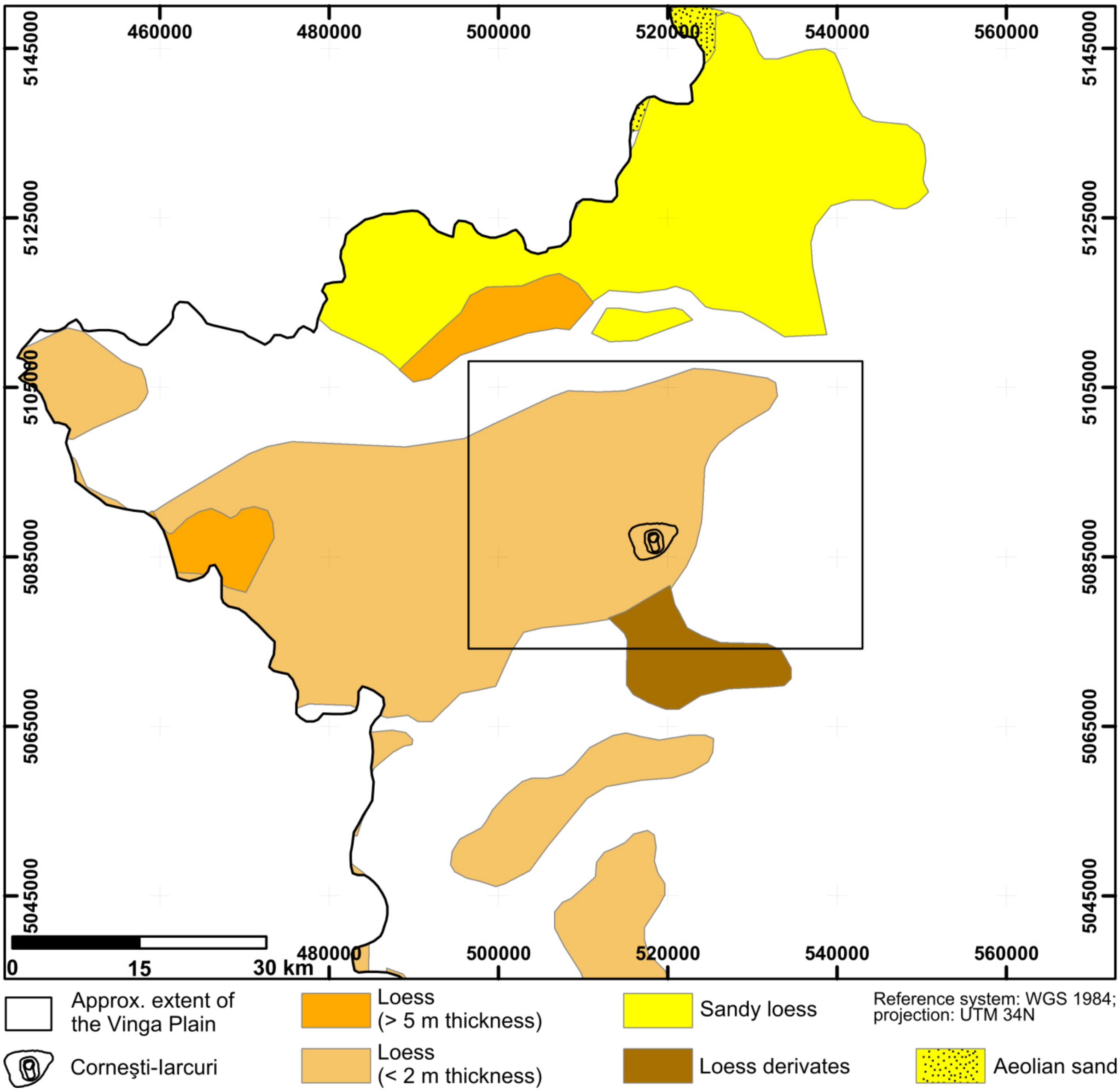

Fig. 6. Distribution of loess and loess-like sediments in western Romania (modified after Haase et al., 2007; extent of the Vinga Plain according to Grigoraş et al., 2004).

The topography of the Vinga Plain is characterized by low slope gradients and its slight southwest dipping determines the general northeast-southwest alignment of the drainage network forming extensive, slightly undulating interfluves that alternate with wide saucer-shaped valleys (Grigoraş et al., 2004; Micle et al., 2009).

Corneşti-Iarcuri is crossed by two creeks that flow at a distance of c. 1 km in wide saucer-shaped valleys from northeast to southwest: the Carani valley in the north and the Lake valley in the south (Fig. 7). Accordingly, the topography in the immediate vicinity of the site is composed of two general geomorphic units: the high plain and the intersecting valleys. The high plain is characterized by slightly undulating interfluves that decline from c. 170 m a.s.l. in the northeast to c. 130 m a.s.l. in the southwest showing slope gradients between 0° and 2° that locally reach up to 5°. At the shoulders of the valleys the inclinations usually increase to 5-10°. The midslope sections of the hillslopes show inclinations of 10-18°, locally up to 22.5°. The inclinations decrease at foot slopes, in the transition to the alluvial plains, to 2-5° and the alluvial plains are flat (0-2°) and relatively narrow. Locally, they widen as in the area of the central part of enclosure II. The hillslopes of the Carani and the Lake valley are dissected by numerous hollows and gully-like first order tributaries that frequently formed well-pronounced alluvial fans at their outlets (Fig. 7; Nykamp et al., 2015).

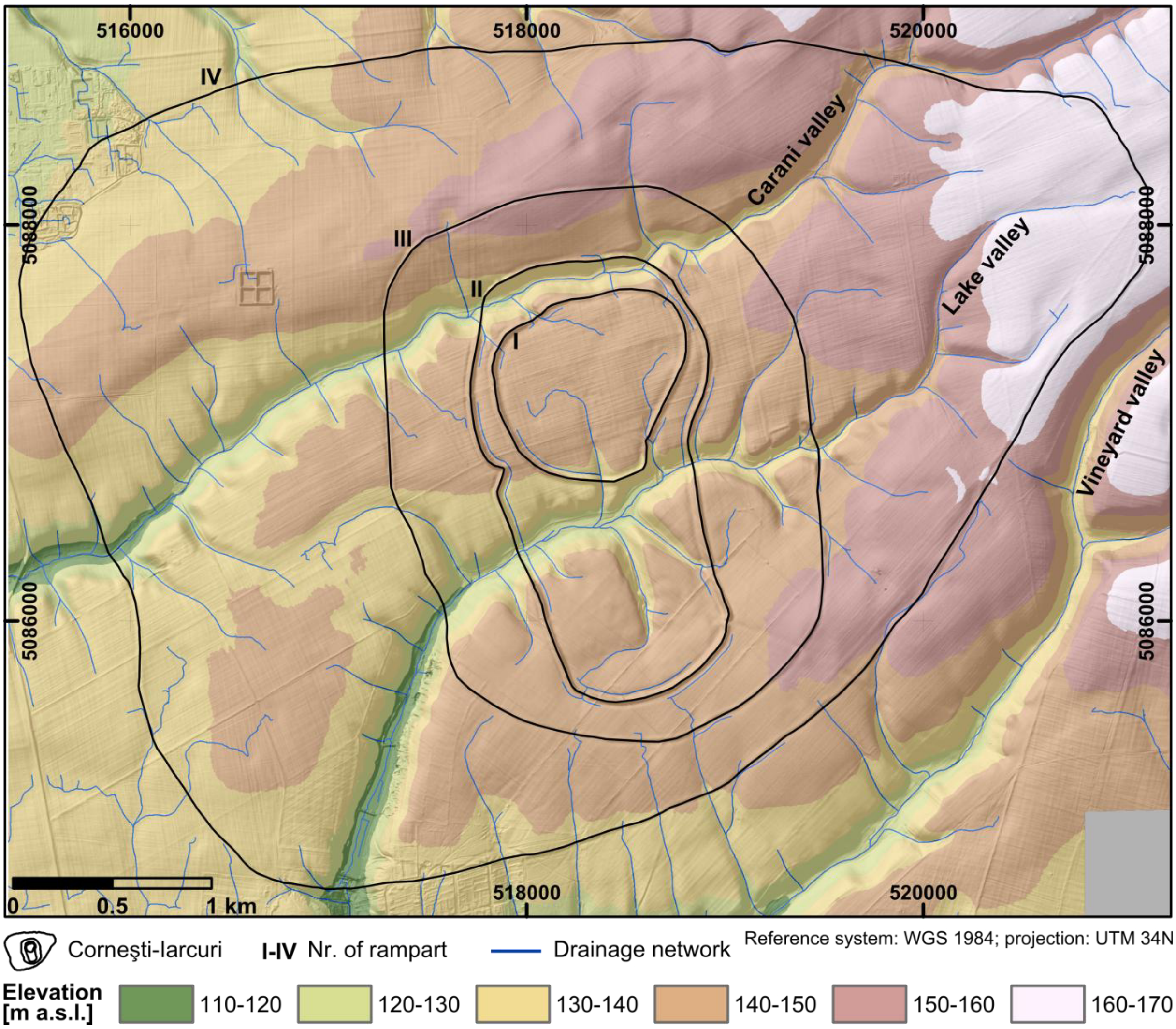

Fig. 7. Overview map showing the local environs of Corneşti-Iarcuri (drainage network calculated according to Ehlschlaeger, 1989 and Jasiewicz and Metz, 2011 based on LiDAR data).

The present-day morphodynamics in the study area are mainly controlled by vegetation and land use; agriculturally used areas show different forms of sediment movement whereas the areas where steppe grass persists usually lack signs of sediment redistribution. The process areas can be subdivided according to the two general geomorphic units: gully erosion, sheet wash and soil creep occur on the hillslopes of the valleys while the bare surfaces of the agricultural fields are affected by splash erosion and deflation (Nykamp et al., 2016). The processes of wind-driven soil erosion are a known serious issue in the Romanian lowlands as well as in the entire Great Hungarian Plain (Kiss et al., 2015; Mezősi et al., 2015; Borrelli et al., 2017), but field-based studies lack for the study area. Regional information are available from modeling approaches (Borrelli et al., 2015; Mezősi et al., 2015; Borrelli et al., 2016; Borrelli et al., 2017). A low to very low land susceptibility to wind erosion is predicted for the study area itself, but moderate to high values for the area in its southern vicinity (Borrelli et al., 2015; Borrelli et al., 2016). Accordingly, the potential soil loss due to wind erosion is predicted to be low in the environs of Corneşti-Iarcuri, but moderate to high in its southern surroundings (Borrelli et al., 2017).

3.1.2. Climate

The coldest and driest climatic period of the Quaternary in the area of the Great Hungarian Plain prevailed during the Weichselian, with mean annual temperatures between 0 and -4 °C and mean annual precipitation amounts of 180-250 mm. The area was not covered with inland ice during the Pleistocene, but periglacial conditions prevailed (Kiss et al., 2015). The Weichselian was a period of pronounced climatic variability. The Last Glacial Maximum in the area of the Great Hungarian Plain was a phase characterized by cold and dry conditions. Palynological results suggest that cold and dry conditions occurred c. 27-21 ka BP. Other scholars, however, postulate a more intensive cooling and a longer duration around c. 25-15 ka BP (Kiss et al., 2015). The following phase was characterized by warmer and more humid conditions between c. 19 and 16.5 ka BP. Coinciding with the Oldest Dryas in Northwest Europe, a short cold, and at the beginning rather dry, phase occurred between c. 16.5 and 14.7 ka BP. In comparison to the Last Glacial Maximum the climate during the Late Glacial was generally less extreme in the area of the Great Hungarian Plain. It showed at its beginning, during the Bølling interstadial, generally warm and humid conditions. The next phase, which is coinciding with the Older Dryas in Northwest Europe, was again cold and dry (Kiss et al., 2015). The Allerød interstadial marks the second warm period of the Late Glacial showing rapidly increasing temperatures and precipitation. At around 12.8 ka BP a phase of rapid and substantial cooling and decreasing precipitation occurred in the area of the Great Hungarian Plain that coincides with the Younger Dryas (Kiss et al., 2015).

The results of a stalagmite from the Poleva Cave in southwestern Romania that was analyzed for oxygen isotopes indicate a gradual warming after the Younger Dryas and several marked events in the course of the Holocene. Punctuated cold events occurred around c. 8, 7.2 and 4.2 ka BP and warm oscillations are recorded for around c. 5.2 and 3.3 ka PB, respectively (Constantin et al., 2007). According to Constantin et al. (2007) this is the only detailed Holocene isotopic record for the region, outside the Carpathians.

The Preboreal, at the beginning of the Holocene, showed rapid warming and increased humidity in the area of the Great Hungarian Plain (Fig. 8; Kiss et al., 2015). During the Boreal the temperatures further increased, but regarding the humidity it remains unclear whether it was moister or drier compared to present conditions. The climate at the beginning of the Atlantic became warmer and moister in comparison to the preceding Holocene periods. However, in the course of the Atlantic it became increasingly dry (Fig. 8; Kiss et al., 2015). During the Subboreal a marked decrease in temperatures occurred in the area of the Great Hungarian Plain whereas precipitation amounts increased in the second half. At the beginning of the Subatlantic the temperatures slightly increased and precipitation amounts decreased (Fig. 8; Kiss et al., 2015).

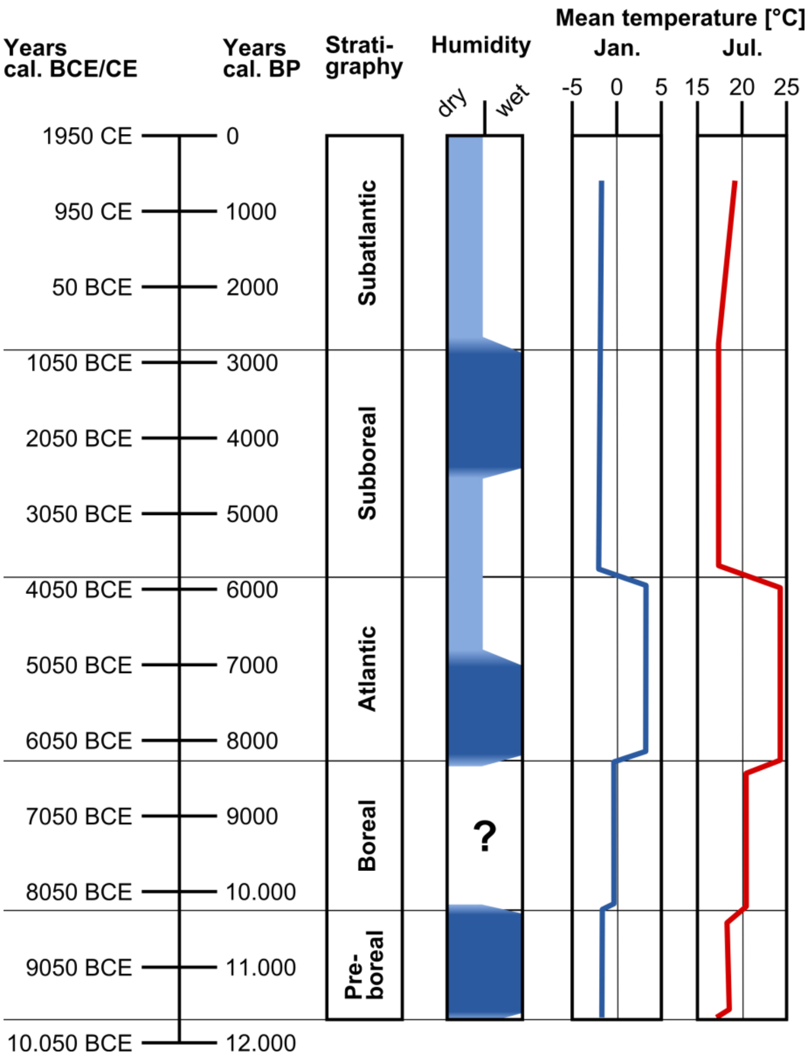

Fig. 8. Diagram of the development of the Holocene climate (modified according to Nádor et al., 2007 and Kiss et al., 2015).

The present-day climate is moderate temperate, with a mean annual temperature of c. 11 °C, a mean annual precipitation of c. 550 mm and a potential mean annual evapotranspiration of c. 700 mm (Fig. 9; Grigoraş et al., 2004).

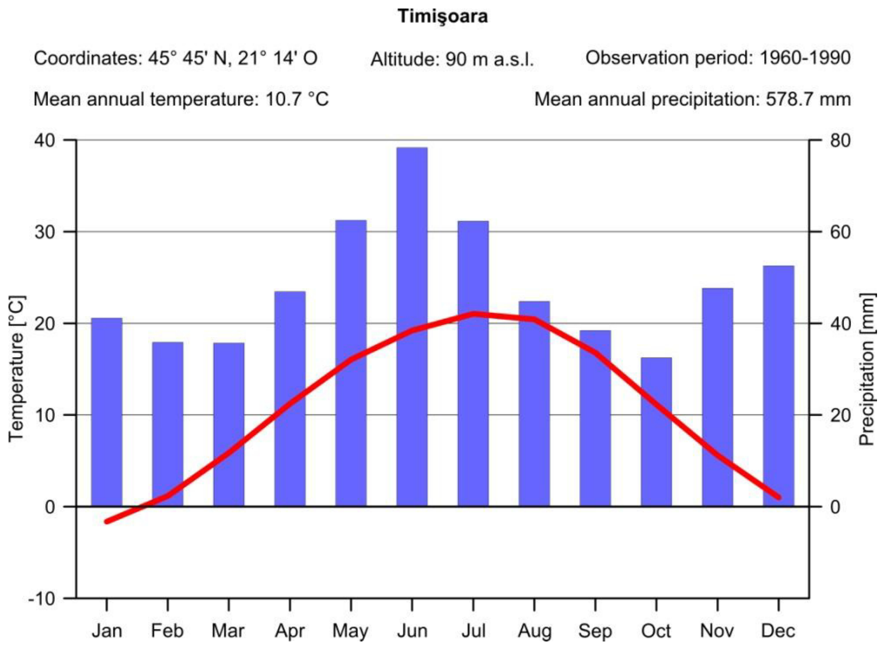

Fig. 9. Climate diagram of Timişoara for the period 1960 to 1990 (climate data from NOAA, 2017, according to Baker et al., 1994). The red curve represents the annual course of the temperature and the blue columns represent the monthly precipitation.

3.1.3. Soils

Typically, Chernozems have developed in the silt-dominated aeolian sediments and Cambisols are characteristic for the sandier areas of the Great Hungarian Plain (Borsy, 1990). The soils that developed in loess or loess-like sediments are generally highly erodible so that even loess-covered lowland areas are prone to gully formation. Water-controlled soil erosion is dominated by sheet wash, rill and gully formation on harvested agricultural areas. These processes are intensified by reduced infiltration due to compaction, sealing or crusting of the surface or subsurface pan formation, respectively (Lóczy et al., 2012).

On the high plains, in the vicinity of Corneşti-Iarcuri, typically Luvic Chernozems and Luvic Phaeozems are developed in the loess deposits. The northern part is dominated by Luvic Chernozems, while Luvic and Luvic-chromic Phaeozems predominate in the central and southern parts (Fig. 10). Usually, the Chernozems and Phaeozems in the study area have a very dark brown to black mollic A-horizon, loamy to clayey textures and humus contents between 2.0 and 3.5 % (Grigoraş et al., 2004). Sherwood (2013) describes soil profiles in the environs of Corneşti-Iarcuri that usually show calcrete horizons of different development stages at depths between 50 and 110 cm pointing to Calcic Chernozems, which were, however, not identified by Grigoraş et al. (2004; Fig. 10). Variations of the dominating soil types mainly occur due to the geomorphic unit and its prevailing relief. Eroded Chernozems characterize the hillslopes of the valleys in the northwestern part of the study area, while the hillslopes in the southeastern part are characterized by Eroded Luvisols (Fig. 10). Colluvisols develop in the colluvial deposits, which form as slope sediments due to human activity causing soil erosion (c.f. Leopold and Völkel, 2007), at the foot slopes (Sherwood, 2013). The alluvial plains of the valleys are dominated by Fluvic-gleyic Chernozems or Phaeozems and Gleyic-luvic Phaeozems, respectively (Fig. 10; Grigoraş et al., 2004).

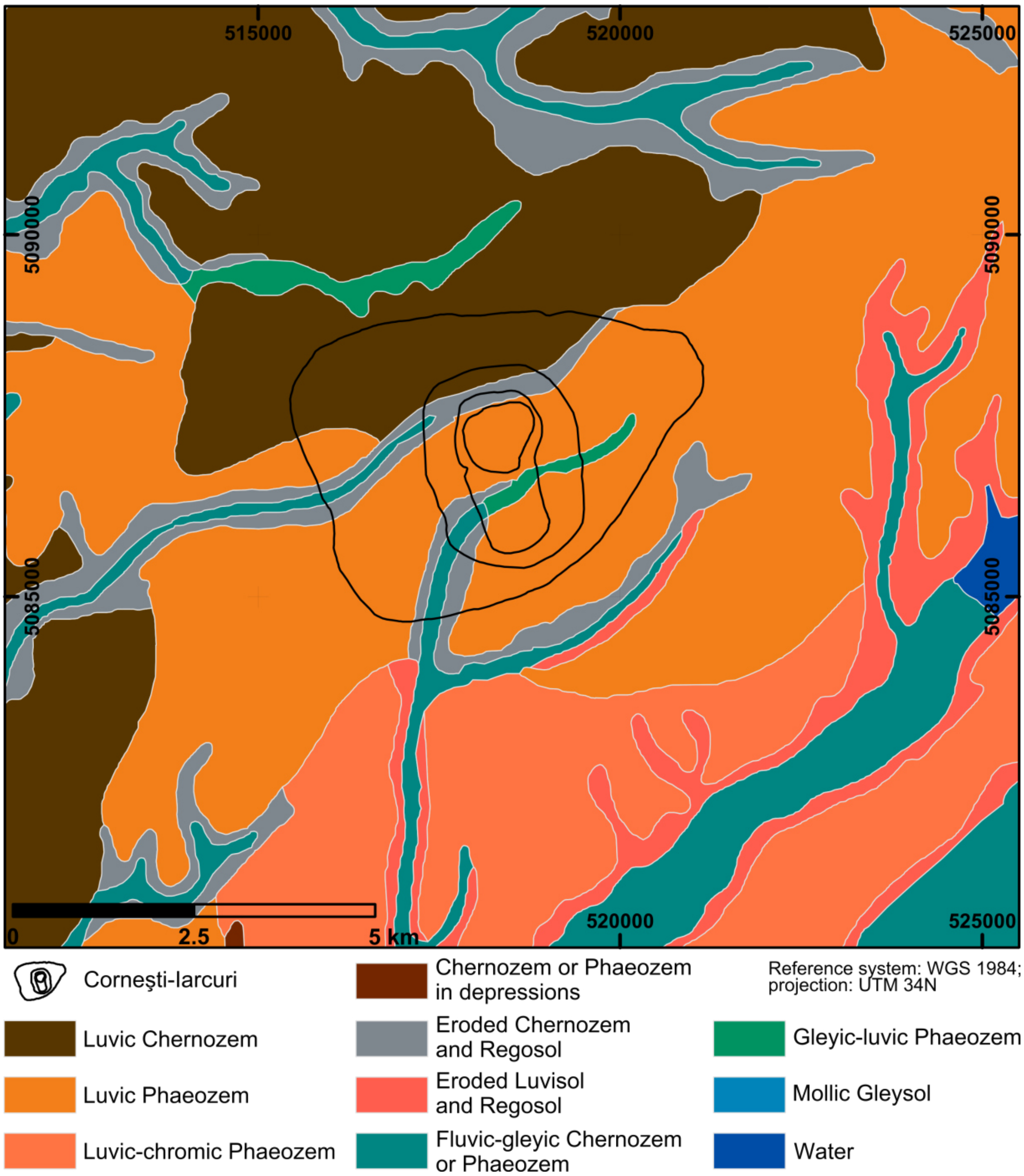

Fig. 10. Soil map showing the distribution of the dominating soil types in the immediate surroundings of Corneşti-Iarcuri (modified after Grigoraş et al., 2004).

3.1.4. Vegetation

The potential natural vegetation of western Romania consists of floodplain vegetation in the alluvial plains of the larger rivers, forest-steppe in the lowlands and the piedmont plains and thermophilous mixed deciduous broadleaved forests in piedmont hills and the mountains; scattered stands of inland halophytic vegetation occur in lowland areas (Fig. 11; Bohn et al., 2004). The area of the Vinga Plain is largely characterized by forest-steppe and some thermophilous mixed deciduous broadleaved forests at its eastern rim (Fig. 11; Bohn et al., 2004).

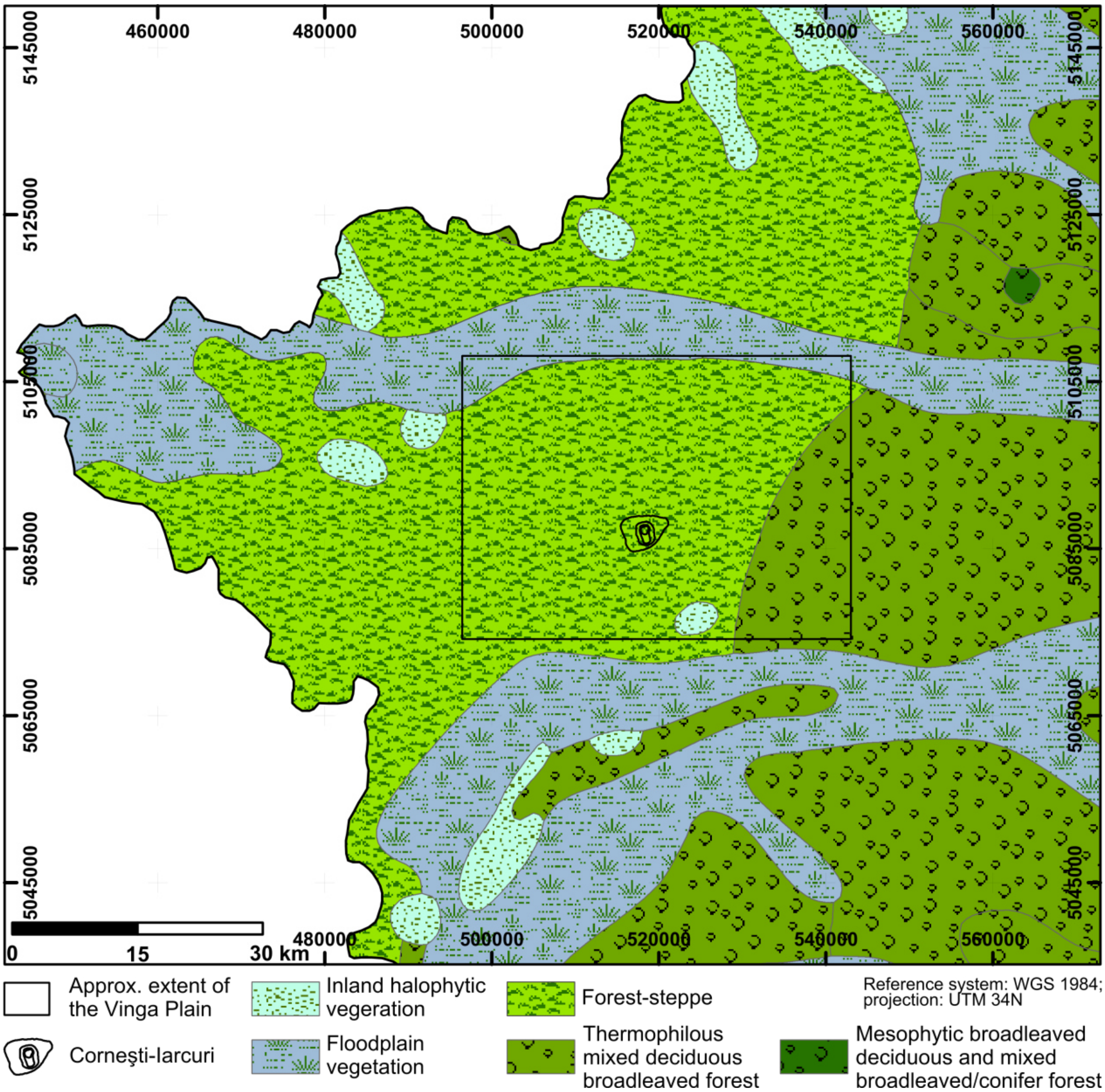

Fig. 11. Potential natural vegetation in western Romania (modified after Bohn et al., 2004; extent of the Vinga Plain according to Grigoraş et al., 2004).

The present-day land cover of western Romania, however, gives a completely different impression. Extensive areas are covered with arable land whereas only smaller areas of the piedmont hills and mountains are covered with forests; steppe or forest-steppe associations are almost absent in the lowland areas (Fig. 12; European Environment Agency, 2010).

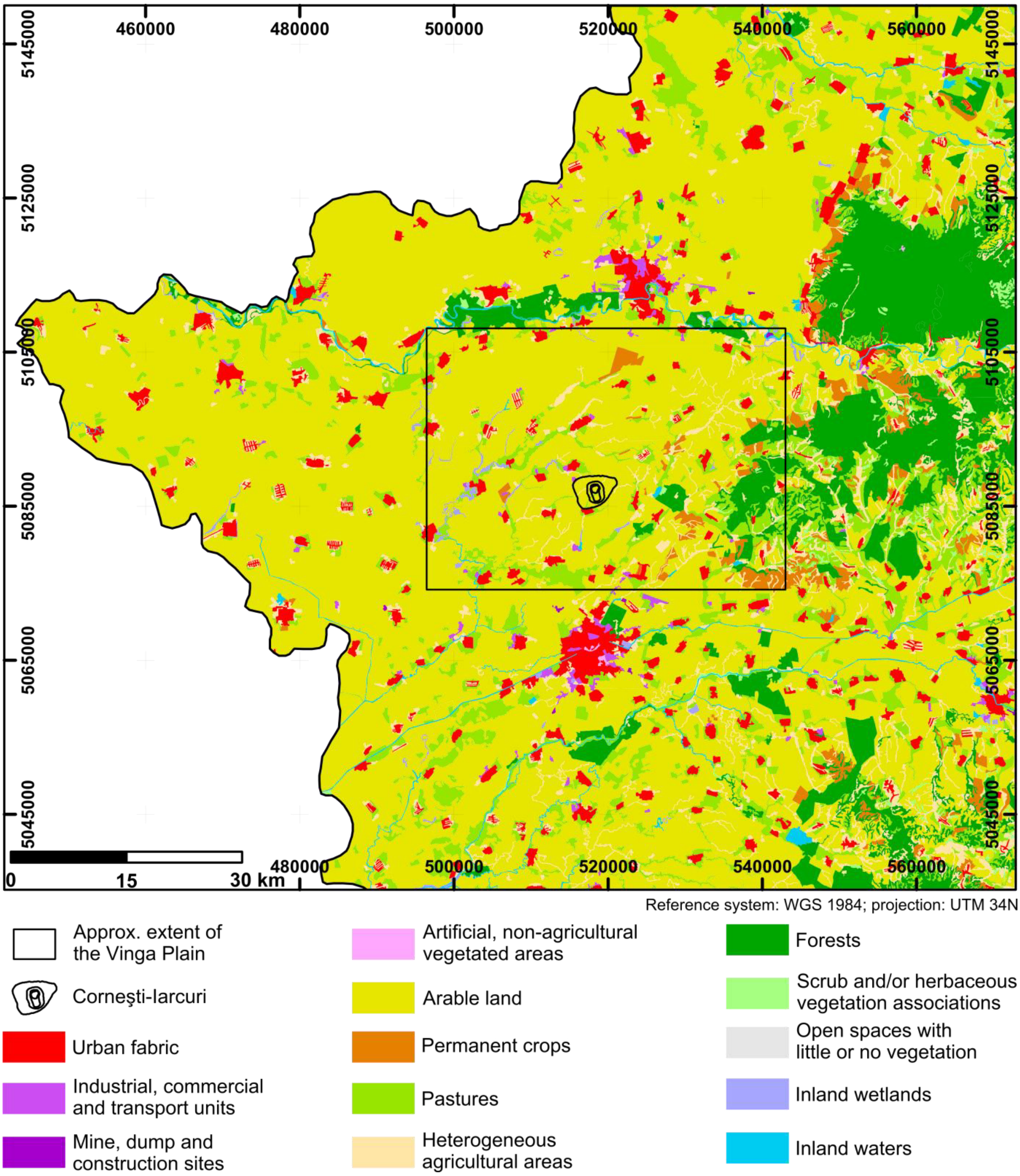

Fig. 12. Present-day land cover in western Romania (modified after European Environment Agency, 2010; extent of the Vinga Plain according to Grigoraş et al., 2004).

The Holocene vegetation development in the area of the Great Hungarian Plain begins during the Preboreal with a general increase of the vegetation density and a rapid forest expansion towards a birch forest-steppe including a mixture of frost-tolerant and cryophilous species. In the course of the Preboreal the cryophilous elements gradually disappeared and the Great Hungarian Plain was covered with a forest-steppe (Kiss et al., 2015). During the following Boreal pine trees gradually disappeared from the thermophilous deciduous forests, but due to reoccurring drought periods in the course of the Boreal the forests were replaced by steppe and forest-steppe vegetation. In the Atlantic the plains, hills and lower mountain regions of the Great Hungarian Plain were covered with closed oak forests (Kiss et al., 2015). Other scholars, however, characterize the vegetation of the Great Hungarian Plain at the beginning of the Atlantic as a mosaic of mixed oak-hazelnut forest and open meadows (Salisbury et al., 2013) or more general as wooded steppe that persisted throughout the entire Early and Middle Holocene (Magyari et al., 2010). The interpretation of Magyari et al. (2010) is based on the compilation of 21 previously published palynological studies that is also supported by studies of fossil bone assemblages from prehistoric sites that contained bones of mammals, which are characteristic for a wooded steppe or woodland environment. The Atlantic was also the first period in the area of the Great Hungarian Plain when human disturbances in the form of slash and burn agriculture by Neolithic settlers impacted the vegetation development (Salisbury et al., 2013; Kiss et al., 2015). The Subboreal vegetation was characterized by widespread dense forests on the mountains and plains of the Great Hungarian Plain. Extensive swamps and marshes developed in the lowlands due to the increased precipitation in the second half of the Subboreal (Kiss et al., 2015). Human activities became more intensive towards the end of the Subboreal causing the development of a cultural steppe in the area of the Great Hungarian Plain (Magyari et al., 2010). Oak forests are characteristic for the Subatlantic in the area of the Great Hungarian Plain, but human activity became more and more pronounced after the Medieval Warm Period causing the clearance of the majority of the forests and a substantial alteration of the vegetation (Kiss et al., 2015).

The consideration of the Holocene vegetation development cannot be extended to the wider surroundings of Corneşti-Iarcuri or even to the regional scale, i.e. the Romanian Banat, due to a complete lack of successful palynological studies. Due to climatic and environmental reasons the localization of suitable coring sites to set up reference pollen diagrams is difficult in the entire area of the Romanian Banat and was not successful until now (Rösch and Fischer, 2000; Fischer and Rösch, 2005). Nevertheless, several attempts of have been made in the region. J. Kalis conducted archaeobotanical corings in the environs of Corneşti-Iarcuri, in the southern half of rampart II, and describes the pollen samples as being "suboptimal" (Szentmiklosi et al., 2011). Also, the attempts of archaeobotanical corings at several different locations within the four ramparts and in a c. 20 km radius around Corneşti-Iarcuri conducted by A. Stobbe, A. Röpke and M. Nykamp in summer 2014 failed to obtain pollen samples that cover a longer time period than since c. the Late Middle Ages. The attempts by M. Rösch and E. Fischer in the surroundings of the archaeological site of Uivar, c. 30 km southwest of Timişoara and near the village of Satchinez, c. 30 km northwest of Timişoara, also failed (Rösch and Fischer, 2000; Fischer and Rösch, 2005). In their four meter core from Satchinez that entirely consisted of clay the pollen content was very low and the pollen spectra seemed to be the residue of selective corrosion (Rösch and Fischer, 2000). Similar results, generally low pollen contents and very bad pollen preservation, are reported by Kadereit et al. (2006) from the surroundings of Uivar, too.

North of the Mureş alluvial fan, in the shallow depression of the Körös Basin (Fig. 3), the search for suitable pollen archives to reconstruct the local Holocene vegetation development was more successful (Salisbury et al., 2013). In an oxbow lake of the Körös river Salisbury et al. (2013) obtained pollen samples and describe the local vegetation until the Neolithic human impact as patchy wooded steppe. In the Neolithic first evidence of cultivated plants, including cereals and anthropogenic weed-indicator taxa, and forest clearance occurred (Salisbury et al., 2013). Throughout the Late Neolithic and Copper Age an increased human impact on the vegetation, including the reduction of trees in favor of cereals, sedges and ruderal weeds, is evident pointing to a significant increase of human production and long-term intensive occupation of the area. The human impact on the vegetation becomes even more pronounced during the second half of the Copper Age and the Early Bronze Age leading to extensive deforestation in this area of the Körös Basin (Salisbury et al., 2013). However, these results must be regarded as preliminary, because the age-depth model is based on only one ^{14}C dating and thus must be regarded as hypothetical (Salisbury et al., 2013).

3.1.5. Hydrology

Hydrologically, the study site is located in the catchment area of the middle reaches of the Danube (Bayrisches Landesamt für Wasserwirtschaft, 1986). In the area of the Great Hungarian Plain the Tiza river, which is the receiving stream of the Mureş river and also the largest tributary of the Danube, flows into the Danube. About 60 km downstream of the confluence of the Tiza river and the Danube the Timiş river flows into the Danube. Both tributaries are situated on the left side of the Danube (Fig. 13; Bayrisches Landesamt für Wasserwirtschaft, 1986).

Corneşti-Iarcuri is located at the northern edge of the Timiş catchment, c. 12 km west of the Beregsău river, which is one of the major tributaries of the Timiş river (Fig. 13).

The Beregsău river is the receiving stream of all rivers that drain the wider surroundings of Corneşti-Iarcuri (Fig. 14). The area of the Vinga Plain covers approximately the northern half of the Beregsău catchment. The northeast-southwest alignment of the drainage network that is determined by the slight southwest dipping of the Vinga Plain (Grigoraş et al., 2004) is evident (Fig. 14).

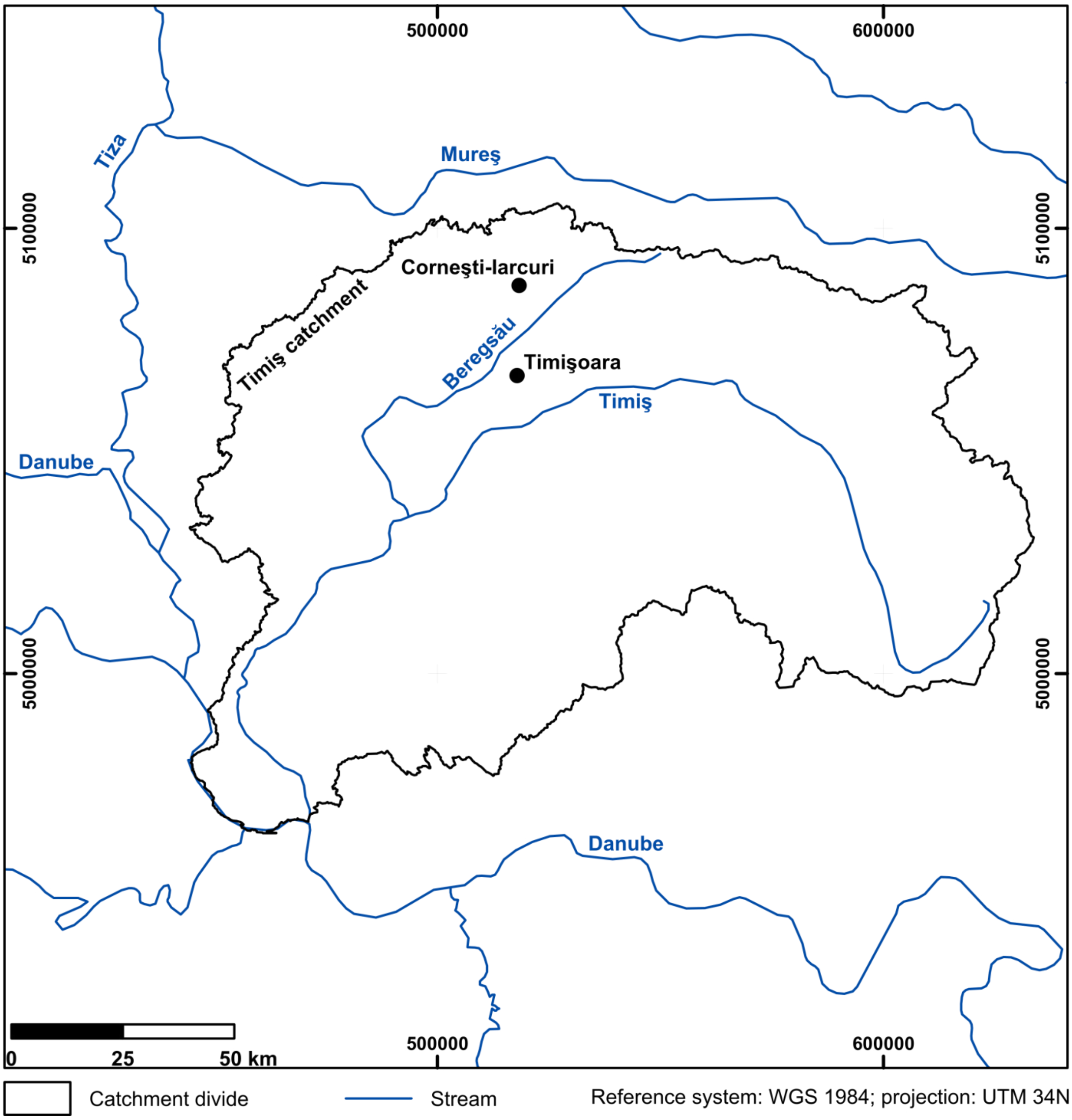

Fig. 13. Regional hydrological characteristics of the study area (river vector data from Natural Earth Data, 2014; Timiş catchment calculated according to Ehlschlaeger, 1989 and Jasiewicz and Metz, 2011 based on STRM data according to Jarvis et al., 2008).

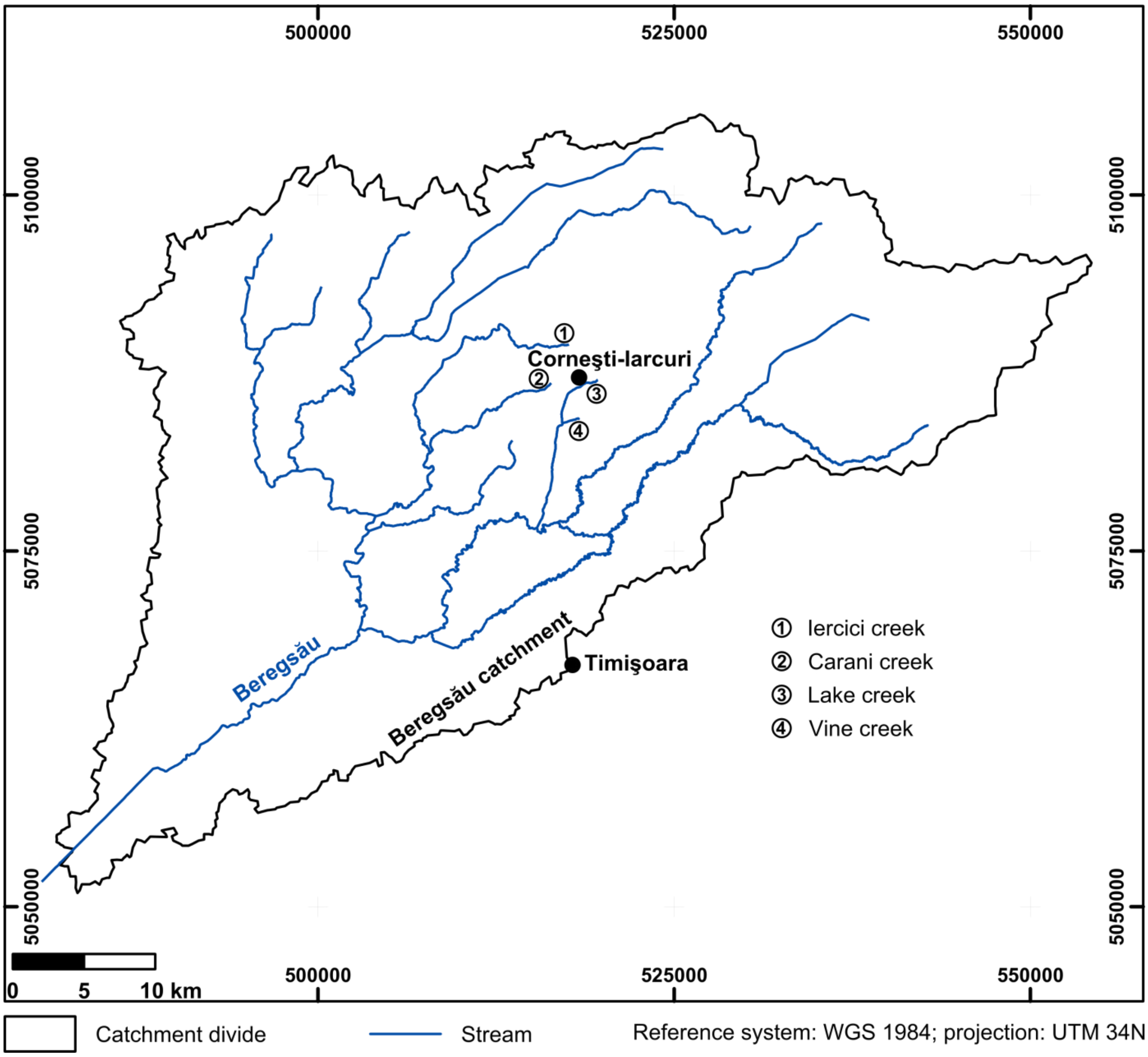

Fig. 14. Hydrological characteristics in the wider surroundings of Corneşti-Iarcuri (river vector data digitized from the perennial streams of topographic map, Direcţia Topografică Militară, 1982; Beregsău catchment calculated according to Ehlschlaeger, 1989 and Jasiewicz and Metz, 2011 based on STRM data according to Jarvis et al., 2008).

The hydrological characteristics in the immediate surroundings of Corneşti-Iarcuri follow the general pattern that is present in the area of the Vinga Plain. The third order (according to Strahler, 1957) streams generally drain southwestwards (Fig. 15). Two creeks, the Carani and the Lake creek, cross the central part of the built-up area of Corneşti-Iarcuri receiving the waters from numerous first and second order (according to Strahler, 1957) tributaries that drain the surface of the high plain (Fig. 15). Some of these first order tributaries, particularly in the central part of the built-up area, bend unnaturally or show reaches that run reverse to the general surface gradient (Fig. 15; Nykamp et al., 2015).

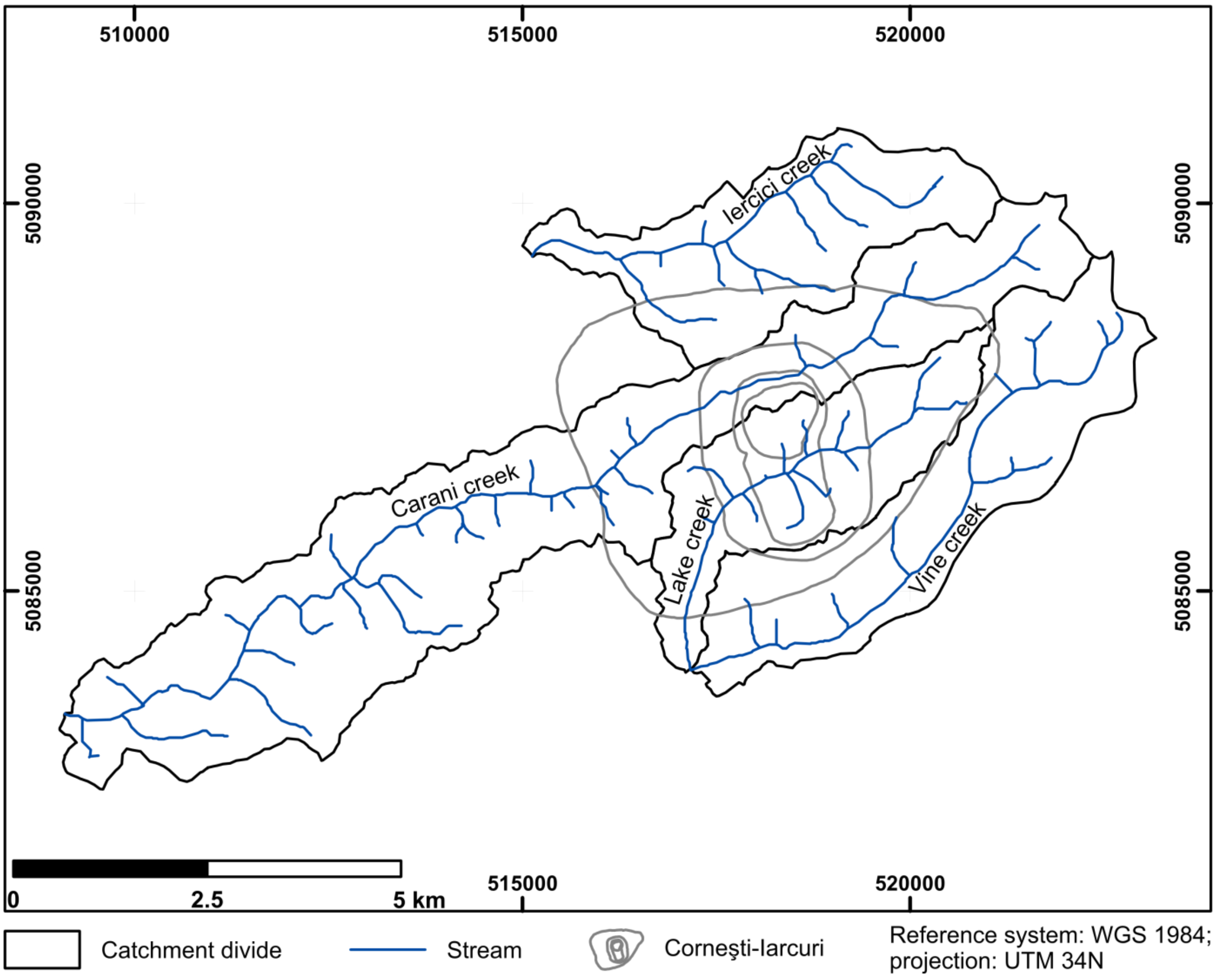

Fig. 15. Hydrological map showing the third order streams in the immediate surroundings of Corneşti-Iarcuri (river vector data and catchments calculated according to Ehlschlaeger, 1989 and Jasiewicz and Metz, 2011 based on the topographic map, Direcţia Topografică Militară, 1982; stream ordering according to Strahler, 1957).

3.2. Historic landscape development

The historically relevant region of the Banat (*Temeser Banat*) roughly extends the area between the Mureş river, the Tiza river, the Danube and the Transylvanian foothills (Schwicker, 1872). The historic landscape development as well as the waves of depopulation and resettlement, including the history of drainage works and land reclamation is particularly well recorded for the Banat region in several historic and modern maps and descriptions (von Dorner, 1839; Schwicker, 1872; Bußhoff, 1938; Hofstätter, 1989; Rieser, 1992; Kretschmer et al., 2004; Timár, 2004; Timár et al., 2006; map data of the First, Second and Third Military Survey of the Habsburg Empire available from Arcanum, 2006).

The Turks conquered the city of Timişoara in the year 1552 and ruled the region in a cruel manner for the following 164 years (Schwicker, 1872). The war between the Turks and the Hungarians caused the devastation of many villages and the region became widely depopulated (Schwicker, 1872; Bußhoff, 1938; Petrovszki and Mészáros, 2010). The Banat region remained largely depopulated and uncultivated during the Turkish rule. Even 200 years later often only heaps of debris reminded of villages that were first mentioned in written form in 1536. During this time the rivers were mostly unmanaged and frequently flooded the low-lying areas forming extensive swamps (Schwicker, 1872; Bußhoff, 1938; Petrovszki and Mészáros, 2010). In the year 1717 the Turks were finally ousted by the Habsburgs and in 1720 the land reclamation from the wilderness and the swamps was initiated by Count Mercy (Schwicker, 1872; Rieser, 1992). Only ten years later the first results regarding the transformation of the barren land, the wilderness and the swamps into fertile arable land as well as the foundation of new villages became visible. However, a repeated depopulation of the region occurred due to the plaque in the years 1737 until 1739 (Schwicker, 1872). The imperial colonization patent that was issued in the year 1763 led to the resettlement of several thousand people into the Banat region. During the following time extensive swamp areas were drained and transformed into arable land and pastures and the Banat region became one of the most productive areas of the Habsburg Empire (von Dorner, 1839; Schwicker, 1872; Rieser, 1992; Petrovszki and Mészáros, 2010; Munteanu et al., 2014). The study area was largely characterized by extended agricultural areas and up to 75 %, partially more, of the area was used for arable farming in the year 1865 (Kókai, 2009).

3.3. Archaeological background

The archaeological site Corneşti-Iarcuri is the largest known enclosure of the European prehistory and, to date, the largest ground monument in Europe (Szentmiklosi et al., 2011; Heeb et al., 2011; Heeb et al., 2015). The site consists of four earth-filled wooden ramparts that are numbered I to IV from inside out. The ramparts have a circular (rampart I) to ellipsoid (rampart II-IV) shape (Fig. 16), at least ten gates and measure altogether a total length of more than 33 km that enclose an area of c. 17.6 km² (Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2014; Heeb et al., 2015; Nykamp et al., 2015).

The first known cartographic representation of the ramparts I and II comes from the map *Mappa von dem Temesvaer District* drawn in 1720. From this time onwards the innermost ramparts I and II, later on also fragments of rampart III, were an integral element in the military maps of the region (Szentmiklosi, 2015). Corneşti-Iarcuri was first mentioned in archaeological literature in 1877 by J. Pech, who stated, however, without providing any evidence, an Avar (Early Medieval) origin. First archaeological investigations in Corneşti-Iarcuri were carried out by I. Miloia in 1933, who dated the site, based on obtained ceramics, into the Bronze Age (Heeb et al., 2008). Minor archaeological investigations including excavations and systematic field surveys were carried out in 1939 under the direction of M. Moga (Heeb et al., 2008; Szentmiklosi, 2015). According to his documentation, which is, however, undetectable nowadays, the ramparts date to the Middle Bronze Age. In 1993 F. Medeleţ summarized all so far unpublished results from the archaeological investigations that were carried out in Corneşti-Iarcuri (Heeb et al., 2008).

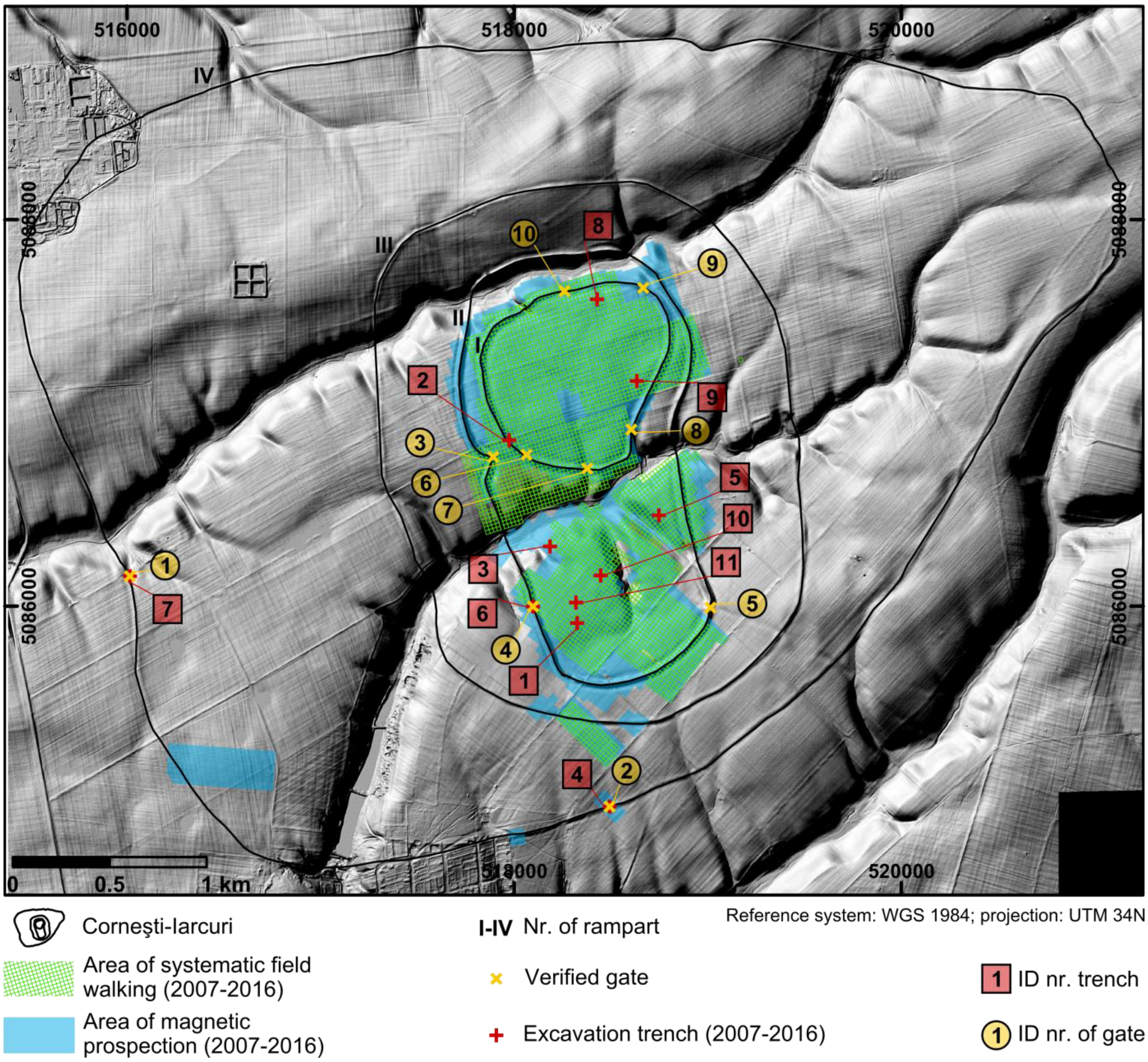

Fig. 16. Overview map showing the locations of the excavation trenches (2007-2016), the areas of systematic field walking (2007-2016), the areas of magnetic prospections (2007-2016) and the locations of the ten so far verified gates (modified after Nykamp et al., 2015).

Since 2007 Corneşti-Iarcuri is re-investigated with modern archaeological methods including the excavation of the ramparts and the settlement structures within, photogrammetric documentation of findings, extensive magnetic prospections, topographic survey, large-scale systematic field walking, airborne photographic documentation and airborne-LiDAR-based acquisition of the topography (Fig. 16; Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2011; Heeb et al., 2012; Heeb et al., 2014; Heeb et al., 2015; Balarie et al., 2016). These studies aim at understanding 1) the construction method of the ramparts, their dating and the functioning of the defensive structures (Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2015), 2) the character and chronology of the settlements within the ramparts, including fine chronology of utilization phases (Heeb et al., 2008; Heeb et al., 2012; Heeb et al., 2015) and 3) the economic basis of the Late Bronze Age society and their social stratification (Heeb et al., 2008; Heeb et al., 2012; Heeb et al., 2015). The results of Szentmiklosi et al. (2011), Heeb et al. (2012) and Heeb et al. (2015) provide new insights regarding the construction methods of the ramparts, their exact dimensions and chronology and how the defensive structures were functioning. Part of the character and chronology of settlement structures in the built-up area of Corneşti-Iarcuri is examined and presented in Szentmiklosi et al. (2011), Heeb et al. (2012) and Heeb et al. (2015). Preliminary results regarding the economic basis of the Late Bronze Age society and the social stratification within and beyond the four enclosing ramparts are presented in Heeb et al. (2015). However, due to the scarcity of earlier research activities, the partially poor preservation conditions of the early documents and mainly due to the relatively short duration of the modern archaeological activities in Corneşti-Iarcuri the archaeological state of the art is at its very beginning.

The ramparts I, II and IV have been excavated and radiocarbon dated to the Late Bronze Age until the transition to the Early Iron Age. The ^{14}C datings from the two innermost ramparts I and II yielded ages between c. 1500 and 1300 cal. BCE (3450-3250 cal. BP) at 2σ and the ones from the outermost rampart IV showed ages between c. 1300-1000 cal. BCE (3250-2950 cal. BP) at 2σ. Rampart III is undated so far, but it is accepted that it dates to the same period of time, because the ramparts do not cut each other (Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2015). To date, ten gates (Fig. 16) have been identified in the four enclosures by the combination of excavation and interpretation of satellite and aerial images and LiDAR and magnetic data (Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2014; Heeb et al., 2015; Nykamp et al., 2015).

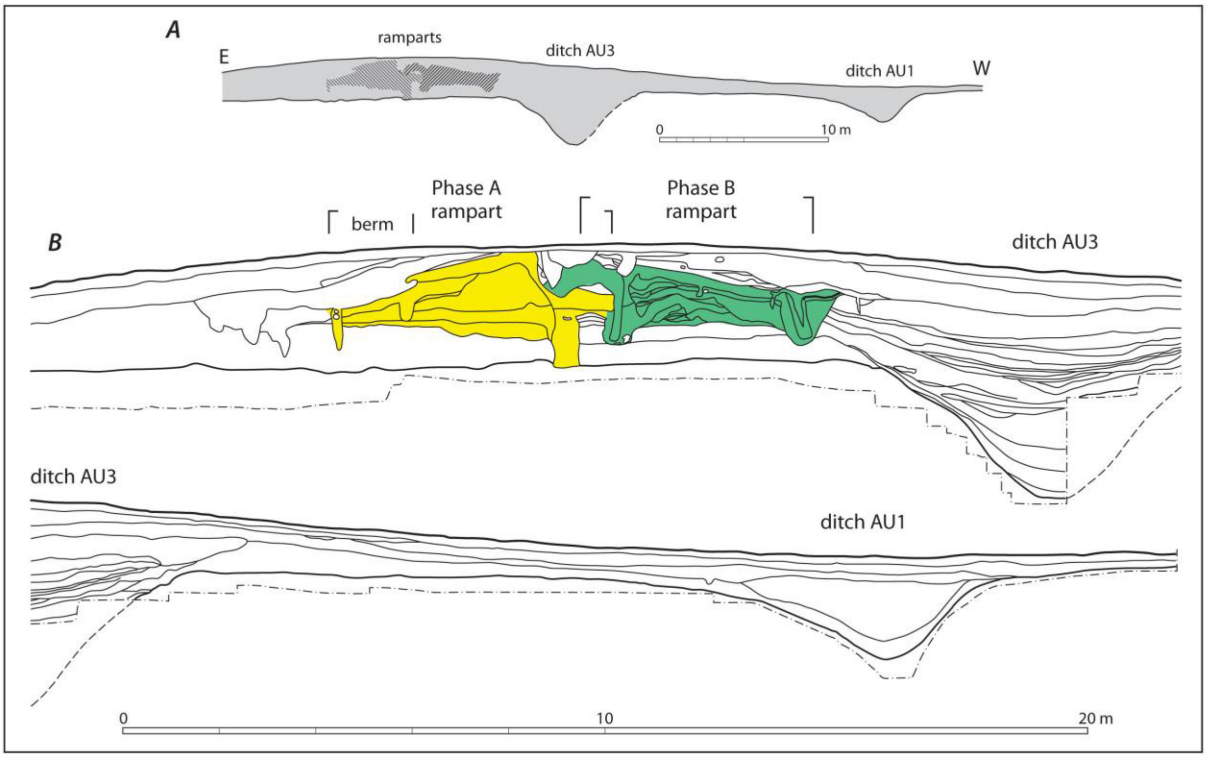

Fig. 17. A) Schematic representation of the excavation trench (trench 2 in Fig. 16) that cuts rampart I and the two defensive ditches in front. B) Detailed drawing of the trench indicating the two different construction phases (Phase A and B) of rampart I (Szentmiklosi et al., 2011).

Fig. 18. Photograph showing the excavation trench (trench 2 in Fig. 16) cutting rampart I. The remains of the earth-filled wooden compartments are clearly visible from the excavated postholes (Photograph taken by A. Szentmiklosi, Timişoara, 2008).

The excavation trench (trench 2 in Fig. 16) that was opened in 2008 had dimensions of 80 m length and 3.6 m depths and yielded a complete profile through rampart I including the two defensive ditches that are located in front of the rampart (Fig. 17 A) and the soil extraction area that lies rearwards (Szentmiklosi et al., 2011; Heeb et al., 2015). The results show that rampart I was constructed in two different phases. However, both phases have been built as earth-filled wooden constructions that were built from large oak beams forming wooden compartments (Fig. 18) that were filled with soil taken from the defensive ditches as well as from the rearwards lying soil extraction areas. The finer details obtained from the excavation demonstrate the differences in the overall construction method of the two phases (Phase A and Phase B in Fig. 17 B; Szentmiklosi et al., 2011; Heeb et al., 2015).

The large-scale excavation (trench 7 in Fig. 16) in 2013 in the western periphery of rampart IV shows a similar way of construction consisting of earth-filled wooden compartments that are known from the excavation of rampart I. In front of the rampart a v-shaped defensive ditch measuring 9.2 m width and 1.7 m depth was found. Since no signs of support posts were found it is assumed that the bridge over the ditch was not permanently installed, but rather a mobile, easy-to-remove construction. In front of the defensive ditch a special feature – in the form of a bridgehead – was uncovered. This kind of outwork – a defensive construction in front of a defensive ditch – is known so far only from the Antiquity in Europe (Heeb et al., 2014; Heeb et al., 2015). The excavation plan (Fig. 19) shows a corridor leading through the bridgehead (F.90A in Fig. 19) towards the bridge. On the other side of the defensive ditch the gate (F.90B in Fig. 19) leads through the rampart that has a width of c. 13 m at this position. After entering the gate it narrows from c. 5 m width (F.90B in Fig. 19) to c. 1.7 m width (F.90C in Fig. 19) so that the passage is restricted to the width of approximately two persons. The entire series of these coordinated and well thought out defensive measures show a complexity that is hardly known from any other European Bronze Age enclosure (Heeb et al., 2014; Heeb et al., 2015).

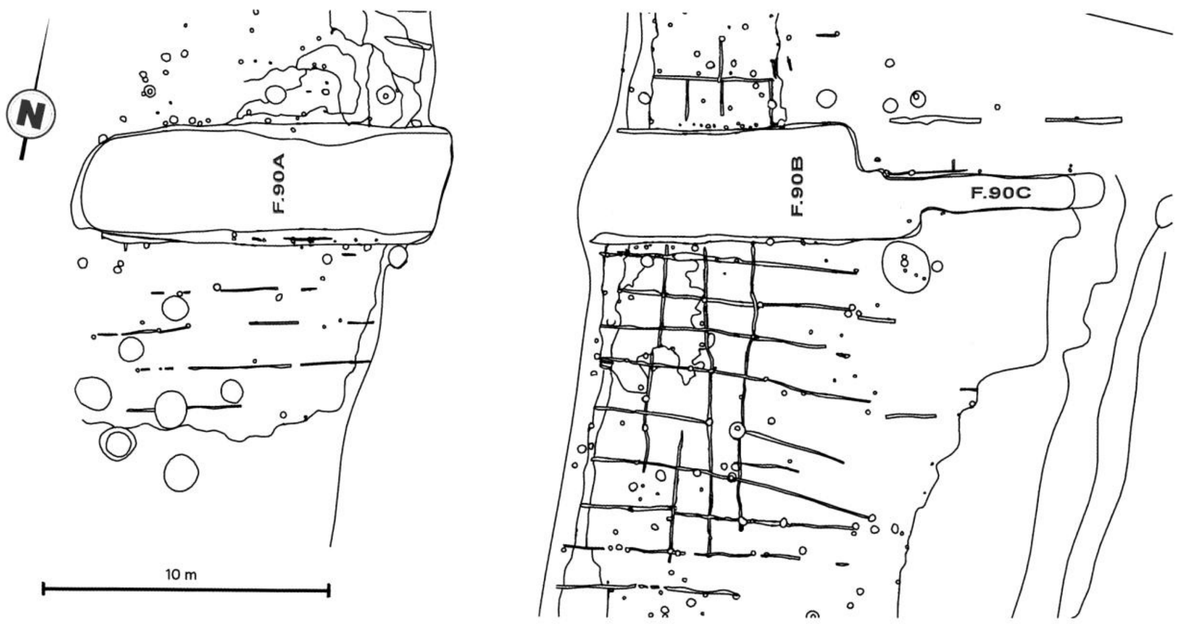

Fig. 19. Excavation plan of the bridgehead at the western periphery of rampart IV (trench 7 in Fig. 16). The corridor through the outwork (F.90A) is connected by a mobile bridge to the gate (F.90B) that considerably narrows (F.90C) in its course (Heeb et al., 2014).

The interpretation of the magnetic data and the results of the extensive systematic field walking allow identifying subsurface settlement structures and estimating the building density of the settlement areas within the innermost ramparts I and II (Szentmiklosi et al., 2011;

Heeb et al., 2012; Heeb et al., 2015). According to the obtained chronology of the documented artifacts, mostly pottery sherds, it is evident that its predominant majority date to the Late Bronze Age (Cruceni-Belegiş culture, phase I-III). In addition, fewer quantities of artifacts from the Copper Age (Tiszapolgár culture), Early Bronze Age (Makó culture), Middle Bronze Age (Vatina culture) and Iron Age (Gornea-Kalakatča culture) have been recorded, too (Fig. 20; Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2015). The ongoing archaeological re-investigation of Corneşti-Iarcuri since 2007 allows differentiating areas within the innermost two ramparts I and II that were densely settled during the Late Bronze Age in comparison to areas that show substantially lower settlement densities, or settlement clusters from other cultural epochs such as the Copper Age, respectively (Fig. 20 A, B; Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2015). The southern part within rampart II shows the highest Late Bronze Age settlement densities of the entire investigated area. Another area that was densely settled during the Late Bronze Age is located in the northeastern part of rampart I (Fig. 20 B). However, the comparison of the obtained amount of pottery sherds per square meter shows that the assumed settlement density during the Late Bronze Age must have been much higher in the southern part of rampart II than in the northeastern part of rampart I (Heeb et al., 2012; Heeb et al., 2015). Also, a round enclosure consisting of four ditches and settlement structures within have been identified in the southeastern part of rampart II. Based on the form and orientation of the houses and the distinct concentration of pottery sherds from the Tiszapolgár culture this finding is assumed to represent a defended Copper Age settlement (Fig. 20 A; Szentmiklosi et al., 2011).

Notwithstanding the numerous excavations that have been realized and the extensive areas that have been covered by magnetic prospections and systematic field walking since 2007, the impression of the prehistoric settlement landscape within the environs of Corneşti-Iarcuri remains fragmentary regarding its structure, its development and its dating. Moreover, the construction technique of the houses from wattle and daub or solid loam construction and the ongoing modern agricultural activities largely cause that the structures in the magnetograms are rather blurry and diffuse (Heeb et al., 2015) indicating the continuous destruction of the archaeological remains (Szentmiklosi et al., 2011) and thus the loss of the cultural heritage of this mega-site.

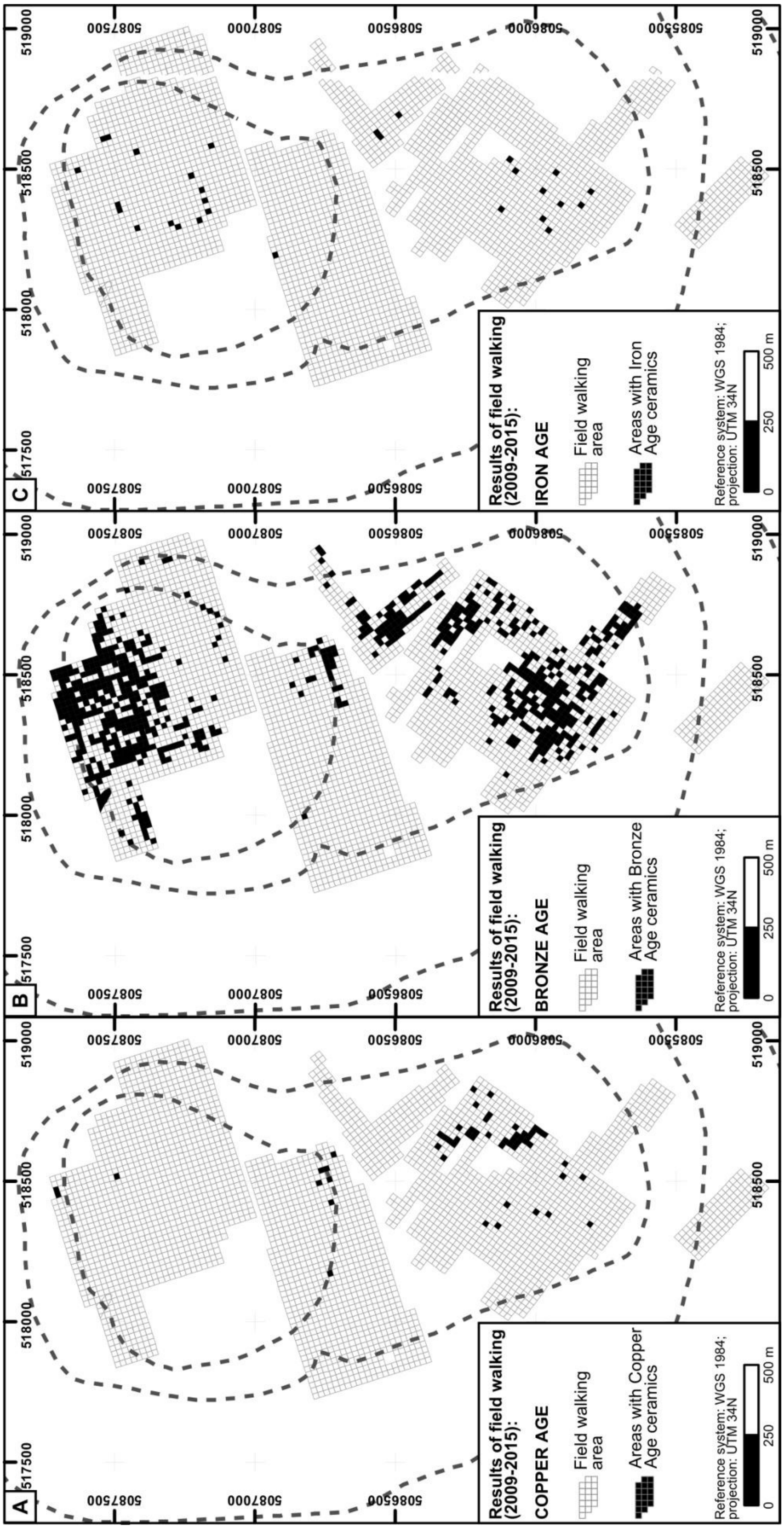

Fig. 20. Results of the archaeological field walking (2009-2015). Shown are the areas where ceramic fragments were found, but quantities are not indicated. A) distribution of Copper Age ceramics, B) distribution of Bronze Age ceramics, C) distribution of Iron Age ceramics (modified after Nykamp et al., 2017b).

4. Material and methods

The material and methods section comprises the texts of the corresponding chapters of the case studies (Nykamp et al., 2015; Nykamp et al., 2016; Nykamp et al., 2017a; Nykamp et al., 2017b). Partially these texts are modified and extended for this thesis; partially the original texts from the publications are used.

4.1. Field work

During two field campaigns in the summers 2013 and 2014 the present-day morphodynamic conditions, dominating relief forming processes and minor landforms were recorded systematically (Fig. 21) according to the guidelines of geomorphological mapping by Leser and Stäblein (1975). The nomenclature follows Leser and Stäblein (1985). Additionally, sediment archives for subsequent coring were systematically mapped in the environs of Corneşti-Iarcuri. Open and closed sediment cores (Table 1) with 5 cm diameter were obtained from selected sediment archives by vibra coring using a petrol driven hammer (Atlas Copco Cobra; Wacker BHF 30 S). The considered sediment archives comprise the high plain, the alluvial plains of the intersecting valleys, secondary alluvial fans originating from gully-like first order tributaries that dissect the hillslopes of the valleys and colluvial deposits originating from the foot slopes of the valleys (Fig. 21; Table 1). In order to allow the reconstruction of varying past morphodynamics in relation to the development of the settlement landscape and thus, to infer past human–environment interactions in the environs of Corneşti-Iarcuri coring locations in relation to the built-up area were chosen.

During a third field campaign subsurface compaction measurements were conducted in transects across selected present-day and historic field paths (Fig. 21) using a static hand penetrometer (Eijkelkamp Agrisearch Equipment). The spacing between the measurements was c. 5 m and usually a penetration depth of 90 cm was reached. The time of sampling was mid-March 2016. The compaction values are recorded in $N*cm^{-2}$ and were interpolated for the entire transect applying thin plate regression splines (Wood, 2003). At selected locations along two penetrometer transects 1 m open sediment cores with a diameter of 5 cm, driven in by vibra coring, were extracted (Table 1). The coring locations were placed on the former or present-day field paths and on the adjacent arable fields to allow comparison between these two different locations. Sediment samples for grain size analyses were systematically taken from the top, from c. 45 cm and c. 85 cm depth.

Table 1. UTM coordinates of the coring locations and short description of the cores and locations.

Coring ID	UTM coordinates		Remarks on cores and coring locations
	Easting	Northing	
COR 01	518402	5087567	Open core (3 m), on the high plain within enclosure I
COR 02	518448	5086462	Open core (4.1 m), on an alluvial fan
COR 03	518440	5086478	Closed core (3 m), on an alluvial fan
COR 04	518076	5086397	Closed core (7 m), in an alluvial plain
COR 05	518166	5086388	Open core (5 m), at a foot slope
COR 06	516902	5083823	Closed core (5 m), in an alluvial plain
COR 07	518598	5084380	Closed core (6 m), on an alluvial fan
COR 09	518382	5087731	Closed core (4 m), in an alluvial plain
COR 10	516822	5083887	Closed core (5.6 m), transition of a hillslope and an alluvial plain
COR 11	518276	5084382	Open core (5 m), on an alluvial fan
COR 12	517964	5087587	Open core (3 m), on an alluvial fan
COR 13	517977	5087584	Open core (1 m), on an alluvial fan
CL 10	516733	5085674	Open core (1 m), on a field path used in c. 1865 and in 1982, too; still in use
CL 11	516742	5085657	Open core (1 m), on an arable field (no field path delineated)
CL 12	516753	5085638	Open core (1 m), on an arable field (no field path delineated)
CL 13	520435	5085179	Open core (1 m), on an arable field (no field path delineated)
CL 14	520455	5085170	Open core (1 m), on a field path used in 1982; arable field at present
CL 15	520462	5085168	Open core (1 m), on an arable field (no field path delineated)
CL 16	520475	5085162	Open core (1 m), on an arable field (no field path delineated)

4.2. Sediment analyses

4.2.1. Sediment description and initial sample preparation

The sediments were described macroscopically according to Ad-Hoc-AG Boden (2005) and Schoeneberger et al. (2011); open cores were described on-site and closed cores were described off-site. Sediment units were identified according to their macroscopic characteristics. Color determination was done on non-dried sediments using the Munsell soil color charts (Fig. 22). Samples for chemical and physical analyses were taken in 10 cm intervals and processed at the Laboratory for Physical Geography of the Freie Universität Berlin. Initial sample preparation comprised sub-sampling, air-drying, crushing of aggregates in an agate grinder and separation of coarse components with a 2 mm sieve. The sub-samples used to determine chemical elements and carbon contents were homogenized in a vibrating disc mill followed by drying at 105 °C (Fig. 22).

4.2.2. Grain size distribution

The grain size distribution for the fraction ≤ 1 mm Ø was determined using a laser diffraction particle size analyzer (Beckmann-Coulter LS13 320). Sample preparation (Fig. 22) included removing of organic carbon using 10 % H_2O_2 and placing the samples for several days in a water bath at 50 °C. For the removal of carbonate 17 % HCl acid was used. Thereafter, the samples were washed and bi-distilled water together with about 0.5 g $Na_4P_2O_7$ as anti-coagulation agent was added. The samples were placed in an overhead shaker for 24 hours and treated with ultrasonic for 5 minutes directly before the measurement. The prepared samples were given to a liquid sample divider and two control samples were measured with three independent runs each. All six measurements per sample were averaged to obtain the grain size distribution (Vogel et al., 2016). Mie-theory was applied as the optical model using a refractive index (RI) of 1.55 and an absorption index (AC) of 0.1 as suggested by Özer et al. (2010) to avoid the underestimation of the clay fraction relative to the silt fraction (Eshel et al., 2004). Particle sizes were defined according to Ad-Hoc-AG Boden (2005).

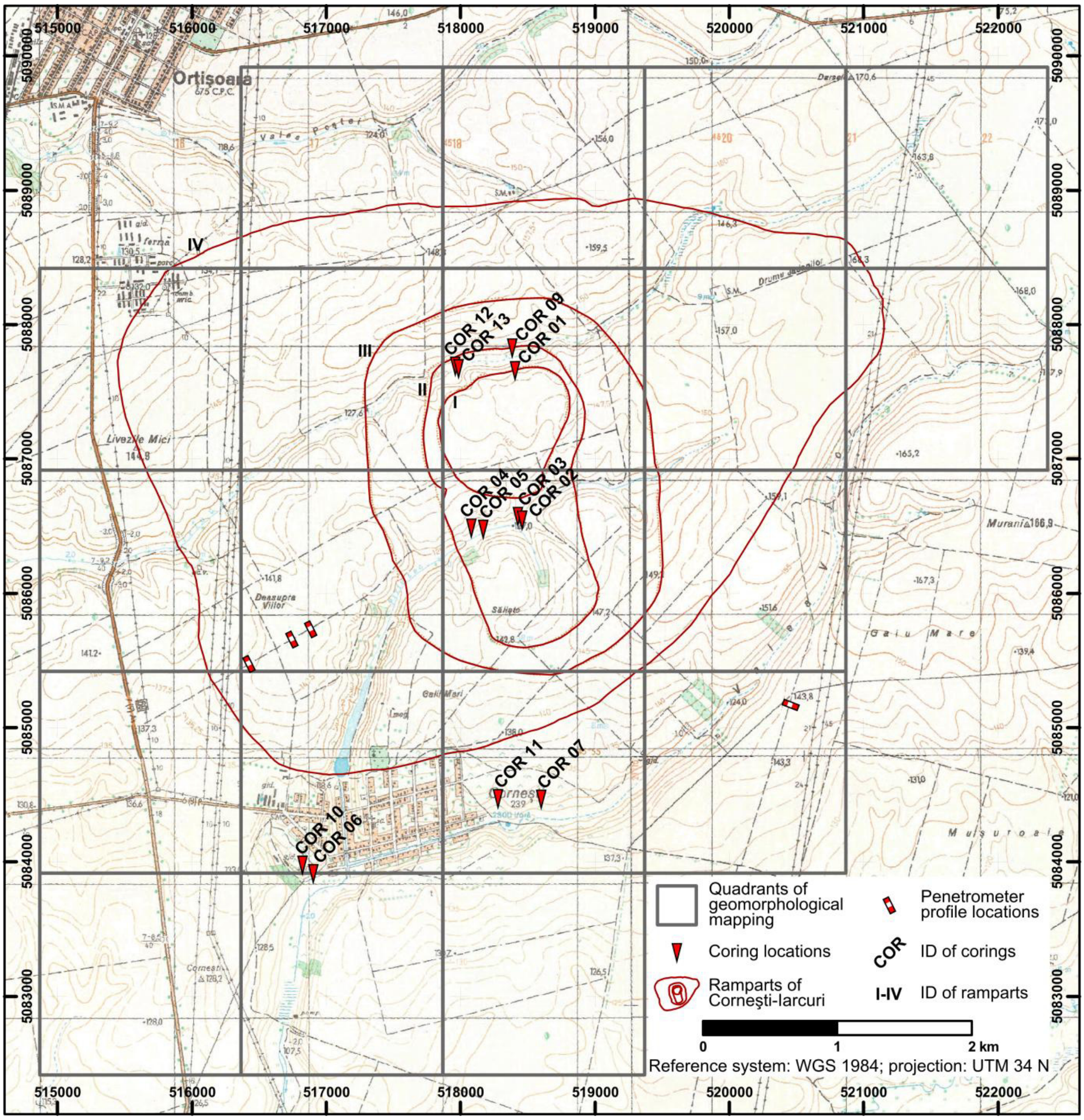

Fig. 21. Overview map of the conducted field work in the close vicinity of the enclosure of Corneşti-Iarcuri. Indicated are the quadrants that were mapped geomorphologically, the locations of the corings and the penetrometer profiles, and the four ramparts (I-IV) of Corneşti-Iarcuri (map basis: of topographic map, Direcţia Topografică Militară, 1982).

4.2.3. Magnetic susceptibility

Magnetic susceptibility (MS) at low frequency (0.46 kHz) was measured on air-dried weighted samples using the MS2B sensor (Bartington Instruments) with 10 cm^3 sample containers (Fig. 22). The bulk density of the samples was used to calculate the mass specific susceptibility (Dearing, 1999).

4.2.4. Carbon content

The total carbon (TC) contents (Fig. 22) were determined using the TruSpec CHN (Leco) analyzer. The samples were dry combusted at 950 °C in an O_2 atmosphere and carbon fluxes were quantified by infrared spectroscopy. A multi-point calibration curve was created using certified reference materials (CRMs) (Leco 502-309; 12.29 ± 0.37 mass.-% C; Leco 502-308; 3.6 ± 0.29 mass.-% C) and applied to calibrate the measured sample values. The relative standard deviation (RSD) of the measurements of all CRMs was < 2 mass.-% for the TC. The total inorganic carbon (TIC) contents (Fig. 22) were analyzed conductometrically using the Carmhograph C-16 (Wösthoff) carbon analyzer. The samples were treated with 42.5 % H_3PO_4 acid at 80 °C and the CO_2, evolving from the dissolved carbonates, was quantified through the change of conductivity of a 0.05 M NaOH solution. $CaCO_3$ (12.01 ± 0.14 mass.-% C) was used as a calibration standard and the RSD was < 2 mass.-%. By subtracting the TIC from the TC the total organic carbon (TOC) contents (Fig. 22) were calculated (Müller et al., 2014).

4.2.5. Loss on ignition

The loss on ignition (LOI_{550}; LOI_{900}) was determined following the procedure of Dean (1974) and calculated according to the equations in Heiri et al. (2001). The dried samples were placed in a muffle furnace and heated for four hours at 550 °C and 900 °C, respectively (Fig. 22). The results of the LOI_{550} and LOI_{900} measurements were tested on their linear relationship to the TOC and TIC contents applying the Pearson product-moment correlation (Crawley, 2007). The correction factor achieved by applying a multi-point calibration curve is used to calculate the TOC contents from the LOI_{550} and the TIC contents from the LOI_{900} measurements. The tests on linear relationship between the LOI_{500} and the TOC and the LOI_{900} and the TIC reveal strong positive correlations that are highly significant ($\alpha < 0.01$). The correlation of the LOI_{550} and the TOC ($n = 124$) shows a correlation coefficient of $r = 0.912$ ($\alpha < 0.05$) and a slope of 1.906. The correlation of the LOI_{900} and the TIC ($n = 124$) results in a correlation coefficient of $r = 0.941$ ($\alpha < 0.05$) and a slope of 3.331.

Workflow of laboratory analyses

Macroscopic sediment description (Ad-Hoc-AG Boden, 2005; Schoeneberger et al. 2011):
considered characteristics and features: color (Munsell soil color charts), texture, consistence, moisture, roots, rock fragments, carbonates (primary and secondary precipitated), organic matter, redoximorphic features, artefacts and charcoal (for dating).

Initial sample preparation:
sub-sampling, air-drying, crushing of aggregates in an agate grinder, separation of coarse components with a 2 mm sieve.

Grain size distribution (Beckmann-Coulter LS13 320):
- removal of organic carbon with 10 % H_2O_2
- removal of carbonate with 17 % HCl
- anti coagulation with $Na_4P_2O_7$
- overhead shaker treatment
- ultrasonic treatment
- sub-sampling with liquid sample divider
- determination of grain size distribution
- application of Mie-theory as optical model

Further sample preparation:
- drying at 105 °C

Magnetic susceptibility (Bartington Instruments MS2B sensor):
- determination of dry weight
- determination of volume
- calculation of bulk density
- measurement at low frequency (0.46 kHz)
- calculation of mass specific susceptibility

Loss on ignition (LOI_{550}; LOI_{900}):
- determination of dry weight
- ignition in muffle furnace at 550 °C
- determination of ignition weight (550 °C)
- ignition in muffle furnace at 900 °C
- determination of ignition weight (900 °C)

Further sample preparation:
- homogenization in vibrating disc mill

Total inorganic carbon (TIC) contents (Wösthoff Carmhograph C-16):
- determination of dry weight
- treatment with 42.5 % H_3PO_4 acid at 80 °C
- conductometric quantification of evolving CO_2 in 0.05 M NaOH solution

Total carbon (TC) content (Leco TruSpec CHN analyzer):
- determination of dry weight
- dry combustion at 950 °C in O_2 atmosphere
- quantification of carbon fluxes by infrared spectroscopy

Total organic carbon (TOC) content:
- subtraction of TIC from TC

Determination of chemical elements (Thermoscientific Niton XLt3 pED-XRF analyzer):
- measurement in 32 mm sample cups, covered with 0.4 µm mylar foil
- conversion of major elements into their oxides
- summing up of oxides and LOI_{550} and standardization to 100 %

Fig. 22. Workflow of the laboratory analyses indicating the basic processing steps and their chronological order.

4.2.6. Determination of chemical elements

A selection of chemical elements (Al, Si, Ca) were determined using a portable energy dispersive X-ray fluorescence (pED-XRF) analyzer (Thermoscientific Niton XLt3) on powdered and dried samples (Fig. 22) that were placed in 32 mm sample cups and covered with a mylar foil (0.4 µm) (Simandl et al., 2014). Four certified reference materials (CRMs: GBW 07312; NSC DC 73325; NSC DC 73387; NCS DC 73389) were used to create a multi-point calibration for each element (De Vleeschouwer et al., 2011). The measurements were carried out by applying the previously achieved calibration. To assess accuracy and reproducibility of the analyses the CRMs were re-measured after every ten sample measurements. The accuracy is an indicator of relative proximity of the measured values to the certified values and is expressed as percent difference (% diff). The repeated measurements of the CRMs under identical conditions allow achieving the reproducibility by calculating the relative standard deviation (% RSD) (Simandl et al., 2014). The high accuracy (Al = 5.13 % diff; Si = 3.52 % diff; Ca = 2.71 % diff) and good reproducibility (Al = 1.72 % RSD; Si = 0.74 % RSD; Ca = 2.63 % RSD) demonstrate the reliability of the sample measurements. However, only elements that show mean values larger than four times the 2 sigma error of the measurements were taken into account for the analyses. The major elements were converted into their oxides. All oxides, including the LOI_{550}, were summed up and standardized to 100 % (Schütt, 2004a).

4.2.7. Identification of core sections

Based on the macroscopically identified sediment units and the measured geochemical and sedimentological properties the different core sections were delimited. Geochemical and sedimentological variations among the individual core sections were tested on significance ($\alpha < 0.05$) applying the Wilcoxon rank-sum test, because not all sample distributions met the requirement of normality to apply the t-test (Crawley, 2007).

4.2.8. Radiocarbon dating

Radiocarbon datings (^{14}C AMS) were performed on charcoal remains at the Poznan Radiocarbon Laboratory. The ^{14}C ages were calibrated with OxCal 4.2 (Bronk Ramsey, 2009) and the IntCal13 calibration curve (Reimer et al., 2013). The yielded results provide an estimation of the maximal age as reworking of the material could not be excluded (Chiverrell et al., 2007).

4.3. Spatial data sets and GIS-based analyses

For the environs of Corneşti-Iarcuri LiDAR data was acquired and processed by ArcTron Airborne Sensing in spring 2013. The resulting digital elevation model (DEM) has a spatial resolution of 0.5 x 0.5 m^2. It was used to delineate the basic geomorphic units in the study area and to perform hydrological and morphometric analyses. The basic geomorphic units were complemented with the digitized mapping of the present-day morphodynamics, dominating relief forming processes and minor landforms. Thus, a detailed geomorphological of the study area based on classical field mapping and high resolution remote sensing data is achieved. Additionally, the topographic map with a scale of 1:25.000 (Direcţia Topografică Militară, 1982) was used to create a digital elevation model (DEM) of the wider surroundings of Corneşti-Iarcuri for complementary hydrological and morphometric analyses. The DEM was created by applying the TOPOGRID algorithm (Hutchinson, 1989) to the digitized contour lines of the topographic map (Direcţia Topografică Militară, 1982). The resulting DEM has a spatial resolution of 10 x 10 m^2. For the purpose of visualization of the study area within its regional and supra-regional context SRTM data (Shuttle Radar Topography Mission, 1 arc-second; USGS, 2014) and physical raster and vector data (Natural Earth Data, 2014) were used. All used spatial data sets have WGS 1984 as reference system; at the regional and local scale the data sets are projected in UTM 34N.

4.3.1. Map interpretation

Three map data sets (Fig. 23) were used for interpretation and digital feature extraction. The First Military Survey (Fig. 23 A) of the Habsburg Empire (Hofstätter, 1989; Kretschmer et al., 2004; data available from Arcanum, 2006) was done in the area of Timişoara between 1769 and 1772 at a scale of 1:28.800 (Petrovszki and Mészáros, 2010). Details of the georeferencing procedure can be found in Molnár et al. (2014). The mapping of the Second Military Survey (Fig. 23 B) of the Habsburg Empire (Hofstätter, 1989; Kretschmer et al., 2004; Timár, 2004; Timár et al., 2006; data available from Arcanum, 2006) in the study area was done between 1864 and 1865 at a scale of 1:28.800 (Petrovszki and Mészáros, 2010). Details of the georeferencing procedure can be found in Timár et al. (2006) and Molnár et al., (2014). The topographic map (Fig. 23 C; Direcţia Topografică Militară, 1982) was used as the modern reference to qualitatively record the historic landscape development. The changes of vegetation cover and land use were recorded from the maps of the First and the Second Military Survey, thus providing a qualitative interpretation for the two time slices from the late eighteenth and late nineteenth century. The field paths from the Second Military Survey map and the topographic map were digitized to record and compare the development of the local field path system.

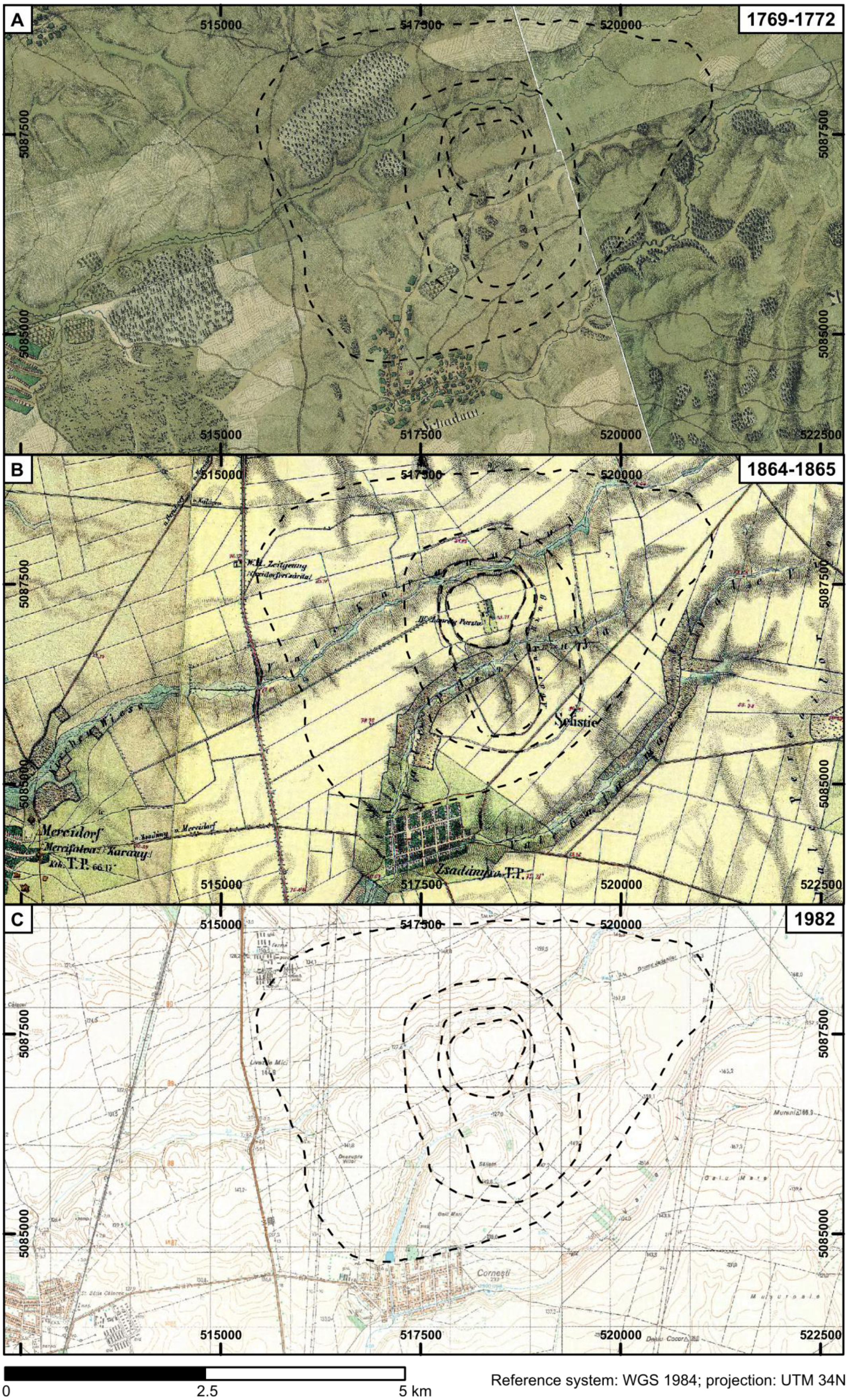

Fig. 23. Comparison of historic and modern maps (Nykamp et al., 2017b). A) First Military Survey of the Habsburg Empire (Hofstätter, 1989; Kretschmer et al., 2004). B) Second Military Survey of the Habsburg Empire (Hofstätter, 1989; Kretschmer et al., 2004; Timár, 2004; Timár et al., 2006). C) Topographic map (Direcţia Topografică Militară, 1982).

4.3.2. Morphometric and hydrological analyses

The topographic map-derived DEM was used to compare different catchments in the wider surroundings of Corneşti-Iarcuri that show a different impact of prehistoric settlement activities regarding their hydrologic characteristics. Therefore, drainage divides and ordered (Strahler, 1957) drainage networks were derived using an A^T least-cost search algorithm (Ehlschlaeger, 1989; Jasiewicz and Metz, 2011). Based on this the basin size and drainage density (Leopold et al., 1995) were calculated for the basins. First and second order tributaries that directly drain into the main channel were counted and the frequency of tributaries per kilometer of the main channel course was recorded. The ratio between length of the flow path and the distance from the source to the mouth (Ahnert, 2003) of the tributaries was used to distinguish between the straight, slightly bending and bending courses. The basin of the Lake valley is compared to neighboring third order basins: while the Lake valley is almost entirely surrounded by the four ramparts of Corneşti-Iarcuri and therefore represents an area highly affected by settlement activities. The neighboring third order basins are more or less unaffected by prehistoric settlement activities. The basins to be compared with the Lake valley basin are chosen due to their order, size and proximity to site of Corneşti-Iarcuri.

Morphometric and hydrological analyses were also conducted on the LiDAR-based DEM. Initial DEM processing comprised smoothing and resampling. To reduce the noise of the surface elevation that is caused by the high ground resolution of the LiDAR data (initially 0.5 x 0.5 m^2) a large moving window (69 x 69 cells) was applied for smoothing (Wood, 1996). A pixel resampling to a resolution of 1 x 1 m^2 was done in order to reduce the impact of very small artificial features like furrows. The processed DEM was used to derive the slope angle and the profile curvature using a moving window of 11 x 11 cells (Wood, 1996). The drainage divides and ordered (Strahler, 1957) stream segments were deduced applying an A^T least-cost search algorithm to the LiDAR DEM (Ehlschlaeger, 1989; Jasiewicz and Metz, 2011). The DEM derivates were used to characterize the relief and the stream network morphometrically. The geometry of all tributaries that contribute to the creeks in the Carani and Lake valley was assessed using the flow path length to distance-ratio (Ahnert, 2003).

4.3.3. Local relief model

A local relief model is used to extract shallow, small-scale features from a LiDAR-derived DEM by removing large-scale landscape forms (Hesse, 2010). The LiDAR-derived DEM (ground resolution: 0.5 x 0.5 m^2) covering the site of Corneşti-Iarcuri was used to create the local relief model. The original DEM was smoothed by applying a low-pass filter with a kernel size of 49 cells, which is in good agreement with the kernel size found experimentally by Hesse (2010). The smoothed DEM was subsequently subtracted from the original DEM and a purged DEM was created. The purged DEM was then subtracted from the original DEM to obtain the local relief model (Hesse, 2010). The workflow described by Hesse (2010) was applied using the GRASS GIS (GRASS Development Team, 2015) add-on r.local.relief and the LiDAR DEM as input elevation data. Due to the known problem that convex and concave landforms often cause the generation of artifacts in the local relief model (Hesse, 2010) a landform classification was applied to extract the flat areas of the high plain in the surroundings of Corneşti-Iarcuri. The approach published by Stepinski and Jasiewicz (2011) and Jasiewicz and Stepinski (2013) was applied using the GRASS GIS (GRASS Development Team, 2015) add-on r.geomorphons with an outer search radius of 50 m, an inner search radius of 20 m, a flatness threshold of 1.5° and a flatness distance of 0 m. Thus, a rather general classification, from a higher and wider perspective (Stepinski and Jasiewicz, 2011), was used to extract the high-lying flat areas that are used for the local relief model.

4.3.4. Topographic swath profiles

The analysis of topographic profiles as a traditional method in geomorphology always involves the subjective selection of profile locations. The profiles can be either placed rather randomly or, by contrast, in a tendentious way, reducing the objectiveness of a study. To avoid this problem topographic swath profiles can be used (Telbisz et al., 2013; Hergarten et al., 2014). Generally, topographic swath profiles are stacked parallel profiles whereby the profile line is extended to a rectangular swath of a given width. By calculating e.g. the mean of the considered profiles a three dimensional phenomenon, e.g. a river valley, can be represented in two dimensions (Telbisz et al., 2013; Hergarten et al., 2014). Hergarten et al. (2014) modify this approach in the way that a curved baseline along the feature of interest is defined (Fig. 24). The signed (oriented) distance from the baseline is then used to generate lines of constant distance. At defined intervals along the lines of constant distance the elevation values of a DEM are used to generate the swath profile (Fig. 24). The advantage over ordinary swath profile approaches is that each point of elevation data contributes only once to the profile, thus over or under sampling and asymmetric sampling is avoided (Hergarten et al., 2014). The topographic swath profiles were generated along selected digitized path ways of the Second Military Survey map (Hofstätter, 1989; Kretschmer et al., 2004; Timár, 2004; Timár et al., 2006) and the topographic map (Direcţia Topografică Militară, 1982). The LiDAR DEM was used as input elevation data. The procedure described by Hergarten et al. (2014) was applied using the QGIS (QGIS Development Team, 2014) swath profile plug-in (available from: www.krambach.de/swath-profile/index.html). Lines of constant distance were generated at intervals of 0.5 m within a swath of 40 m width and then sampled at intervals of 0.5 m.

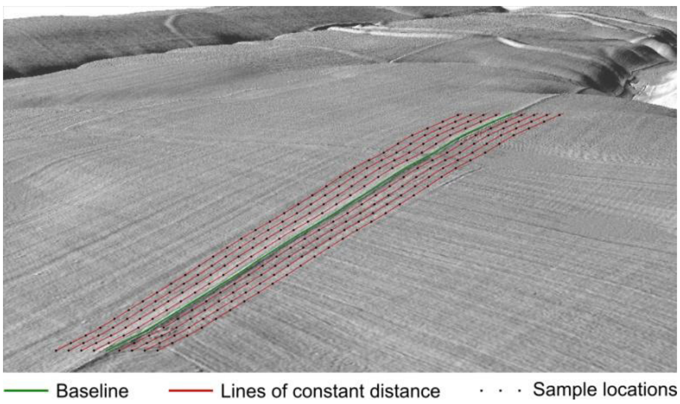

Fig. 24. Visualization of the applied method generating topographic swath profiles (Nykamp et al., 2017b).

5. Case studies

5.1. Estimation of wind-driven soil erosion of a loess-like sediment and its implications for the occurrence of archaeological surface and subsurface finds – An example from the environs of Corneşti-Iarcuri, western Romania

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Key words: Tillage-induced erosion; Topographic swath profiles; Local relief model; LiDAR data; Historic maps; Archaeological heritage management; Geoarchaeology

Abstract

This study introduces an easy-to-apply approach to studying historic landscape development and tillage-induced wind-driven soil erosion of a loess-like sediment. It discusses the implications of these processes for the preservation of cultural remains in the environs of the largest known European ground monument – Corneşti-Iarcuri. This Late Bronze Age enclosure is located in the loess-covered, undulating plains of western Romania and consists of four earth-filled wooden ramparts. Interpretation of historic and modern maps is combined with the study of written sources to qualitatively record historic landscape development. It is shown that major changes in the natural environment, including the intensification of arable farming and the regular establishment of straight field paths, occurred in the study area between c. 1770 and c. 1865. The amount of surface lowering due to wind-driven soil erosion is estimated using a combination of systematic feature extraction from the historic and modern maps, high resolution modeling of the topography based on LiDAR data, subsurface compaction measurements and grain size analyses. The surface lowering on the arable fields of the high plain since c. 1865 totals between 10 and 40 cm. This, together with the actual plowing depth of c. 30 cm, implies that archaeological structures must have penetrated the subsurface to between 40 and 70 cm in order to be preserved in the present-day subsurface. Thus, this study shows that a considerable portion of the cultural heritage has presumably been lost. Moreover, the still intact lower-lying stratigraphy is threatened by the destructive impact of plowing that successively reaches greater depths due to ongoing tillage-induced wind-driven soil erosion on the arable fields. However, bioturbation causing distortion of the systemic context of the cultural remains cannot be excluded, as Luvic Phaeozems and Luvic Chernozems prevail in the study area.

5.1.1. Introduction

Modern agricultural techniques, particularly plowing, pose a serious yet underestimated threat to archaeological heritage, affecting the systemic context of the features or even causing the complete destruction of the cultural remains. The destructive impact of plowing on archaeological sites is especially severe when accelerated by soil erosion (Lambrick, 1977; Wildesen, 1982; Wilkinson et al., 2006; Navazo and Díez, 2008; Trow, 2010; Meylemans et al., 2014). Thus, for many archaeological studies it is crucial to know how the environment has changed and to what extent the archaeological record has been altered by the combination of soil erosion and plowing in order to evaluate the completeness of the documented archaeological record (Lambrick, 1977; Waters and Kuehn, 1996; Wilkinson et al., 2006; Navazo and Díez, 2008).

Archaeological sites located on fine-grained sediments, such as loess, are of special interest for the study of plowing and soil erosion impacts on cultural remains for two main reasons. First, early agricultural settlements in Central Europe (e.g. Linear Pottery culture) are frequently found along the so-called loess-belt that can be seen as a series of basins filled with fine-grained aeolian sediments generally forming easily workable and fertile soils (Bogucki and Grygiel, 1993; Bogucki 1996). These loess-derived soils are among the most fertile soils and are of particular significance for agriculture – both in the past and today (Catt, 2001). Thus, a large number of archaeological sites can be expected at these locations. In consequence, many archaeological sites occur in areas of intensive arable farming, because these areas have always favored the development of human settlements (DEFRA, 2002). Second, due to their high silt contents loess soils are generally very prone to erosion by wind and water (Pécsi and Richter, 1996). Mainly due to increased electrostatic and molecular cohesion, silt-sized particles require larger erosive forces for entrainment by wind, however, once entrained they are usually transported in suspension over large distances (Pye, 1987; Livingstone and Warren, 1996; Wiggs, 2011a). The entrainment of particles by wind is significantly altered when the land is prepared for agriculture; bare agricultural fields are far more susceptible to wind erosion and disturbance is heightened by practices such as plowing and weeding causing the break-up of aggregates and the artificial lifting of particles (Pye, 1987; Tsoar and Yekutieli, 1992; Wiggs, 2011b).

Any form of erosion causes, among other effects, the active lowering of the surface. In the light of archaeological heritage management, this implies that the destructive action of plowing successively reaches greater depths leading to the disappearance of the cultural remains (DEFRA, 2002).

Here we present a case study from the archaeological site Corneşti-Iarcuri in western Romania (Fig. 25). The value of studying historic landscape development and soil erosion in order to evaluate their effect on the occurrence and alteration of archaeological surface and subsurface finds is demonstrated. A combination of historic map interpretation, high resolution topography modeling, underground compaction measurements and grain size analyses is applied to record the landscape development and estimate the soil erosion-induced lowering of the surface in historic times. Subsequently, the minimum penetration depth required by archaeological structures to ensure their preservation is deduced and the combined impact of plowing and soil erosion is discussed. Thus, this study aims to answer the following questions: (1) How much was the surface of the Late Bronze Age site Corneşti-Iarcuri lowered in historic times? (2) What is the minimum penetration depth that archaeological structures must have had to be preserved in the present-day subsurface? (3) What is the dominating erosion process?

5.1.2. Study site

5.1.2.1. Environmental characteristics

The archaeological site Corneşti-Iarcuri is located at the eastern edge of the Great Hungarian Plain in western Romania (Fig. 25), c. 20 km north of the city of Timişoara. The landscape in which Corneşti-Iarcuri was erected is part of the southern Vinga Plain, which is part of the geomorphic unit of the Romanian high piedmont plain (Badea et al., 1979; Grigoraş et al., 2004). Large coalescing lobes of the Mureş alluvial fan formed the high piedmont plain that is widely covered with Quaternary loess and loess-like deposits (Grigoraş et al., 2004; Haase et al., 2007). The present-day climate is moderately temperate with a mean annual precipitation of 550 mm and a potential evapotranspiration of 700 mm (Grigoraş et al., 2004). Typically, Luvic Chernozems and Luvic Phaeozems are developed in these silt-dominated sediments (Grigoraş et al., 2004). The relief of the Vinga Plain is generally characterized by low slope gradients and its slight southwest dipping determines the northwest-southeast alignment of the drainage network (Grigoraş et al., 2004). In the environs of Corneşti-Iarcuri, extensive, slightly undulating interfluves with slope gradients of between 0° and 2° alternate with wide saucer-shaped valleys (nomenclature according to Leser and Stäblein, 1985) where slope gradients of 10° to 18° in the midslope sections of the hillslopes are reached (Nykamp et al., 2015). The present-day morphodynamics are mainly controlled by the vegetation cover and land use; agricultural areas show different forms of sediment movement while the steppe grass areas usually lack signs of sediment redistribution. Overall, the different process areas can be subdivided according to the two general landscape units: the high plains on the interfluves and the intersecting valleys. Gullying, sheet wash and soil creep occur on the hillslopes of the valleys, whereas splash erosion and deflation dominate on the bare surfaces of the high plain (Nykamp et al., 2016). Even though the processes of wind-driven soil erosion are known to be a serious issue on the arable land of the Great Hungarian Plain and in the lowlands of Romania (Kiss et al., 2015; Mezősi et al., 2015; Borrelli et al., 2017), there is a lack of field-based studies for the study area. Information on the regional scale can be gained from modeling approaches (Borrelli et al., 2015; Mezősi et al., 2015; Borrelli et al., 2016; Borrelli et al., 2017). Borrelli et al. (2015, 2016) predicted a low to very low land susceptibility to wind erosion for the study area itself, but moderate to high values for the areas in its southern vicinity. Likewise, the potential soil loss due to wind erosion is predicted to be low in the environs of Corneşti-Iarcuri, but again moderate to high further to the south (Borrelli et al., 2017).

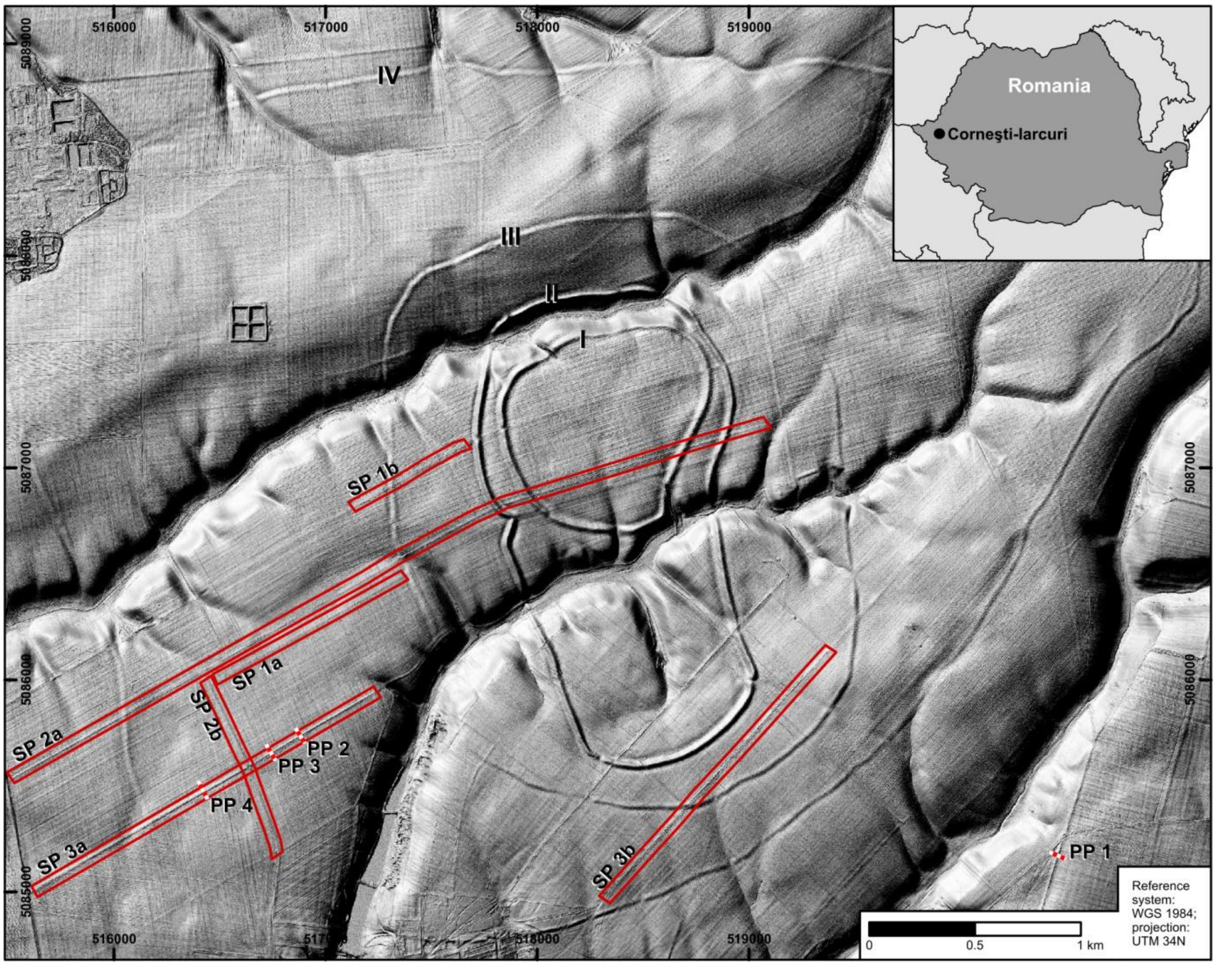

Fig. 25. Overview of the study site in western Romania (upper right; vector data from Natural Earth Data, 2014) and shaded relief of the environs of Corneşti-Iarcuri (based on LiDAR data). The four ramparts (numbered from I to IV from the inside out) and the linear structures are clearly visible in the shaded relief. The locations of the selected swath profiles (SP) along the linear features are indicated as vector polygons to avoid the covering of the linear features by vector polylines. The locations of the compaction measurement along the penetrometer profiles (PP) crossing the linear features are also indicated. The maps are projected in UTM 34N.

5.1.2.2. Archaeological background

Corneşti-Iarcuri is the largest known enclosure of European prehistory and, to date, the largest ground monument in Europe (Szentmiklosi et al., 2011; Heeb et al., 2015). Its four earth-filled wooden ramparts have a circular to ellipsoid shape (Fig. 25), altogether a total length of > 33 km, and enclose an area of c. 17.6 km² (Szentmiklosi et al., 2011; Heeb et al., 2014; Heeb et al., 2015). The ramparts date to the Late Bronze Age and the transition to the Early Iron Age and are numbered I to IV from the inside out (Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2015). The results of extensive systematic field walking and the chronology of the obtained artifacts (Fig. 26), mostly pottery sherds, confirm that the vast majority of the documented artifacts date to the Late Bronze Age (Cruceni-Belegiş I-III). Also, artifacts from the Copper Age (Tiszapolgár), Early Bronze Age (Makó), Middle Bronze Age (Vatina) and Iron Age (Gornea-Kalakatča) are present, but in much lower quantities (Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2015) (Fig. 26).

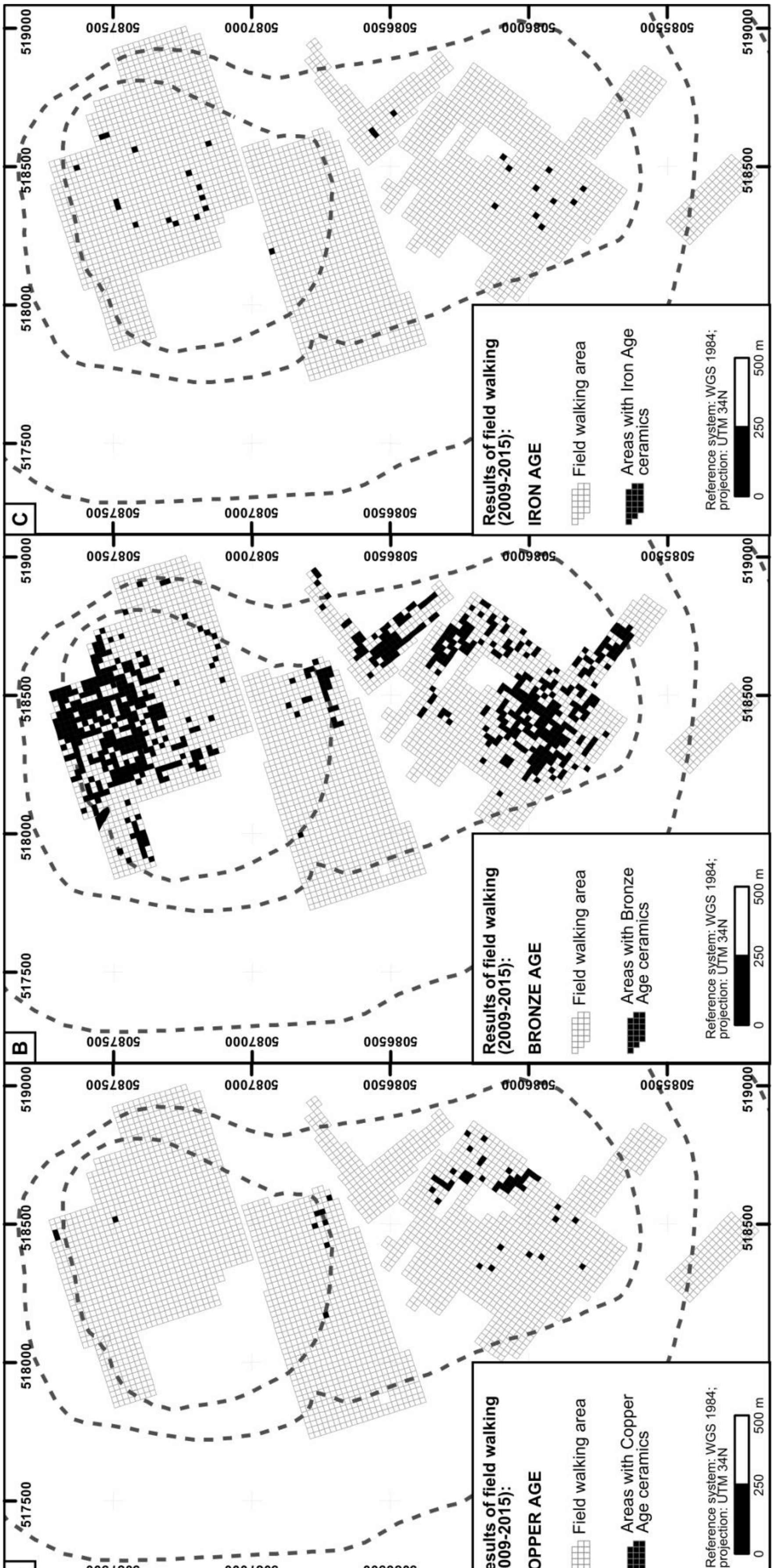

Fig. 26. Results of the archaeological field walking (2009-2015). The areas where ceramic fragments were found are shown, but quantities are not indicated. The maps are projected in UTM 34N.

Many of the sherds obtained are clearly from prehistory, but a more precise dating is not possible (Heeb et al., 2012). In combination with the results of magnetic prospections, the results of the field walking and the excavations indicate that the remains of settlements of varying density and from different cultural epochs are present in the area of the two innermost ramparts (Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2015). Notwithstanding the extensive areas covered by systematic field walking, magnetic prospection and excavations, it has only been possible to gain a fragmentary impression of the structure, development and dating of the prehistoric settlement landscape within the ramparts. The houses were constructed from wattle and daub or solid loam, and this combined with modern agricultural practices in the environs of Corneşti-Iarcuri, mean that the structures in the magnetograms are rather blurred and diffuse (Heeb et al., 2015), indicating the ongoing destruction of the archaeological remains in the area (Szentmiklosi et al., 2011).

5.1.2.3. Historic landscape development

The Banat region (*Temeser Banat*) roughly covers the area between the Mureş River, the Tisa River, the Danube and the Transylvanian foothills (Schwicker, 1872). Its historic landscape development, the waves of depopulation and resettlement, and the history of drainage works and land reclamation are particularly well recorded in several historic and modern descriptions (von Dorner, 1839; Schwicker, 1872; Bußhoff, 1938; Rieser, 1992). In the year 1552 the city of Timişoara was conquered by the Turks, who ruled the region harshly for the following 164 years (Schwicker, 1872). Due to the war between the Turks and the Hungarians many villages were devastated and wide areas of the region were depopulated (Schwicker, 1872; Bußhoff, 1938; Petrovszki and Mészáros, 2010). During Turkish rule the Banat largely remained depopulated and uncultivated, and even 200 years later heaps of debris were often the only reminders of villages that were first mentioned in written form in 1536. The rivers, unmanaged during this time, frequently flooded the low-lying areas forming extensive swamps (Schwicker, 1872; Bußhoff, 1938; Petrovszki and Mészáros, 2010). The Turks were finally ousted by the Habsburgs in the year 1717, and in 1720 Count Mercy initiated land reclamation from the wilderness and the swamps (Schwicker, 1872; Rieser, 1992). It took only ten years to see first results regarding the transformation of the barren land, the wilderness and the swamps into fertile arable land and the new formation of the villages. However, between 1737 and 1739 the plague again caused depopulation of the region (Schwicker, 1872). In 1763 an imperial colonization patent was issued leading to the resettlement of several thousand people into the Banat region. Large swamp areas were subsequently drained and transformed into arable land and pastures to become one of the most productive areas of the Habsburg Empire (von Dorner, 1839; Schwicker, 1872; Rieser, 1992; Petrovszki and Mészáros, 2010; Munteanu et al., 2014). In the year 1865 the study area was largely characterized by extended agricultural areas. Up to 75 %, in some cases more, of the area was used for arable farming at this time (Kókai, 2009).

5.1.3. Materials and methods

5.1.3.1. Map interpretation and feature extraction

Three map data sets were used for interpretation and digital feature extraction. The First Military Survey of the Habsburg Empire (Hofstätter, 1989; Kretschmer et al., 2004; data available from Arcanum, 2006) was undertaken in the area of Timişoara between 1769 and 1772 and was recorded at the scale of 1:28.800 (Petrovszki and Mészáros, 2010). The mapping of the Second Military Survey of the Habsburg Empire in the Banat region (Hofstätter, 1989; Kretschmer et al., 2004; Timár, 2004; Timár et al., 2006; data available from Arcanum, 2006) was conducted in 1864/1865 and was recorded at the scale of 1:28.800 (Petrovszki and Mészáros, 2010). Details on the georeferencing procedure of both map sets can be found in Timár et al. (2006) and Molnár et al., (2014). The modern topographic map (Direcţia Topografică Militară, 1982) has a scale of 1:25.000 and was used as the present-day reference to qualitatively record the historic landscape development.

In addition to topographic information, the maps of the First and Second Military Survey provided information on land use and vegetation cover for the late eighteenth and late nineteenth centuries, respectively. The field paths from the Second Military Survey map and the topographic map were digitized to record and compare the development of the local field path system.

5.1.3.2. Local relief model

A local relief model was used to extract shallow, small-scale features from a LiDAR-derived digital elevation model (DEM) by removing large-scale landscape forms (Hesse, 2010). The LiDAR data covering the site of Corneşti-Iarcuri was acquired and processed by ArcTron Airborne Sensing in spring 2013; its ground resolution is 0.5 m x 0.5 m. The original DEM was smoothed by applying a low-pass filter with a kernel size of 49 cells, which is in good agreement with the kernel size found experimentally by Hesse (2010). The smoothed DEM was subsequently subtracted from the original DEM and a purged DEM was created. The purged DEM was then subtracted from the original DEM to obtain the local relief model (Hesse, 2010). The workflow described by Hesse (2010) was applied using the GRASS GIS (GRASS Development Team, 2015) add-on r.local.relief and the LiDAR DEM as input elevation data.

Due to the known problem that convex and concave landforms often cause the generation of artifacts in the local relief model (Hesse, 2010), a landform classification was applied to extract the flat areas of the high plain in the surroundings of Corneşti-Iarcuri. The approach published by Stepinski and Jasiewicz (2011) and Jasiewicz and Stepinski (2013) was applied using the GRASS GIS (GRASS Development Team, 2015) add-on r.geomorphons with an outer search radius of 50 m, an inner search radius of 20 m, a flatness threshold of 1.5° and a flatness distance of 0 m. Thus, a rather general classification from a higher and wider perspective (Stepinski and Jasiewicz, 2011) was used to extract the high-lying flat areas that are used for the local relief model.

5.1.3.3. Topographic swath profiles

The analysis of topographic profiles, as a traditional method in geomorphology, always involves the subjective selection of profile locations. The profiles can be either placed rather randomly or, by contrast, in a tendentious way, reducing the objectiveness of a study. To avoid this problem topographic swath profiles can be used (Telbisz et al., 2013; Hergarten et al., 2014). Generally, topographic swath profiles are stacked parallel profiles whereby the profile line is extended to a rectangular swath of a given width. By calculating the mean of the considered profiles a three dimensional phenomenon, e.g. a river valley, can be represented in two dimensions (Telbisz et al., 2013; Hergarten et al., 2014). Hergarten et al. (2014) modify this approach so that a curved baseline along the feature of interest is defined. The signed (oriented) distance from the baseline is then used to generate lines of constant distance. At defined intervals along the lines of constant distance the elevation values of a DEM are used to generate the swath profile (Fig. 27). The advantage over ordinary swath profile approaches is that each point of elevation data contributes only once to the profile, thus avoiding over- or under-sampling as well as asymmetric sampling (Hergarten et al., 2014).

The topographic swath profiles were generated along selected digitized path ways (Fig. 25) of the Second Military Survey map (Hofstätter, 1989; Kretschmer et al., 2004; Timár, 2004; Timár et al., 2006) and the topographic map (Direcţia Topografică Militară, 1982). The LiDAR DEM was used as input elevation data. The procedure described by Hergarten et al. (2014) was applied using the QGIS (QGIS Development Team, 2014) swath profile plug-in (available from: www.krambach.de/swath-profile/index.html). Lines of constant distance were generated at intervals of 0.5 m within a swath of 40 m width and then sampled at intervals of 0.5 m.

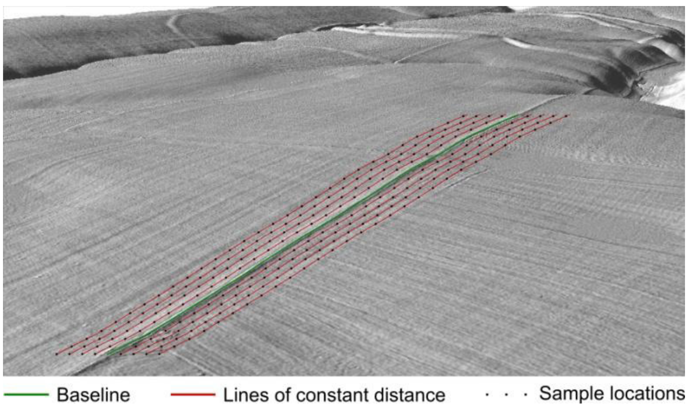

Fig. 27. Visualization of the applied method of generating topographic swath profiles. Lines of constant distance (red lines) are generated using the signed (oriented) distance to the defined baseline (green line); then samples from the underlying DEM are taken at defined intervals (black dots) along the lines of constant distance.

5.1.3.4. Subsurface compaction measurements

Field measurements of subsurface compaction were conducted in transects across selected present-day and historic field paths (Fig. 25) using a static hand penetrometer (Eijkelkamp Agrisearch Equipment). The spacing between the measurements was c. 5 m and usually a penetration depth of 90 cm was reached. The time of sampling was mid-March 2016. The compaction values are recorded in $N*cm^{-2}$ and were interpolated for the entire transect applying thin plate regression splines (Wood, 2003).

5.1.3.5. Grain size analyses

At selected locations along two penetrometer transects (Fig. 31; Table 2) 1 m open sediment cores with a diameter of 5 cm, driven in by vibra coring, were extracted. The coring locations were placed on the former or present-day field paths and on the adjacent arable fields to allow comparison between these two different locations. Sediment samples for grain size analyses were systematically taken from the top, from c. 45 cm and c. 85 cm depth. All samples were processed and their grain size composition analyzed in the Laboratory for Physical Geography of the Freie Universität Berlin. A laser diffraction particle analyzer (Beckmann-Coulter LS13 320) was used to determine the grain size distribution and Mie-theory was applied as the optical model with a refractive index of 1.55 and an absorption index of 0.1 (Özer et al., 2010). The definition of particle sizes follows Ad-Hoc-AG Boden (2005). The sample preparation and measurement procedure for the grain size analyses are described in Nykamp et al. (2016). To test the significance ($\alpha < 0.05$) of variations of the grain sizes for the locations of the former or present-day field paths and the adjacent arable fields the Wilcoxon rank-sum test was applied (Crawley, 2007). Tests on significant variations were performed between the uppermost samples of the two different locations (former or present-day field path and arable field) and between the uppermost sample and the two lower samples of each core. The design of the test statistics allows the identification of any significant variation among the topsoil of the different locations and the top- and subsoil of each coring site.

Table 2. UTM coordinates of the coring locations.

Coring ID	UTM coordinates of coring locations		Remarks on coring locations
	Easting	Northing	
CL 10	516733	5085674	Field path used in c. 1865 and in 1982, too; still in use
CL 11	516742	5085657	Arable field (no field path delineated)
CL 12	516753	5085638	Arable field (no field path delineated)
CL 13	520435	5085179	Arable field (no field path delineated)
CL 14	520455	5085170	Field path used in 1982; arable field at present
CL 15	520462	5085168	Arable field (no field path delineated)
CL 16	520475	5085162	Arable field (no field path delineated)

5.1.4. Results

5.1.4.1. Map interpretation

The historic map sheets of the First and Second Military Survey of the Habsburg Empire visualize the landscape development in the environs of Corneşti-Iarcuri for the time slices 1769-72 and 1864-65. In comparison to the topographic map from 1982 the development of the landscape and the changes of land use and infrastructure can be deduced qualitatively (Fig. 28A-C).

The map sections of the First Military Survey (Fig. 28A) show the environs of Corneşti-Iarcuri at c. 1769-72. The land cover is characterized by vast areas of steppe grass with locally occurring forest patches. Few areas, mostly in the close vicinity of the villages, are used for arable farming. Except for a small area in the northern part of rampart IV agricultural fields were not present in the area of Corneşti-Iarcuri at this time. The network of roads and field paths usually ran across the high plains of the interfluves and connected the villages rather directly. A clear pattern of rectangular field paths or straight country roads is not perceptible (Fig. 28A).

The character of the landscape recorded by the Second Military Survey at c. 1864-65 (Fig. 28B) had changed drastically. Besides few patches of steppe grass vegetation occurring in the direct vicinity of the villages, the entire area was used for arable farming. The areas that were forested or steppe during the First Military Survey had largely changed into agricultural fields within the c. 95 years between the surveys. Even most of the hill slopes of the valleys were used for arable farming at c. 1864-65. Also, the entire layout of the country roads and field paths changed substantially during this time. At c. 1864-65 straight country roads connected the villages, a rectangular pattern of field paths had been established, and the main road connecting Timişoara and Arad, west of Corneşti-Iarcuri, had been developed (Fig. 28A and B).

In the topographic map from 1982 (Fig. 28C) the areas used for arable farming or pasture are not delineated, but the regular set up of roads and rectangular field paths as already recorded by the Second Military Survey is shown. The locations of the country roads and the main road west of Corneşti-Iarcuri did not change between c. 1864-65 and 1982. The locations of the field paths, however, changed in some areas while other field paths remained at the same location (Fig. 28B and C).

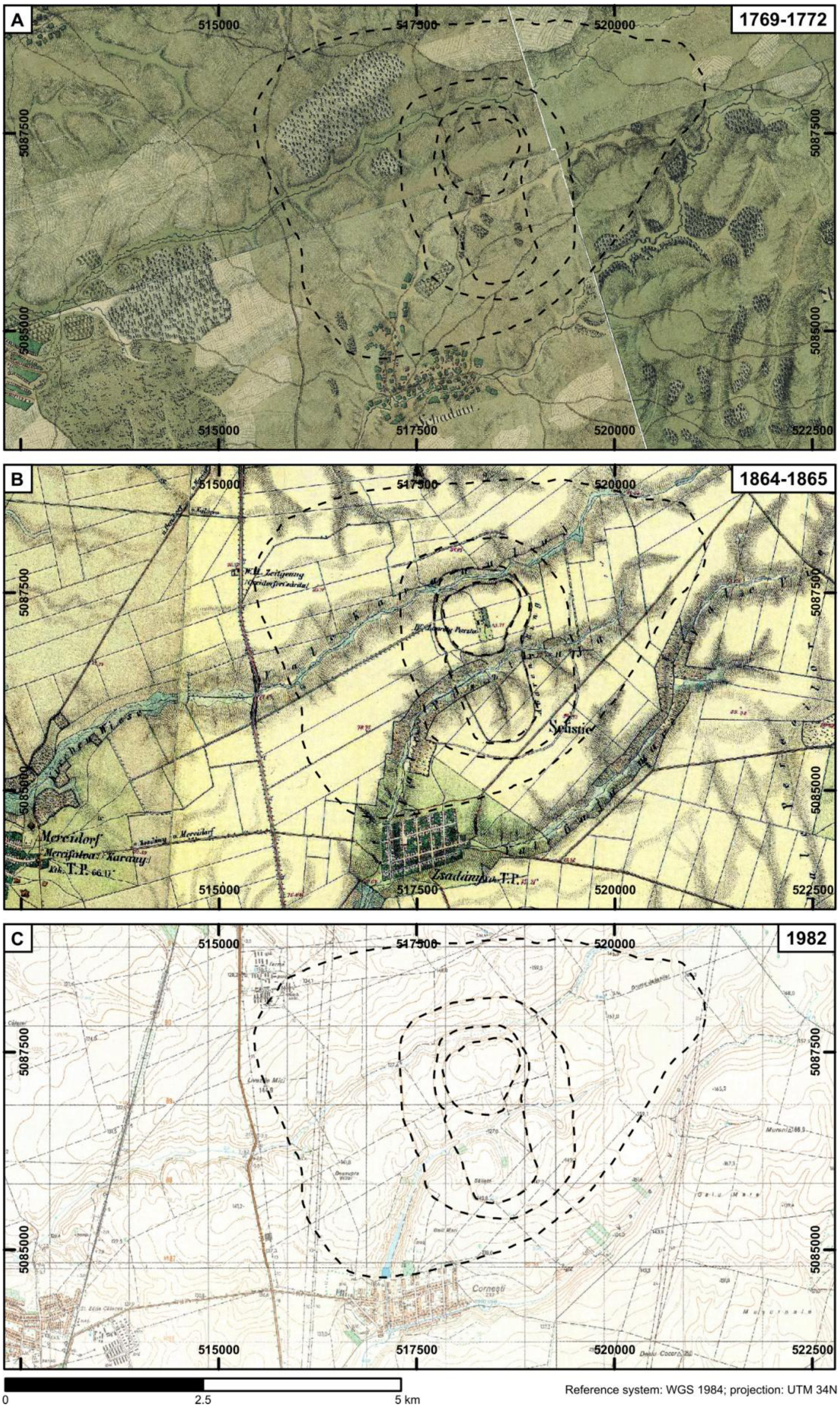

Fig. 28. Historic landscape development in the environs of Corneşti-Iarcuri as represented in the three maps considered. (A) First Military Survey of the Habsburg Empire (1769-1772) (Hofstätter, 1989; Kretschmer et al., 2004; data available from Arcanum, 2006). (B) Second Military Survey of the Habsburg Empire (1864-1865) (Hofstätter, 1989; Kretschmer et al., 2004; Timár, 2004; Timár et al., 2006; data available from Arcanum, 2006). (C) Topographic map (Direcţia Topografică Militară, 1982). The maps are projected in UTM 34N. The legends of the map sheets of the First and Second Military Survey usually indicate the kind of road or path and specify the vegetation and land use (data available from Arcanum, 2006).

5.1.4.2. Local relief model

The local relief model for the environs of Corneşti-Iarcuri shows the area-wide distribution of areas on the high plain that are relatively elevated in comparison to their local neighborhood (Fig. 29). Besides the areas of the ramparts III and IV, the model illustrates that many elevated linear features cross the high plain. Locally, these features are up to 40 cm higher than their surroundings, but more frequently they overtop their neighborhood by 10 to 30 cm (Fig. 29). Generally, these elevated linear features are more often found in the southwestern and southern part of the study area. Comparison of the locations of the field paths used at c. 1864-65 and 1982 (Fig. 28B and C), respectively, with the locations of the elevated linear features shown in the local relief model (Fig. 29) reveals that they are often located in the same positions. Thus, former and present-day field paths are preserved as little dam-like linear features that are elevated in comparison to the present-day surface of the high plain.

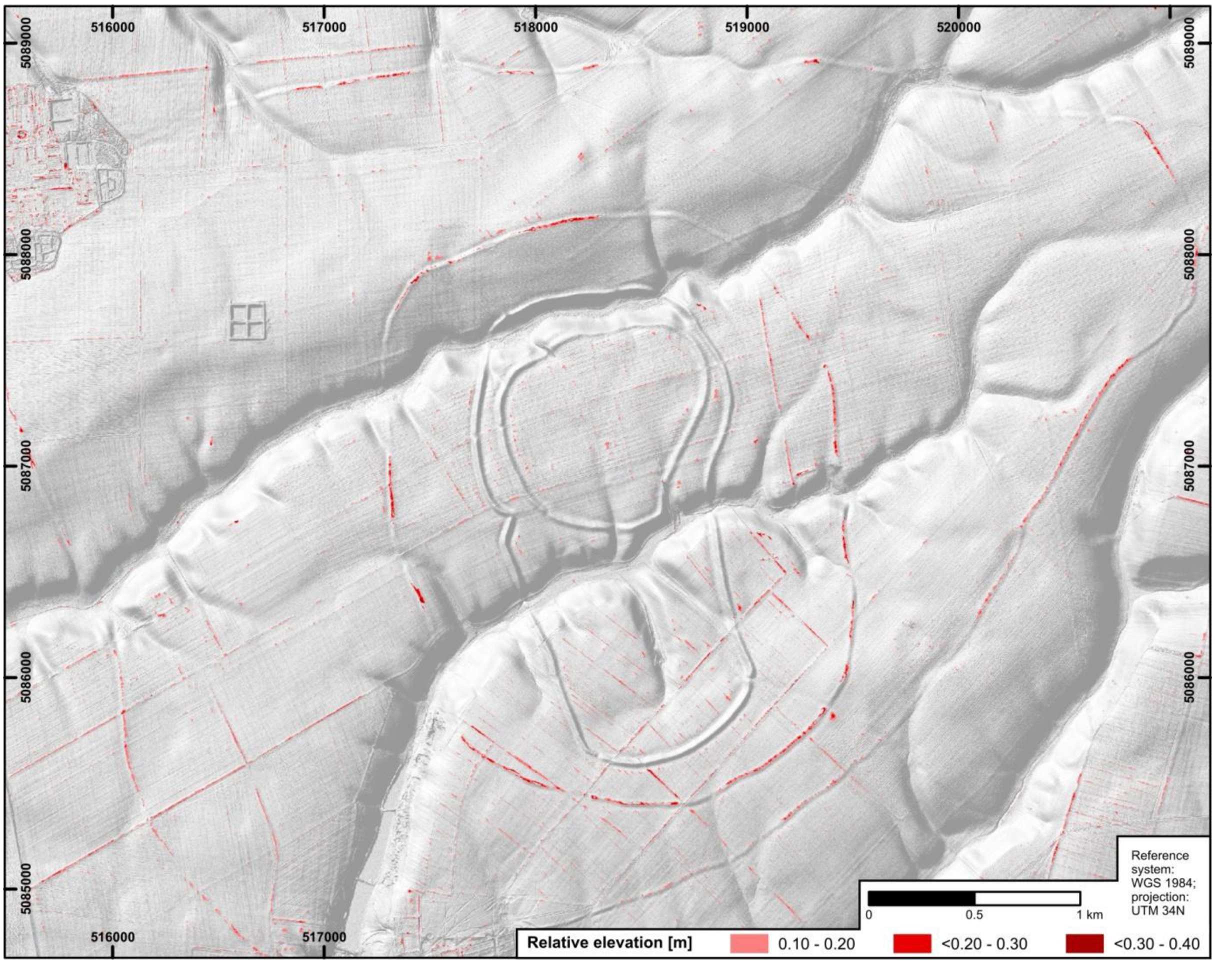

Fig. 29. Local relief model indicating the areas that overtop their local neighborhood. The map is projected in UTM 34N.

5.1.4.3. Topographic swath profiles

The topographic swath profiles along selected former and present-day field paths show the mean relative elevation of the dam-like linear features. All profiles indicate that the former and present-day field paths overtop the lower-lying arable fields on the high plain (Fig. 30). The topographic swath profiles SP 1a and SP 1b are sampled along two different field paths that are delineated in the maps of the Second Military Survey from c. 1864-65, but not in the topographic map from 1982 (Fig. 25; Fig. 28B and C). At present, the area where these two field paths were located is used for arable farming. By contrast, the profiles SP 2a and SP 2b are sampled along two different field paths that are delineated in the topographic map from 1982 but not in the maps of the Second Military Survey from c. 1864-65 (Fig. 25; Fig. 28B and C). At present, these two field paths are still in use. The profiles SP 3a and SP 3b are sampled along two different field paths that are delineated in both maps; the Second Military Survey and the topographic map (Fig. 25; Fig. 28B and C) and that are still in use at present. The profiles SP 1a and SP 1b show a rather smooth form and within the swath of 40 m their centers overtop the surrounding high plain by almost 20 cm (Fig. 30). The form of the profiles SP 2a and SP 2b show stronger convexities and concavities than described for profiles SP 1a and SP 1b. The center of the profile SP 2a is c. 20 cm higher than its surroundings and the center of SP 2b overtops its surroundings by even > 20 cm (Fig. 30). In comparison to the aforementioned the courses of the profiles SP 3a and SP 3b show the strongest convexities and concavities. While the center of SP 3b lies c. 20 cm above the high plain the center of SP 3a overtops it by > 30 cm (Fig. 30).

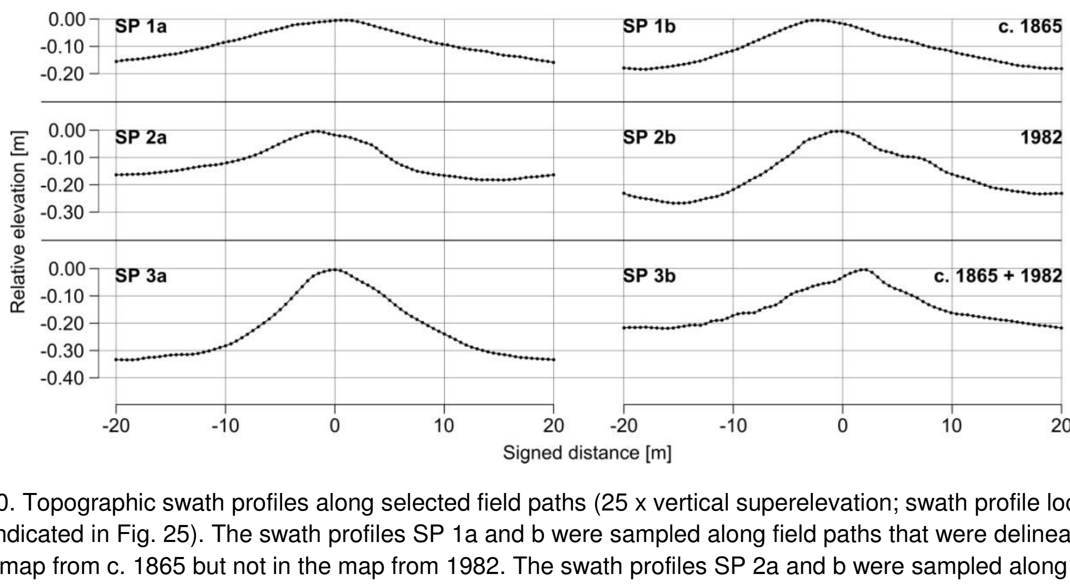

Fig. 30. Topographic swath profiles along selected field paths (25 x vertical superelevation; swath profile locations are indicated in Fig. 25). The swath profiles SP 1a and b were sampled along field paths that were delineated in the map from c. 1865 but not in the map from 1982. The swath profiles SP 2a and b were sampled along field paths that were delineated in the map from 1982 but not in the map from c. 1865. The swath profiles SP 3a and b were sampled along field paths that were delineated in the map from c. 1865 and in the map from 1982, too. The LiDAR DEM was used in all three cases as input elevation data.

5.1.4.4. Subsurface compaction measurements

The penetrometer subsurface compaction measurements were conducted across selected former and present-day field paths (Fig. 25; Fig. 28B and C). The results show that the parts of the profiles that are affected by the field paths have in all cases the highest compactness in the subsurface (Fig. 31). The penetrometer profile PP 1 (Fig. 25; Fig. 31) runs from west-northwest to east-southeast across a field path that was only delineated in the topographic map from 1982, but not in the maps of the Second Military Survey from c. 1864-65 (Fig. 28B and C). At present, this field path does not exist anymore and the area is used for arable farming. The compactness at the former field path, at a distance between c. 17 and 30 m, reaches up to 350 $N*cm^{-2}$ at a depth of 90 cm and decreases to both sides to a maximum of 250 $N*cm^{-2}$ at 90 cm depth. Also, a subsurface compactness of up to 300 $N*cm^{-2}$ in the area of the former field path is already reached c. 40 cm below the surface while usually values between 150 and 250 $N*cm^{-2}$ are reached at the same depth in the area where no field path was delineated (Fig. 31). The penetrometer profiles PP 2, PP 3 and PP 4 (Fig. 25; Fig. 31) run from north-northwest to south-southeast and cross a field path that is delineated in the maps of the Second Military Survey from c. 1864-65 and in the topographic map from 1982 (Fig. 28B and C) and which is still in use at present. In the area where the penetrometer profile PP 2 (Fig. 31) crosses the field path, at a distance between c. 10 and 20 m, a compactness of up to 300 $N*cm^{-2}$ is reached at c. 30 cm depth, whereas the parts of PP 2 that are unaffected by the field path hardly reach these values at 90 cm depth. Moreover, in the area of the field path high compactness of up to 250 $N*cm^{-2}$ is reached already at c. 10 cm depth (Fig. 31). The penetrometer profile PP 3 (Fig. 31) crosses the field path at a distance between c. 15 and 25 m. At a distance of 20 m a compactness of up to 300 $N*cm^{-2}$ is reached at c. 40 cm depth, which is usually reached at greater depth in the course of PP 3 (Fig. 31). The penetrometer profile PP 4 (Fig. 31) is with a total length of 55 m the longest profile. It crosses the field path at a distance between c. 25 and 35 m and shows the highest subsurface compactness there. In this area PP 4 shows a compactness of up to 300 $N*cm^{-2}$ at c. 35 cm depth. The areas that are unaffected by the field path show a compactness at c. 35 cm depth that ranges between 150 and 200 $N*cm^{-2}$ (Fig. 31).

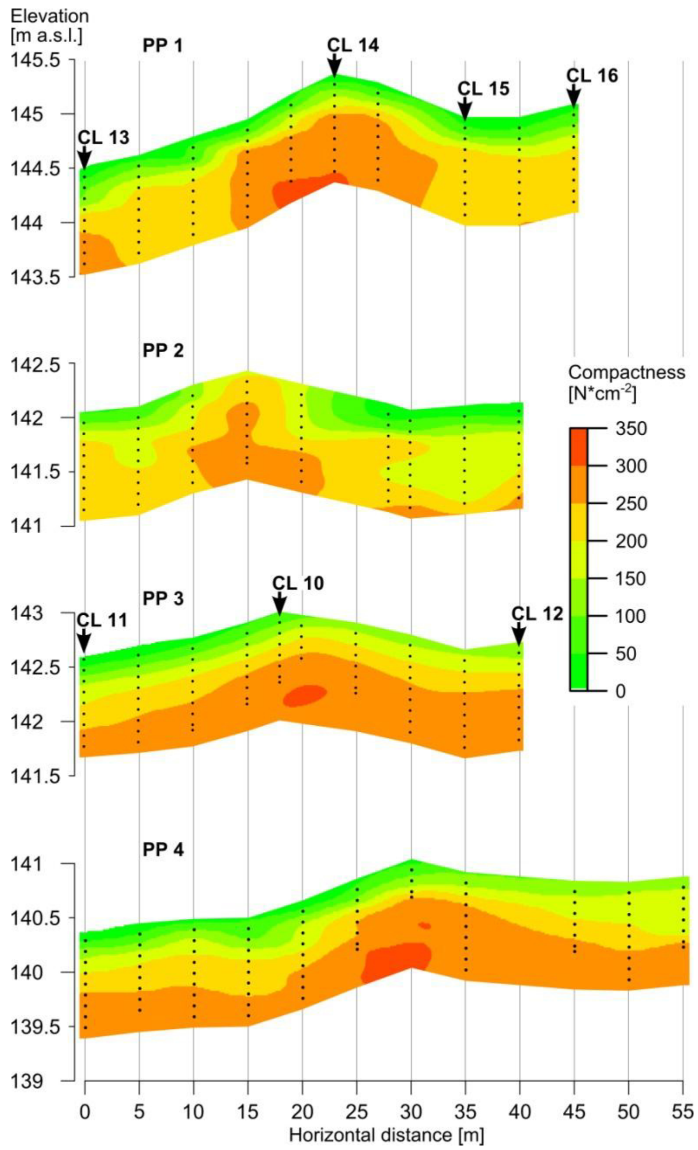

Fig. 31. Subsurface compactness along the penetrometer profiles PP 1, PP 2, PP 3 and PP 4. Compaction measurements were interpolated applying thin plate regression splines (Wood, 2003). The black dots indicate the depth at which the subsurface compaction was recorded. For penetrometer profile locations see Fig. 25. The black arrows indicate the coring locations (CL 10, CL 11, CL 12, CL 13, CL 14, CL15 and CL 16) along selected penetrometer profiles from where sediments for grain size analyses were extracted. For UTM coordinates of the coring locations see Table 2.

5.1.4.5. Grain size analyses

The results of the grain size analyses show that the sediments have a homogeneous texture without much variation. This holds true for the variation among the uppermost samples of the different locations as well as among the samples from each core. Silt, particularly coarse and medium silt, is the dominating grain size class (Table 3). The coring site of core CL 10 is located on a field path that is delineated in the map sheets of the Second Military Survey from c. 1864-65 and in the topographic map from 1982 (Fig. 25; Fig. 28B and C) and which is still in use at present. The coring sites of the cores CL 11 and CL 12 are located on adjacent arable fields. The Wilcoxon rank-sum tests reveal that the grain sizes do not have significant variations ($\alpha < 0.05$); neither among the uppermost samples of CL 10 in relation to the uppermost samples of CL 11 and CL 12, nor among the individual samples of the three cores in relation to each other. The coring site of core CL 14 is located on a field path that is delineated in the topographic map from 1982, but not in the maps of the Second Military Survey from c. 1864-65 (Fig. 25; Fig. 28B and C). This field path is not in use anymore and the area is used as arable field at present. The coring sites of the cores CL 13, CL 15 and CL 16 are located on arable fields. There is no significant variation ($\alpha < 0.05$) of the grain sizes among the uppermost samples of CL 14 in relation to the uppermost samples of CL 13, CL 15 and CL 16 or among the individual samples of all cores in relation to each other.

Table 3. Results of the grain size analyses.

	Grain size class [vol.-%] Equivalence diameter [µm]	Fine clay < 0.2	Medium clay 0.2 - < 0.63	Coarse clay 0.63 - < 2.0	Fine silt 2.0 - < 6.3	Medium silt 6.3 - < 20	Coarse silt 20 - < 63	Fine sand 63 - < 200	Medium sand 200 - < 630	Coarse sand 630 - < 2000
Coring ID	Sample depth [cm b.g.s.]									
CL 10	13-15	4.61	7.70	8.21	14.25	27.45	31.83	5.91	0.03	0.00
CL 10	43-45	4.81	7.28	7.74	13.86	26.82	33.72	5.75	0.01	0.00
CL 10	83-85	6.03	10.04	7.09	14.22	27.68	29.77	5.13	0.05	0.00
CL 11	4-6	5.52	8.60	8.09	14.67	27.98	30.99	4.15	0.00	0.00
CL 11	44-46	6.24	8.49	6.77	13.34	27.08	32.27	5.68	0.14	0.00
CL 11	84-86	6.37	8.75	7.02	14.33	27.90	30.46	5.16	0.02	0.00
CL 12	5-7	5.21	7.64	7.46	13.70	27.45	31.62	6.83	0.09	0.00
CL 12	45-47	6.98	9.22	7.12	13.65	26.30	29.60	6.84	0.28	0.00
CL 12	85-87	5.78	8.14	6.67	13.81	28.09	31.34	6.11	0.06	0.00
CL 13	11-13	5.56	7.79	7.16	13.80	25.80	29.92	8.52	1.47	0.00
CL 13	51-53	5.83	8.69	6.87	14.51	28.39	30.07	5.60	0.04	0.00
CL 13	81-83	6.30	9.06	6.96	13.54	27.53	30.84	5.59	0.18	0.00
CL 14	11-13	4.81	6.93	7.21	14.26	27.87	31.84	6.93	0.14	0.00
CL 14	51-53	5.34	7.69	7.76	14.47	27.16	29.84	7.47	0.27	0.00
CL 14	81-83	5.19	7.89	7.71	13.43	22.90	35.11	7.77	0.00	0.00
CL 15	14-16	4.86	7.98	8.18	14.95	28.15	31.24	4.63	0.02	0.00
CL 15	44-46	5.55	8.24	8.14	15.17	27.17	28.75	6.61	0.37	0.00
CL 15	84-86	5.74	7.69	6.77	14.48	27.92	30.32	7.04	0.04	0.00
CL 16	7-9	5.53	8.54	8.13	14.09	27.28	30.50	5.45	0.49	0.00
CL 16	47-49	6.13	8.69	6.97	14.11	27.67	30.37	6.04	0.03	0.00
CL 16	87-89	8.13	9.82	7.19	13.58	25.39	28.23	7.04	0.64	0.00

5.1.5. Discussion

The results of land use and land cover change as derived from the historic maps from the First and Second Military Survey of the Habsburg Empire (Hofstätter, 1989; Kretschmer et al., 2004; Timár, 2004; Timár et al., 2006; data available from Arcanum, 2006) are in good agreement with the descriptions of historic landscape development (von Dorner, 1839; Schwicker, 1872; Bußhoff, 1938; Rieser, 1992) and the map interpretations performed by Petrovszki and Mészáros (2010). Thus, the accuracy of the maps and our interpretations are regarded as a robust source for further interpretations. The resettlement and the land reclamation activities after the end of the war in 1717 and especially the imperial colonization patent from 1763 caused a substantial change in the natural environment of the area (von Dorner, 1839; Schwicker, 1872; Rieser, 1992) that is revealed by comparing the map sheets of the First and Second Military Survey (Hofstätter, 1989; Kretschmer et al., 2004; Timár, 2004; Timár et al., 2006; Petrovszki and Mészáros, 2010; data available from Arcanum, 2006). These changes include a great decrease in steppe grass areas and forest patches in favor of agricultural fields (Petrovszki and Mészáros, 2010) and also the development of straight country roads and the establishment of a rectangular pattern of field paths (Fig. 28). Thus, the intensification of arable farming (Munteanu et al., 2014) and the establishment of the rectangular field path system in the environs of Corneşti-Iarcuri can be roughly dated to the time between c. 1770 and c. 1865. Here, the map sheets of the First Military Survey from c. 1770 represent the terminus *ante quem* of major impacts on the land use system and the rectangular field path system, while the map sheets of the Second Military Survey from c. 1865 represent the terminus *post quem*. Today, some of these field paths are still used, while others have been abandoned and arable farming is now conducted in their previous locations; however, remains of these field paths are still visible in the LiDAR-derived DEM from 2013 in the form of little dam-like linear structures that overtop the surface of the high plain (Fig. 25).

The local relief model (Fig. 29) indicates that these linear structures occur systematically in the entire study area. However, the model also shows that their relative elevation differs in different areas. Locations where the linear structures overtop the surface of the high plain by up to 40 cm are mostly found in the southwestern corner of the study area and in the central part around the southern section of rampart II. In the rest of the study area their relative elevation often remains between 10 and 20 cm above the high plain (Fig. 29).

The extraction and systematic analysis of the field paths from the historic map sheets allows comparison of their locations with the locations of the modern field paths. This comparison reveals that the locations of the field paths that were in use in c. 1865 have in some cases remained stable so that they are still used today. In other cases their positions were changed in the time between c. 1865 and 1982 so that three different situations can be observed. First, a field path was used in c. 1865 and in 1982, too, i.e. at the locations of SP 3a and SP 3b (Fig. 25; Fig. 28B and C). Both field paths are still in use at present. Second, a field path was used in c. 1865 but not in 1982, i.e. at the locations of SP 1a and SP 1b (Fig. 25; Fig. 28B and C); the areas where the field paths were located are now used for arable farming. Third, a field path was used in 1982 but not in c. 1865, i.e. at the locations of SP 2a and SP 2b (Fig. 25; Fig. 28B and C); these two field paths are still used at present.

For each situation two samples were selected and analyzed using topographic swath profiles. The results of the topographic swath profile analysis support the results of the local relief model showing that in all three situations the surface of the field path is higher than the surface of the surrounding arable fields on the high plain (Fig. 30). Moreover, the analysis documents the differences between the three situations. The form of the profiles along field paths used in c. 1865 is much smoother than the form of the profiles along more recently used field paths, and their relative elevation above the surface of the high plain is larger (Fig. 30).

The analysis of the subsurface compaction along profiles crossing selected field paths revealed that in all cases the highest compaction values are found in the area of the field paths (Fig. 31). This shows that the pressure applied by vehicles, humans and animals repeatedly using the field paths causes a substantial increase in subsurface compactness in comparison to the surrounding agricultural fields (van den Akker and Soane, 2005). The increased subsurface compactness causes an increased strength of the material (van den Akker and Soane, 2005) and thus prevents wind erosion and the generation of dust, most likely even during severe windstorms (Pye, 1987).

Moreover, the systematic analysis of the locations of the field paths and the subsurface compaction measurements indicate that the locations of the field paths were stable over a fairly long period of time and thus not under cultivation. Besides the generally lower susceptibility to wind erosion of the field paths due to higher compactness (Pye, 1987; van den Akker and Soane, 2005), it is assumed that plowing was the main cause for the higher susceptibility to wind-driven soil erosion of the agricultural fields (Goossens et al., 2001; Funk et al., 2008); this caused lowering of the surface in historic times. Even though the study area shows a low to very low susceptibility to wind erosion (Borrelli et al., 2015; Borrelli et al., 2016) and low potential soil loss due to wind erosion (Borrelli et al., 2017), actual wind-driven soil erosion can in fact be much higher than predicted because human activities such as tillage, as one dominant mechanism of particle release (Goossens et al., 2001; Funk et al., 2008), are not considered in the regional modeling approaches (Borrelli et al., 2015; Borrelli et al., 2016; Borrelli et al., 2017). For comparable sediments on arable lands in Lower Saxony, Germany, Goossens et al. (2001) found that dust emission due to tillage was more than six times higher than dust emission caused by wind erosion. The main reason for this is the much longer duration of the period of tillage, usually several weeks, in comparison to the total duration of wind erosion events (Goossens et al., 2001). Thus, a strong relationship between the periods of tillage and the intensity of dust release is emphasized (Goossens et al., 2001). In contrast to coarser sediments, e.g. sandy soils, which are often redistributed within the same agricultural field, the majority of fine particles, i.e. silt and clay, are ultimately evacuated from the field in question (Goossens et al., 2001, Funk et al., 2008) and thus the surface of the field is actively lowered over time. The results of the grain size analyses show the clear dominance of silt-sized particles and only minor proportions of fine and medium sand. Thus, ultimate evacuation of the dust-sized particles transported in suspension is assumed for the environs of Corneşti-Iarcuri rather than redistribution within the same agricultural field.

The combination of compaction along the regularly used field paths and wind-driven soil erosion on the surrounding agricultural fields facilitated by tillage operations is assumed to be responsible for the lowering of the surface of the agricultural fields in the time period after c. 1865. This combination of processes caused the creation of the dam-like linear structures that are systematically observable in the study area (Fig. 29) and overtop the surface of the high plain by between 10 and 40 cm (Fig. 29; Fig. 30). Hence, it can be inferred that the surface of the high plain in the areas of the agricultural fields has been lowered by between 10 and 40 cm since c. 1865 due to tillage-induced wind-driven soil erosion.

In terms of archaeological heritage management, our findings suggest that archaeological remains are continuously threatened by the destructive action of plowing that successively reaches greater depths and may cause the complete disappearance of cultural remains in the environs of Corneşti-Iarcuri. Due to the erosion-induced lowering of the surface on the arable fields in relation to the surviving archaeological remains even plowing at a constant depth causes successively deeper penetration of the plow into the archaeological remains (DEFRA, 2002). Although this process is probably a rather slow type of destruction it is regarded as possibly the most widespread one, occurring to some extent on all soils and in many relief situations (Lambrick, 1977). Moreover, a distortion of the systemic context of the cultural remains due to the mixing activity of burrowing animals cannot be excluded, as bioturbation is a common phenomenon in grassland soils (Mason and Zanner, 2005) such as the prevailing Luvic Phaeozems and Luvic Chernozems (Grigoraş et al., 2004).

The reconstructed lowering of the surface on the agricultural fields, which totals between 10 and 40 cm since c. 1865, together with the observed actual plowing depth of c. 30 cm, implies that archaeological structures in these areas must have penetrated the subsurface to between 40 and 70 cm in order to be preserved in the present-day subsurface. This is in good agreement with results from the excavation of four Late Bronze Age house structures in 2013 (Heeb et al., 2015). Here, a clearly definable foundation ditch that was filled up with burnt debris and secondary burnt Late Bronze Age ceramics outlines the structure (Heeb et al., 2015), but there is no sign of a floor. Also, indications for human activities during the Iron Age exist in the environs of Corneşti-Iarcuri in the form of ceramics (Fig. 26) that were plowed to the surface and collected during systematic field walking, but, to date, no excavation evidence has been found for Iron Age settlements. This is a common phenomenon on plowed archaeological sites; the younger stratigraphy has often been lost and the remaining structures survive up to the maximum depth of plowing (Lambrick, 1977). However, the plowed soil often contains archaeological evidence of occupation that is younger than the surviving structure underneath (Lambrick, 1977), as is the case for the study site.

5.1.6. Conclusions

This investigation of historic landscape development and the surface lowering due to tillage-induced wind-driven soil erosion reveals their implications for the preservation of cultural remains in the environs of the largest known European enclosure Corneşti-Iarcuri. The interpretation of historic maps and written sources reveals that major changes in the natural environment occurred between c. 1770 and c. 1865. Scheduled resettlement and land reclamation activities caused a great decrease in steppe grass areas and forest patches and a substantial intensification of arable farming in the study area. Our results show that the surface of these arable fields has lowered by between 10 and 40 cm since that time. The process of surface lowering is controlled by a combination of subsurface compaction along field paths and tillage-induced wind-driven soil erosion on the arable fields leading to the suspended transport of the dust-sized particles and thus to their ultimate evacuation from the field. The estimated lowering, in combination with the actual plowing depth of c. 30 cm, implies that archaeological structures must have penetrated to between 40 and 70 cm into the subsurface in order to be preserved in the present-day subsurface. The ongoing lowering of the surface in combination with plowing poses a serious threat to the still intact lower-lying stratigraphy of this important ground monument, because the erosive impact of plowing continuously reaches greater depths even when a constant plowing depth is maintained.

Acknowledgements

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5.2. Linking hydrological anomalies to archaeological evidences – identification of Late Bronze Age pathways at the fortification enclosure Iarcuri in western Romania

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Key words: Hollow ways; Morpho-hydrological relief characteristics; Human impact on drainage net-work development; Settlement patterns; Landscape archaeology

Abstract

For the environs of the Late Bronze Age fortification enclosure Iarcuri the hydro-morphological relief characteristics are combined with archaeological evidences. Target of the study is to evaluate the impact of settlement activities in the surroundings of Iarcuri on the development of the channel network. Data analysis is based on topographic map-derived and high resolution DEMs provided by LiDAR scanning; derivatives of the DEMs are used to characterize the different sub-catchments that show varying influences by the fortification ramparts. The tributaries reaching the receiving stream close to the central settlement area source close to the gates in the ramparts in the Late Bronze Age built-up areas. Additionally, also the geometry of these tributaries differs from that of other tributaries. The distinct character of the channel network with repeatedly occurring rectangular bends indicates the capture of channels, which developed as gullies along paths by retrogressive erosion.

5.2.1. Introduction

Consisting of four earth-filled wooden ramparts (I-IV) with a total length of more than 33 km the Late Bronze Age fortification enclosure Iarcuri covers a surface of more than 17,6 km². It is situated at the eastern edge of the Great Hungarian Plain and represents the largest prehistoric settlement in Europe known so far. What is known after seven years of excavation and survey is that Iarcuri is a fortified settlement from the Late Bronze Age (Cruceni-Belegiş culture) (Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2014). There are rough ideas on the areas intra muros that were built-up and the density of the population (Heeb et al., 2012). Unknown so far is the reason that a settlement of that size and structure was built in this landscape and what kind of society was powerful enough to impose and organize the construction of those ramparts and how their economic foundation looked like. Likewise, it remains unclear what impacts the fortification enclosures and the economic actions that are mandatory to supply such a society had on the natural environment. Certain archaeological questions can only be fully answered in cooperation with earth sciences and, in turn, some findings obtained applying methods from earth sciences can only be interpreted integrating archaeological findings. Hence, a landscape archaeological approach (Kluiving et al., 2012) is applied in order to avoid the gap between sciences and humanities.

The objective is to relate archaeological evidences from the Late Bronze Age fortification enclosures and the settlement areas to the morphological and hydrological characteristics of its environs. We hypothesize that the activities in and around Late Bronze Age fortification significantly affected the development of the relief and caused varied morpho-hydrological particularities. In order to test our hypothesis digital elevation models (DEMs) are used to compare different basins. Archaeological evidences are linked to LiDAR-based DEM derivatives to explain the formation of the morpho-hydrological anomalies.

5.2.2. Study site

The archaeological site Corneşti-Iarcuri is located in the Romanian Banat, about 20 km north of Timişoara. As a part of the Vinga Plain, the environs of Iarcuri are part of the west Romanian high piedmont plain (Fig. 32; Badea et al., 1979). A moderate temperate climate, with annual mean precipitation of 550 mm and a potential evapotranspiration of about 700 mm prevails on the Vinga Plain (Grigoraş et al., 2004). Geologically, the Vinga Plain is built up by a mixture of Early to Late Pleistocene gravels, sand and clay (Institutul Geologic, 1966; Borsy, 1990). During the Quaternary the area was covered by loess and loess-like deposits. The soils that developed in these aeolian sediments are characteristically Chernozems and Phaeozems. Variations that occur mainly due to relief differences include eroded Chernozems at the hillslopes, colluvisols at the foot slopes and fluvic-gleyic Chernozems in the alluvial plains. The alignment of the mainly northeast-southwest oriented valleys is determined by the slight southwest dipping of the Vinga Plain (Fig. 32; Grigoraş et al., 2004). Two creeks that flow in wide saucer-shaped valleys cross the archaeological site from northeast to southwest (Fig. 33; Micle et al., 2006).

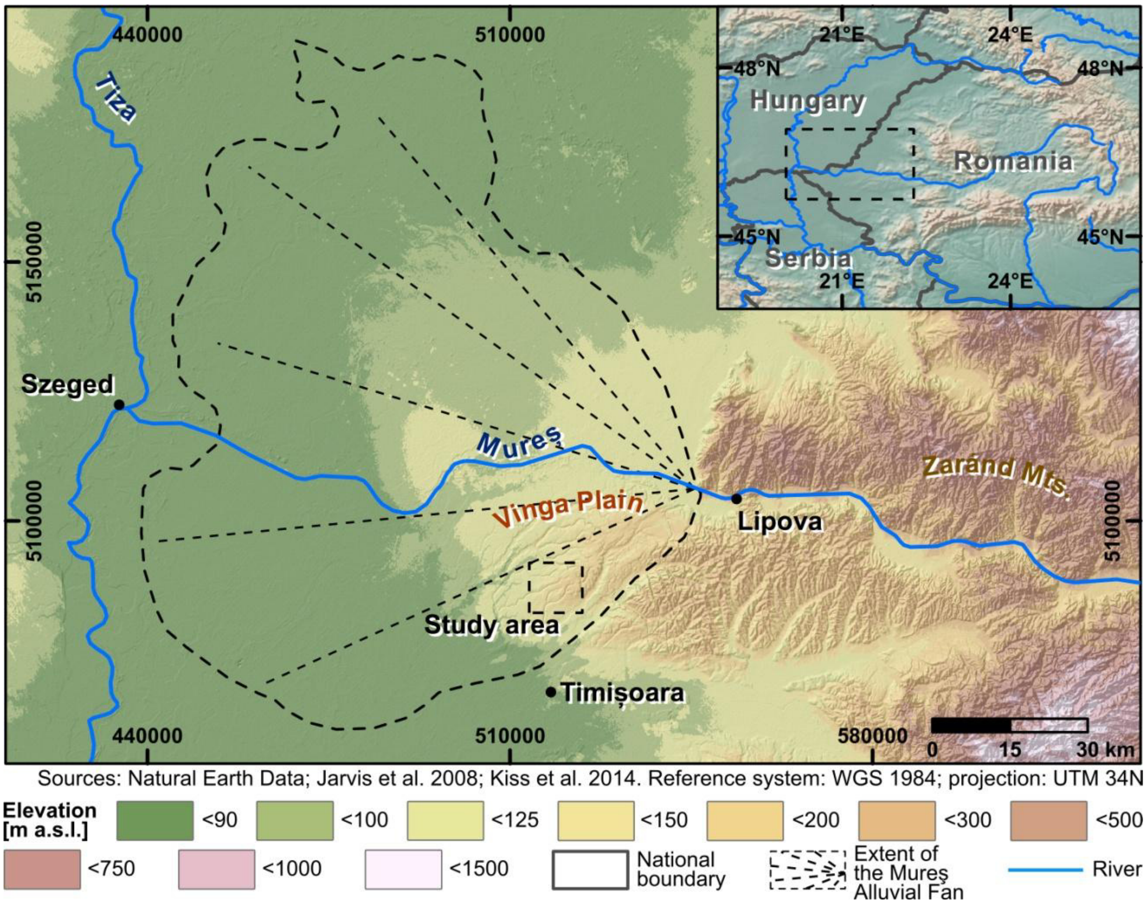

Fig. 32. Overview map of the study area showing the location of the archaeological site Corneşti-Iarcuri on the Vinga Plain and the approximate extension of the Late Quaternary Mureş fan.

The relief in the surroundings of Iarcuri is composed by two general units: the high plain and the intersecting valleys. The high plain consists of wide, slightly undulating interfluves that decline from 170 m a.s.l. in the northeast to 130 m a.s.l. in the southwest (Fig. 33a). Its slopes incline between 0° and 2°, only locally reaching up to 5° like in the northern part of enclosure III (Fig. 33b). The two main valleys that dissect the high plain run in northeast-southwest direction. Numerous hollows and first order tributaries occur alongside these valleys. The course of some of these tributaries bends in an almost right angle and locally runs against the general surface gradient (Fig. 33a). The transition between the high plain and the valleys is usually marked by a shoulder with a distinct convex profile-curvature. At the shoulder inclinations increase up to 5° - 10°. Inclinations of 10° - 18°, locally increasing up to 22.5°, and mainly straight profile-curvatures characterize the midslope sections. At the foot slopes, in the transition zone to the alluvial plains, the inclinations decrease to 2° - 5° and profile-curvatures become slightly concave. The alluvial plains are flat (0° - 2°) and relatively narrow. They only widen locally, e.g. in the central part of the second enclosure (Fig. 33b, c).

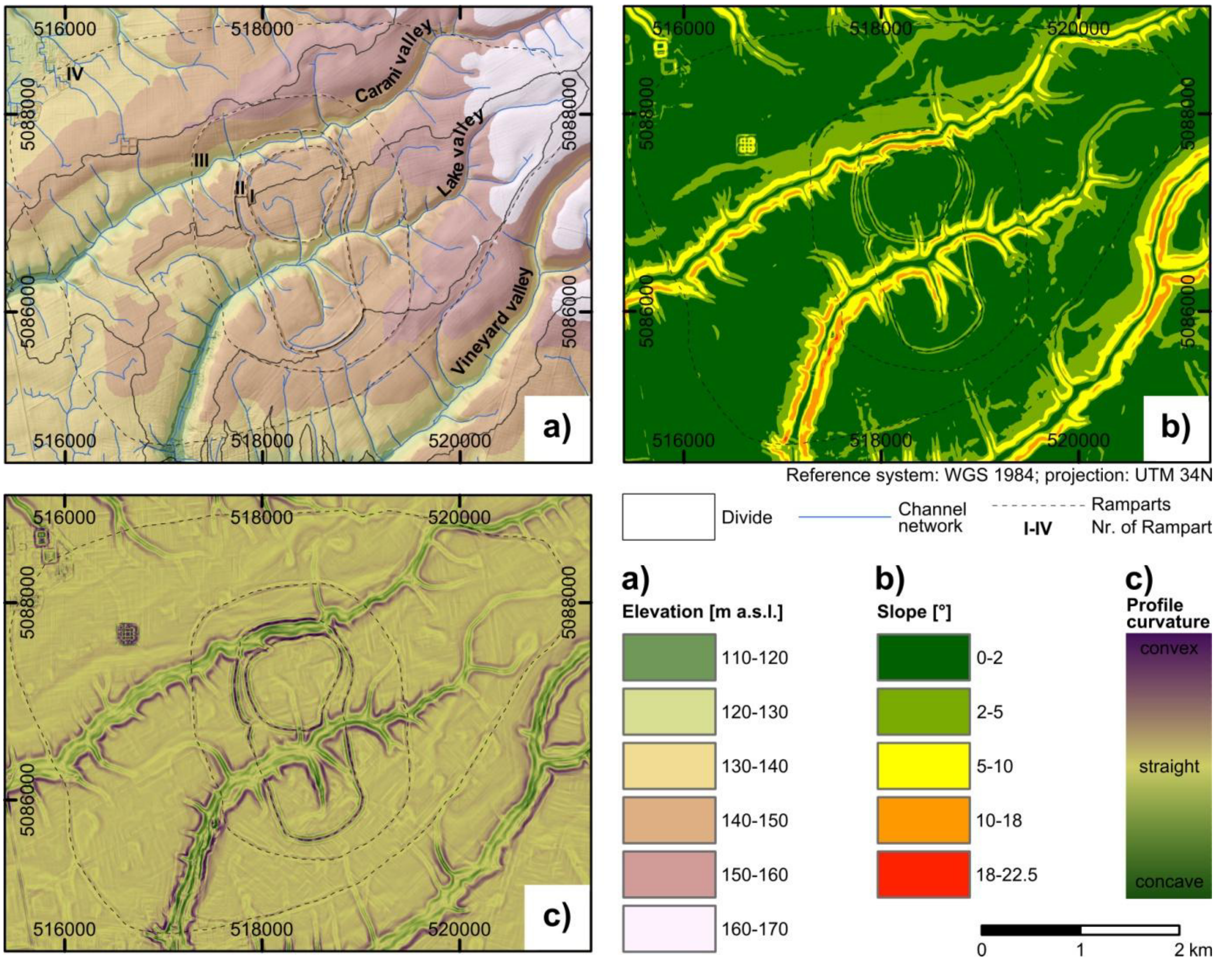

Fig. 33. Detailed maps of the study site. Surface elevation (a), slope gradient (b) and profile curvature (c). The dashed lines in the maps mark the location of the four enclosing ramparts of Iarcuri.

The four earth-filled wooden ramparts of Iarcuri are numbered I to IV from inside out. The innermost rampart I (Fig. 33a) is nearly circular, has a diameter of approximately one kilometer and is situated on the plateau between the Carani and the Lake valley. With respect to the sense of a fortification the situation of rampart I seems to be consequent. Rampart II has an elliptic shape with a north-south running length axis. In its run it crosses both, the Carani and the Lake valley twice. At the present state of knowledge it is not possible to reconstruct whether the interruptions by the two valleys were closed during the settlement period or not. Rampart III has the same oval, north-south elongated shape as the rampart II. Its course follows the divide of the Carani valley in the north and runs across the wide plateau divide between the Lake and Vineyard valley in the south. Rampart IV is northeast-southwest elongated and almost encloses the entire catchment of the Lake valley (Fig. 33a). All four ramparts show defensive ditches in front of the ramparts and rearward depressions from where construction material was extracted.

The site of Iarcuri is the largest prehistoric settlement known by today. It dates to the Late Bronze Age, however, its settlement history starts already in the Copper Age (Tiszapolgár culture) around 4,000 BC (Szentmiklosi et al., 2011; Heeb et al., 2012). The Copper Age finds originate from inside of the ramparts I and II. They do not occur area-covering, but locally lumped in the form of different kinds of settlements like homesteads and a village. The four ramparts all date back to the Late Bronze Age and are not linked to the Copper Age settlements. Rather, the Copper Age settlements are followed by a long hiatus that occurs until the Middle Bronze Age (Vatina culture). What happened during Middle Bronze Age remains widely unclear. It is assumed that a loose occupation with pit dwelling houses existed inside the second rampart (Heeb et al., 2012), forming the nucleus for the big Late Bronze Age settlements. Since 2007 areas inside the ramparts I and II and segments of the ramparts I, II and IV had been excavated. The whole first rampart and large parts inside rampart II have been surveyed by magnetic prospections and field walking (Fig. 34; Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2014).

5.2.3. Methods

5.2.3.1. Geography

A digital elevation model (DEM) of the wider area of Iarcuri is created by applying the TOPOGRID (Hutchinson, 1989) algorithm to the digitized contour lines of the topographic map (Direcţia Topografică Militară, 1982) (1:25,000). Drainage divides and ordered (Strahler, 1957) drainage networks are derived using an A^T least-cost search algorithm (Ehlschlaeger, 1989; Jasiewicz and Metz, 2011). Based on this the basin size and drainage density (Leopold et al., 1995) are calculated for the basins. First and second order tributaries that directly drain into the main channel are counted and the frequency of tributaries per kilometer of the main channel course is recorded. The ratio between length of the flow path and the distance from the source to the mouth (Ahnert, 2003) of the tributaries is used to distinguish between the straight, slightly bending and bending courses. The basin of the Lake valley is compared to neighboring third order basins: while the Lake valley is almost entirely surrounded by the four ramparts of Iarcuri and therefore, represents an area highly affected by settlement activities. The neighboring third order basins are more or less unaffected by prehistoric settlement activities. The basins to be compared with the Lake valley basin are chosen due to their order, size and proximity to site of Iarcuri.

Morphometric and hydrological analyses are conducted on a LiDAR-based DEM. Initial DEM processing comprises smoothing and resampling. To reduce the noise of the surface elevation that is caused by the high ground resolution of the LiDAR data (initially 0.5 x 0.5 m^2) a large moving window (69 x 69 cells) was applied for smoothing (Wood, 1996). A pixel resampling to a resolution of 1 x 1 m^2 was done in order to reduce the impact of very small artificial features like furrows. The processed DEM is used to derive the slope angle and the profile curvature using a moving window of 11 x 11 cells (Wood, 1996). The drainage divides and ordered (Strahler, 1957) stream segments are deduced applying an A^T least-cost search algorithm to the LiDAR DEM (Ehlschlaeger, 1989; Jasiewicz and Metz, 2011). The DEM derivatives were used to characterize the relief and the stream network morphometrically. The geometry of all tributaries that contribute to the creeks in the Carani and Lake valley was assessed using the flow path length to distance-ratio (Ahnert, 2003).

5.2.3.2. Archaeology

Beside excavations, large scale systematic field walking and geophysical prospections were applied (Fig 33). Between 2007 and 2012 the focus of excavation was on how the ramparts were constructed and how they are dating. From 2013 onwards the research concentrated on the investigation of the settlement areas within the ramparts I and II. The trenches cutting the ramparts (so far ring I, II and IV) are long and narrow (2008: 80 x 5 m²) documenting the rampart and the adjoining defensive ditches in front and structures behind (Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2014).

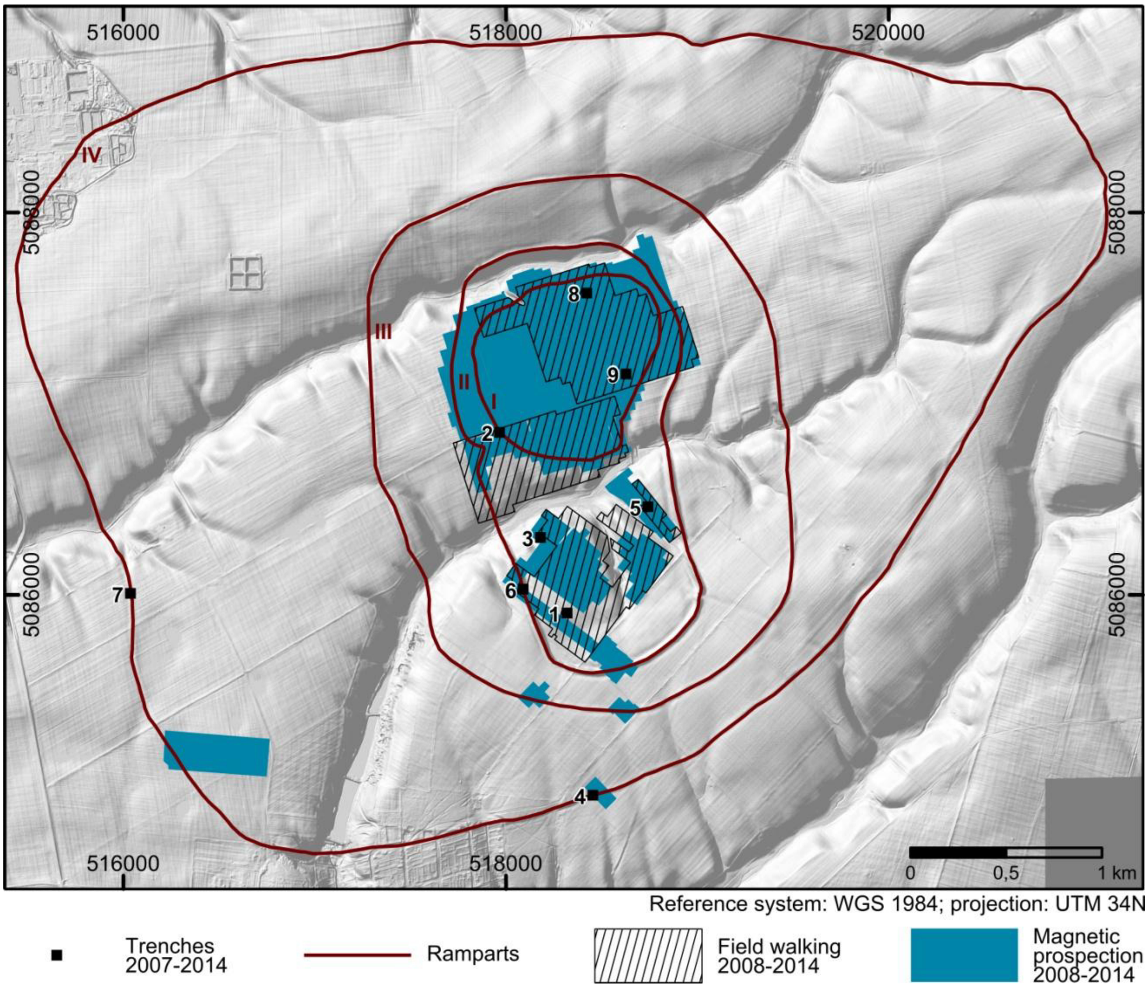

Fig. 34. Locations of the excavations 2007–2014, field walking areas 2008–2014 and magnetic prospection areas 2008–2014 within the ramparts of Iarcuri.

Gates in the ramparts were localized through an integrated application of excavation, magnetic prospections and LiDAR DEM-based mapping. The parameters that define a gate are the evidence achieved by excavation, a gap in the ramparts that is visible on the surface and the interruption of the rampart and the defensive ditch as verified through the magnetic prospections.

5.2.4. Results

5.2.4.1. Geography

The fortification enclosures of Iarcuri lie almost entirely within basin 1 (Fig. 35). Basin 1 has a size of 7.44 km^2 and a drainage density of 1.93 km*km^{-2}. Along the six kilometers of the run of the receiving stream a total of 14 tributaries drain into it; the frequency of tributaries per kilometer of the main channel totals 2.33. A total of nine (64.29 %) of these tributaries are straight, the course of three (21.43 %) tributaries is slightly bending and the course of two (14.29 %) tributaries is strongly bending (Fig. 35).

Small parts of basin 2 are located in the built-up area of Iarcuris' rampart IV. Basin 2 covers an area of 8.31 km^2 and it has a drainage density of 2.07 km*km^{-2}. The main channel has a length of 6.51 km and twelve tributaries drain into it; a tributary frequency of 1.84 per kilometer is resulting. Regarding the form of the tributaries it turns out that ten of them (83.33 %) are straight and two (16.67 %) are slightly bending (Fig. 35).

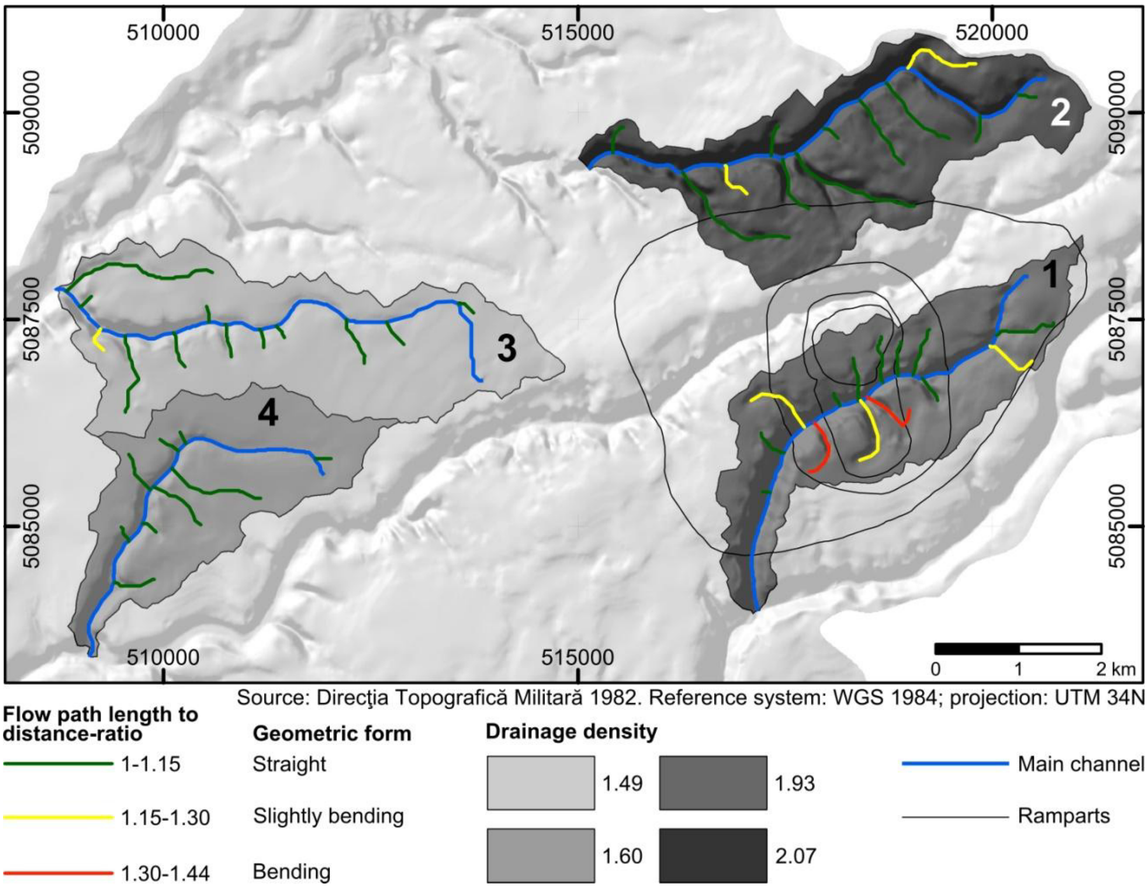

Fig. 35. Hydrological characteristics of selected third order basins in the wider surroundings of Iarcuri based on the topographic map-derived DEM.

Basin 3 lies outside the built-up environment of Iarcuri. It covers an area of 8.67 km^2, has a drainage density of 1.49 km*km^{-2} and its receiving channel is 6.53 km long. Twelve tributaries drain into the receiving channel, consequently the tributary frequency per kilometer totals 1.84. Eleven (91.67 %) of the tributaries have a straight course and one (8.33 %) has a slightly bending course (Fig. 35).

Basin 4 is with an area of 5.71 km^2 the smallest of the four catchments. As basin 3, it lies outside the direct influence of the constructed area of Iarcuri. Its drainage density is 1.6 $km*km^{-2}$ and its main channel has a total length of 4.88 km. Nine tributaries drain into the receiving channel (frequency: 1.84) and all of them are straight (Fig. 35).

The comparison of the four neighboring third order catchments reveals that the basins 1, 2 and 3 are rather similar with respect to basin size (mean: 7.53, STD: 1.32) and length of the main channel (mean: 5.98, STD: 0.77), whereas basin 4 is smaller and has a shorter main channel. In terms of the drainage density (mean: 1.77, STD: 0.27) the basins 1 and 4 are comparable, while basin 2 shows a higher and basin 3 a lower drainage density. Focusing on the character of the tributaries it turns out that in basin 1 the number and frequency of tributaries that drain into the receiving channel is higher than in the other basins (mean: 1.96, STD: 0.25). Comparing the overall frequency of the straight, slightly bending and bending channel courses it becomes evident that the straight running tributaries are fairly even distributed between the four basins (between 23 and 28 %). The distribution of the tributaries with slightly bending and bending courses is, in contrast to that, rather unequally distributed: 50 % of the slightly bending tributaries occur in basin 1 while the other half is located in basin 2 (33.33 %) and basin 3 (16.67 %). Moreover, it turns out that all of the distinctly bending tributaries are located in basin 1 (Fig. 35).

Since the high resolution digital elevation model based on LiDAR data is exclusively available for the site of Iarcuri it is not possible to work with it on a catchment scale. However, the data show that 18.75 % of the tributaries that contribute to the Carani and Lake valley within the built-up area of Iarcuri show direct connections to the construction of the ramparts. These tributaries are located directly in front or rearwards of the ramparts. At the same positions defensive ditches had been created, or material for the construction of the ramparts had been extracted, respectively. Additionally, differences regarding the tributaries within the built-up environment of Iarcuri exist as well. While the frequency of tributaries is higher in the catchment of the Carani creek, the Lake valley shows more bending tributaries (Fig. 36). The course of the Carani creek within the site of Iarcuri has a length of 5.36 km and a total of 24 tributaries drain into it. The resulting frequency of tributaries per kilometer main channel totals 4.48. The evaluation of the flow path to distance-ratio shows that 22 (91.67 %) of the tributaries have a straight course, one (4.17 %) has a slightly bending and one (4.17 %) has a distinctly bending course (Fig. 36). The main channel of the Lake valley has a length of 6.35 km and 24 tributaries drain into it. The frequency of tributaries per kilometer of the receiving channel totals 3.78. With respect to their form the results from the Lake valley show that 19 (79.17 %) of the tributaries have a straight course, two (8.33 %) have a slightly bending and three (12.50 %) have a distinctly bending course (Fig. 36).

Comparing the areas within the built-up environment of Iarcuri it turns out that 75 % of the tributaries with distinctly bending course and 66.67 % of those with slightly bending course occur in the Lake valley, which crosses the site of Iarcuri in the central position between the ramparts I and II (Fig. 36).

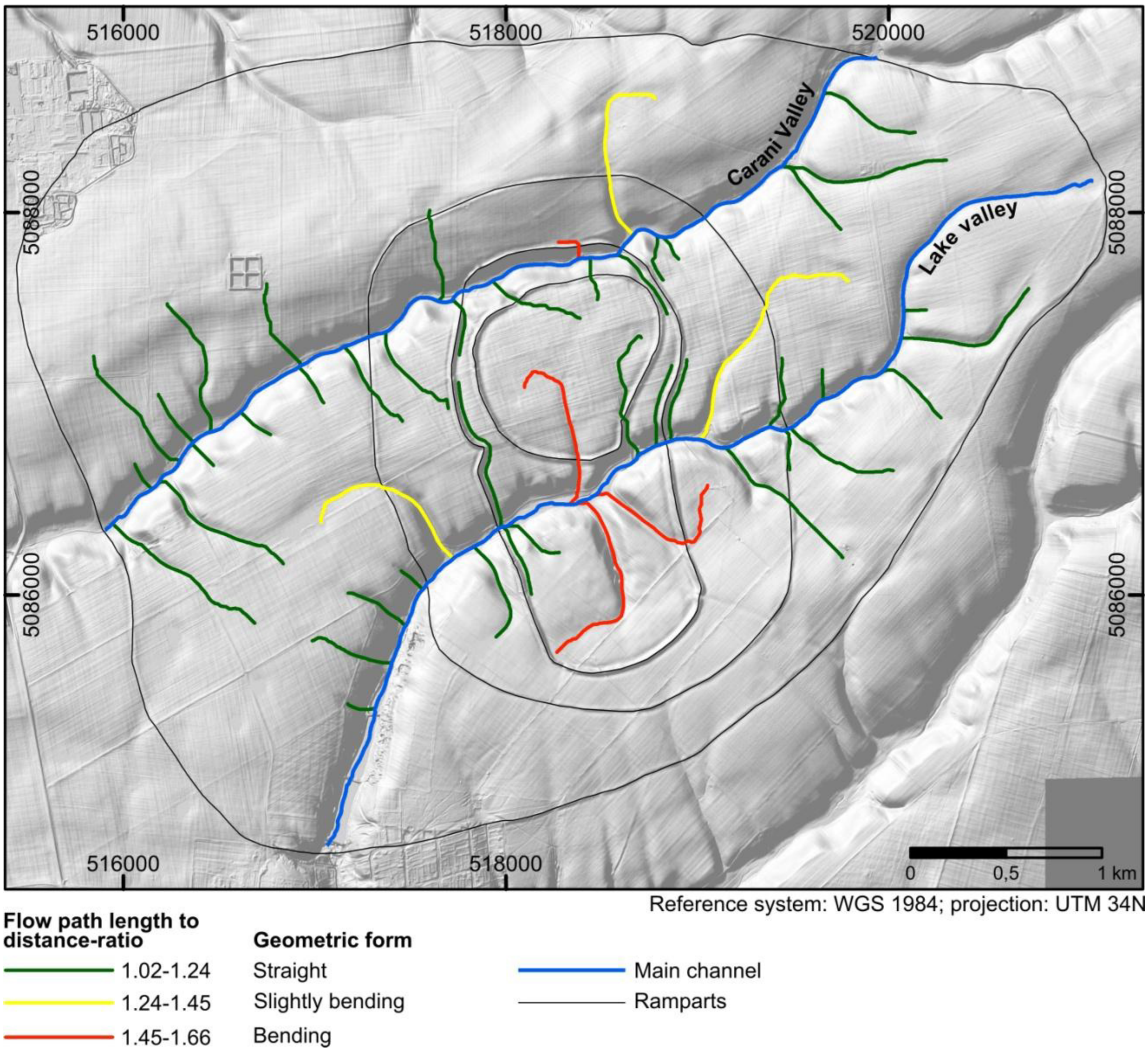

Fig. 36. Flow path length to distance-ratio of the tributaries in the Carani and Lake valley.

5.2.4.2. Archaeology

Archaeological investigation of the Iarcuri fortification took place in four different trenches: one trench each was dug in rampart I and II and in IV two trenches were dug. Ceramics or other finds are rather rare in the ramparts, thus dating is based on ^{14}C samples. Based on this it gets evident that all four ramparts date into the Late Bronze Age. Though the ramparts I and II seem to be the oldest (c. 1,500 to 1,300 cal. BCE/3,450 to 3,250 cal. BP) and rampart IV attends to be a bit younger (1,300 to 1,000 cal. BCE/3,250 cal. BP to 2950 cal. BP) (Szentmiklosi et al., 2011; Heeb et al., 2012). Slight differences in construction can be detected, but whether this is suitable for a chronological difference remains unclear so far.

The excavation of a gate in rampart IV shows a bridgehead, an element of fortification that had been up to this point earliest known from Roman times (Heeb et al., 2014). It is so far the only excavated Late Bronze Age passage of the ramparts in Iarcuri; others have been surveyed by magnetic prospections (Szentmiklosi et al., 2011; Heeb et al., 2012) or by satellite images (Heeb et al., 2008). A total of ten gates have been verified until now (Fig. 37).

In wide areas inside the ramparts I and II magnetic anomalies are measured, which in parts surely indicate houses and developed areas. By now it seems that the buildings inside rampart I are mostly located in the northeastern part (Fig. 37). Inside rampart II the magnetic prospection is still in process. However, preliminary results show that large areas must have been covered by houses and huts. In 2013 remains of at least four Late Bronze Age houses inside rampart I were uncovered in an 800 m² large trench, though their chronological relations are not clarified yet. In 2014 a circular v-shaped ditch with a diameter of approx. 25 m and at least one Copper Age house within was discovered.

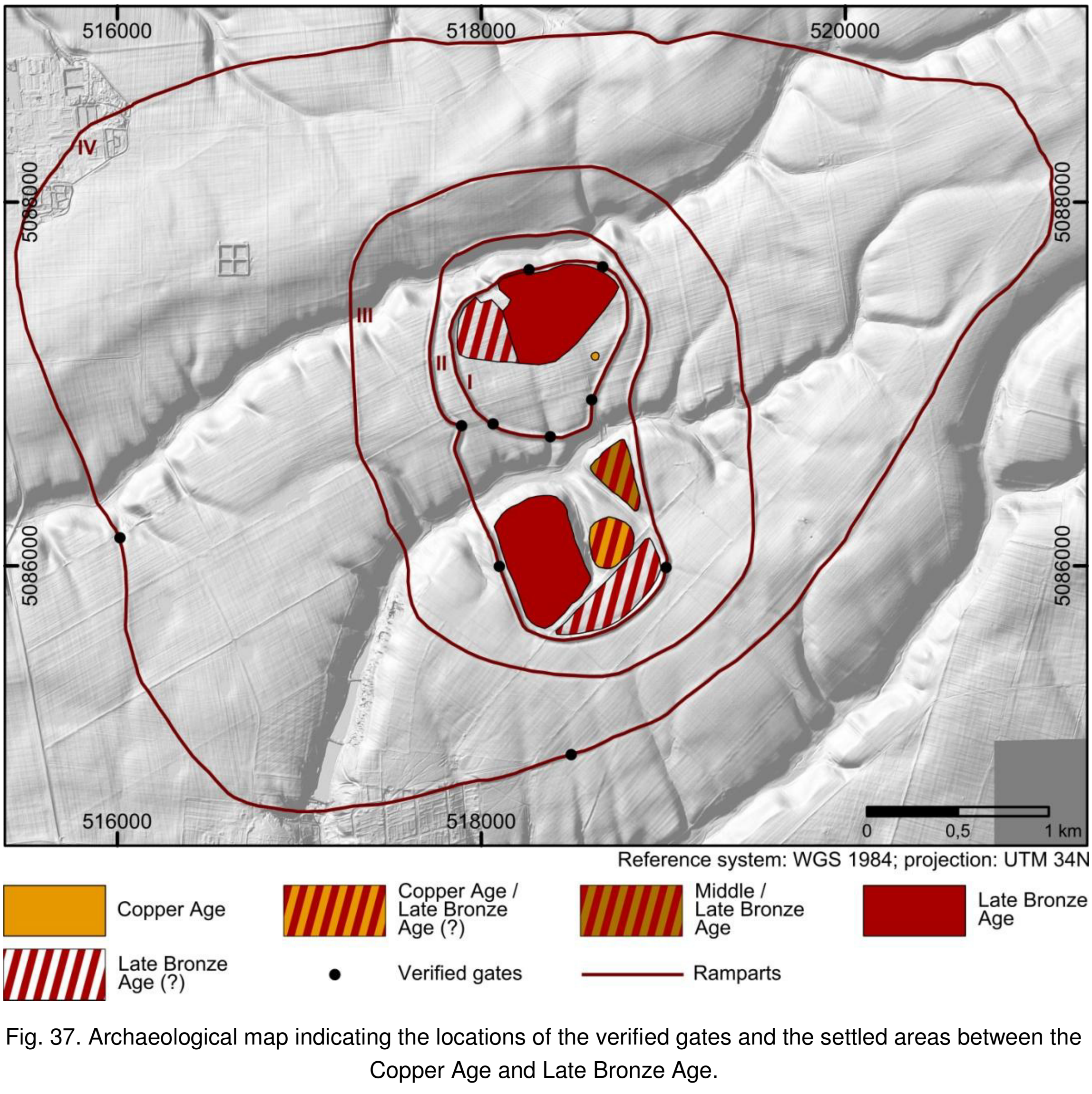

Fig. 37. Archaeological map indicating the locations of the verified gates and the settled areas between the Copper Age and Late Bronze Age.

Since 2008 a total 1.17 km² of systematic field walking and 1.56 km² of magnetic prospections had been carried out. Until 2014 a surface of 0.84 km² was surveyed by both methods so that the results can be combined. By that we suppose that most magnetic anomalies inside the ramparts I and II are likely from Late Bronze Age, except some Middle Bronze Age and Copper Age structures. The number and kind of Late Bronze Age finds collected from the surface give a first idea about the density of inhabitation and the usage of these areas. Inside rampart II nearly double the amount of finds (mostly sherds and daub) were recovered from an area of the same size as in rampart I. That likely indicates a denser occupation in ring II. Quern stones are even more common in ring II, which might indicate that grain processing was mostly carried out in this area (Fig. 37).

5.2.5. Discussion

The characterization of the four drainage basins in the vicinity of the archaeological site Iarcuri shows significant differences regarding their drainage densities and tributary frequencies as well as in terms of tributary geometry. As due to their spatial proximity within the identical geomorphic unit of the Vinga Plain the prevailing local climate is regarded to be uniform across the four catchments (Grigoraş et al., 2004), climatic and geomorphological conditions can be neglected to explain the observed differences. Solely, tectonic activity due to varying subsidence (Urdea et al., 2012) might also be a natural reason for the different catchment characteristics, but due to the proximity of the four basins this factor is also ignored. The geological underground, consisting of Pleistocene gravel, sand and clay (Institutul Geologic, 1966; Borsy, 1990) that were covered with Pleistocene loess (Grigoraş et al., 2004), as well as the soils, mostly consisting of chernozemic Mollisols (Florea et al., 1979;Grigoraş et al., 2004) can also be ruled out causing the observed differences between the catchments. Both, the parent material and the soils that have developed within, are rather uniform and are unrelated to the varying drainage densities as well as the geometric character of the tributary channels. Consequently, past settlement activities around Iarcuri are assumed as the driving force in the development of the channel network as documented for various archaeological sites and elsewhere (Hempel, 1957; Denecke, 1969; Gregory and Park, 1976; Tsoar and Yekutieli, 1992; Wilkinson, 1993; Ur, 2003; Wilkinson et al., 2010). The concentrated appearance of bending tributaries, partially showing reaches with a reversed gradient, indicates that settlement activities in Iarcuri fostered the development of channels, e.g. in the context of gully erosion along paths (Hempel, 1957; Brice, 1966; Piest and Ziemnicki, 1979; Hassler and Hassler 1993a; Wilkinson, 1993).

The two catchments that are directly influenced by the ramparts show distinctly higher drainage densities than the two catchments beyond the built-up area. The higher frequency of tributaries in basin 1 documents the intensive dissection of the valley flanks in this catchment; at least also documenting gullying processes in an intensively used area (Brice, 1966; Piest and Ziemnicki, 1979). The location of the tributaries to be related to former gullies linking between the receiving channels and the ramparts emphasizes that gullying took place along the path system (Hassler and Hassler 1993b; Wilkinson, 1993; Ur, 2003; Wilkinson et al., 2010). Also the course character of the tributaries documents their origin by path-oriented gully erosion: the bending tributaries concentrate on the basin surrounded by the ramparts (Hempel, 1957; Tsoar and Yekutieli, 1992).

The analysis of the high resolution LiDAR DEM documents that almost 20 % of the tributaries inside the built-up environment of Iarcuri source at the ramparts. It is pointed out that the Carani and the Lake valley differ distinctly with respect to their tributaries' frequencies and geometries. Two thirds of the moderately bending and three quarters of the bending tributaries are located in the Lake valley drainage basin. The bending tributaries concentrate in the central part of the Lake valley basin within rampart II. The archaeological map reveals that the Late Bronze Age settlements are concentrated in two areas within the ramparts I and II. By comparing the locations of the Late Bronze Age settlements and the position of the southern gate in rampart I with the location of the three neighboring bending tributaries it appears that both are related.

Typical linear features in landscapes are paths, which develop in consequence of the repeated passage of humans and animals (Brice, 1966; Denecke, 1969; Piest and Ziemnicki, 1979; Tsoar and Yekutieli, 1992; Wilkinson, 1993; Ur, 2003; Wilkinson et al., 2010). Due to compaction processes along the paths they serve as drainage pathways during rainfall events, after a while forming linear hollows, also named sunken lanes or hollow ways, which were formed in association with archaeological sites and contemporaneously to the occupation period of the site (Wilkinson, 1993). The compacted soil tends to reduced water infiltration rates and accelerated surface runoff that leads to soil erosion (Goudie, 2006) and hence, the initiation and lowering of a hollow way. Wilkinson (1993) describes forms of hollow ways in Mesopotamia that are identical to those observed in the vicinity of the archaeological site of Iarcuri. He observed that hollow ways partially became a part of the main channel or of a minor tributary, but elsewhere they clearly run discordant to the natural drainage system, cross watersheds or had reaches with a reversed gradient. Tsoar and Yekutieli (1992) present in their study on ancient paths in the loess landscape of the Northern Negev examples of path-oriented gullies that at some point bend and form a distinct right angle as it is the case for several tributaries in the built-up environment of Iarcuri. They argue that the retrogressive erosion of path-oriented gullies captured minor tributaries or older hollow ways with a completely different orientation. The formation of most of the bending and slightly bending tributaries that occur in the settlement area of Iarcuri can be explained with the capture of former hollow ways by minor tributaries of the Carani and Lake valleys, especially in situations where the reaches of the tributaries flow in the reverse direction to the general surface gradient. The fact that certain tributaries can be associated with the verified gates or the settlements within the Late Bronze Age fortification suggests that they formed during the same period as hollow ways.

5.2.6. Conclusions

The study shows that the fortification enclosures of Iarcuri influenced the development of the drainage system in its immediate environment. Moreover, the analyses reveal that the bending side channels occur clustered in the central part of the Lake valley and in association with the Late Bronze Age settlements and certain verified gates in the ramparts. The association of the Late Bronze Age structures with the unnaturally bending channels suggests that the channels developed during the time period when the site was occupied. Path formation due to trampling by moving humans and animals fostered the development of gullies and linear hollows. Whether the channel geometry could be used to localize additional gates in the fortification enclosures is an issue of future research.

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5.3. Holocene sediment dynamics in the environs of the fortification enclosure of Corneşti-Iarcuri in the Romanian Banat

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Key words: Landscape evolution; Loess derived soils; Alluvial fan formation; Human–environmental interactions; Landscape archaeology; Late Bronze Age

Abstract

The presented study combines data from geomorphological, geochemical, sedimentological, chronometric, and archaeological records providing first insights into the Holocene landscape development in the environs of the Late Bronze Age fortification enclosure Corneşti-Iarcuri. This large-scale archaeological site is located in a loess-covered, undulating landscape at the eastern edge of the Great Hungarian Plain, in western Romania. Sediment archives from geomorphologically different locations, closely related to the Copper Age to Late Bronze Age settlements, are presented. Mainly stable geomorphic conditions throughout the Holocene occurred on the high plains of the Vinga Plain as indicated by chemical alteration of the loss deposits and soil formation processes exceeding 2 m. In contrast, two cores from an alluvial fan of a minor drainage system in direct vicinity of the archaeological site document varying morphodynamics throughout the Holocene. Phases of geomorphic activity and stability are indicated by the formation of fan deposits and paleosols developed in these sediments. ^{14}C dates from charcoal extracted from the fan sediments show maximum deposition ages between c. 4400 cal. BP and c. 2900 cal. BP. Thus, the formation of the charcoal coincides with the Copper Age to Late Bronze Age development of the settlement sites. Daub pieces, incorporated into these reworked soil sediments, provide evidence for human activities in the catchment. This, in turn, may indicate that the erosion processes that led to the fan formation are linked to those activities. However, reworking and redeposition of the charcoal and daub bearing sediments due to retrogressive erosion during the last millennia cannot be excluded.

5.3.1. Introduction

Among terrestrial archives, alluvial fans are often considered to provide a great potential to record past morphodynamics and changes in catchment conditions due to the close proximity of the sediment source in respect to the accumulated alluvial fan. Especially fans originating from small-scale catchments, formed at the confluence of a gully into the main valley, are considered to have a high spatial resolution and a close coupling to hillslope erosion (Chiverrell et al., 2007; Zygmunt, 2009; Dreibrodt et al., 2010a; Dotterweich et al., 2012). Alluvial fans are regarded to react highly sensitive towards land use changes in their upslope catchment areas which may cause gradual soil degradation or severe soil erosion events (Dotterweich et al., 2012). Whereas long-term climatic changes seem to play a minor role with respect to the formation of alluvial fans, peaks of soil erosion occur in phases of more frequent extreme precipitation events together with high land use intensities (Valentin et al., 2005; Dotterweich et al., 2012). In consequence, studying alluvial fans that originate from small-scale catchments often reveal crucial information on past land use changes (Dotterweich, 2008; Zygmunt, 2009). Integrating archaeological records, alluvial fans represent archives in which the interactions of humans and their environments can be investigated (Chiverrell et al., 2007; Dreibrodt et al., 2010a; Dotterweich et al., 2012).

In the surroundings of Corneşti-Iarcuri in western Romania such favorable conditions to study past human–environmental interactions are found. The archaeological site of Corneşti-Iarcuri is known as the largest fortified settlement of Prehistoric Europe (Szentmiklosi et al., 2011). It is located at the eastern edge of the Great Hungarian Plain, about 20 km north of Timişoara (Fig. 38). The site consists of four earth-filled wooden ramparts (Szentmiklosi et al., 2011) that enclose several Late Bronze Age settlements. However, the settlement history in its environs started already in the Copper Age (Szentmiklosi et al., 2011; Heeb et al., 2012). The surrounding landscape, the southern part of the Vinga Plain, is today characterized by wide plains that are completely deforested and intensively used for agriculture. The Vinga Plain is built of Early to Late Pleistocene sediments composed of gravel, sand, silt and clay that were covered by Quaternary loess and loess-like deposits (Institutul Geologic, 1966; Borsy, 1990; Grigoraş et al., 2004). Two general units characterize the landscape in the vicinity of Corneşti-Iarcuri: the slightly undulating high plain and the intersecting saucer-shaped valleys (Leser and Stäblein, 1985). Alluvial fans originate from tributary valleys and interfinger with the alluvial plains of the receiving streams (Nykamp et al., 2015).

Little is known about human–environmental interactions in the environs of Corneşti-Iarcuri. Apart from a case study about the human influence on the development of the drainage network in its built-up area (Nykamp et al., 2015) no geoscientific research has been carried out. In their landscape archaeological approach, Nykamp et al. (2015) apply GIS techniques to link hydro-morphological relief anomalies to archaeological evidence. The results indicate that the presence of the fortification enclosures and settlements had a substantial impact on the evolution of the drainage network, as some of the tributaries could be directly associated with verified gates of the fortifications or to settlements within, respectively. They conclude that trampling by moving humans and animals favored the development of gullies leading to the formation of hollow ways along the ancient paths (Nykamp et al., 2015). To enhance the understanding of the human impact on the landscape evolution in the surroundings of Corneşti-Iarcuri our study aims to investigate Holocene soil formation and sediment dynamics at two geomorphologically different locations in its vicinity. We document present-day morphodynamics and identify former periods of fan formation and pedogenesis through the characterization and interpretation of dated sediment archives. The geoscientific records are combined with archaeological evidences of the Copper Age to Late Bronze Age settlement areas providing first insights into the human impact on the Holocene landscape development in the environs of Corneşti-Iarcuri.

5.3.2. Study site

5.3.2.1. The Great Hungarian Plain

The surface of the Great Hungarian Plain (GHP) (Fig. 38a) is built up from Quaternary fluvial and aeolian deposits. Accordingly, the Great Hungarian Plain is subdivided into wide alluvial plains and large alluvial fans, which are broadly covered by loess or sand dunes (Lóczy et al., 2012).

The tectonic activity of the Pannonian Basin significantly influenced the formation of the alluvial fans of the Great Hungarian Plain. Although the entire basin subsides during the Quaternary, some areas sank with lower velocities and therefore formed relative uplifts. Areas with highest Quaternary subsidence rates, such as the South Tiza Graben or the Körös Basin, sank as much as 300-700 m while other parts of the basin, such as the eastern part of the Mureş alluvial fan, sank to a much lesser degree (Borsy, 1990; Kiss et al., 2012; Kiss et al., 2015). In the western piedmont area of the Zaránd Mountains the Mureş River deposited large amounts of gravel, while the more distal parts of its alluvial fan are characterized by sandy, silty and clayey sediments that were deposited through frequent avulsions (Borsy, 1990; Nádor, 2008; Urdea et al., 2012). The amount and type of sediment transported by the Mureş River was determined by the alternation of the Quaternary glacial and interglacial periods. During the dry and cold glacials coarse sediments were produced and low mean discharges were characteristic whereas the warm and wet interglacials favored chemical weathering and created high mean discharges (Urdea et al., 2012).

In the Pleistocene, extensive parts of the Great Hungarian Plain were covered by loess and alluvial loess (Borsy, 1990; Haase et al., 2007). Chernozems have developed in these aeolian sediments while the sandier areas are characterized by Cambisols (Borsy, 1990). The soils formed on loess or loess-like sediments are generally highly erodible and even loess-covered lowland areas are prone to gully formation. Water-controlled erosion is dominated by sheet wash, and rill and gully erosion processes on harvested agricultural areas. It is intensified by limited infiltration due to compaction, sealing or crusting of the surface or subsurface pan formation, respectively (Lóczy et al., 2012).

With the beginning of the Holocene, the Preboreal showed rapid warming and increased humidity. The temperatures further increased during the Boreal, but it remains unclear whether it was moister or drier compared to present-day conditions. The climate at the beginning of the Atlantic became warmer and moister in comparison to the preceding

Holocene periods, but in the course of the Atlantic it became increasingly drier. With the Subboreal, a marked decrease in temperatures occurred whereas precipitation amounts increased. The temperatures slightly increased with the beginning of the Subatlantic, while precipitation decreased (Kiss et al., 2015).

5.3.2.2. The Vinga Plain

Corneşti-Iarcuri is situated in the southern part of the Vinga Plain (Fig. 38b and c), which belongs to the geomorphic unit of the Romanian high piedmont plain. The high piedmont plain was formed by large coalescing lobes of the Mureş alluvial fan, surrounded by the piedmont hills in the east, the low piedmont plain in the west and south and the Holocene alluvial plain of the Mureş River in the north (Badea et al., 1979; Ianoş, 2002; Grigoraş et al., 2004; Micle et al., 2009). Quaternary loess and loess-like deposits cover extensive parts of the Vinga Plain (Grigoraş et al., 2004). A moderate temperate climate, with annual mean precipitation of 550 mm and a potential evapotranspiration of about 700 mm, prevails on the Vinga Plain (Grigoraş et al., 2004).

Luvic Chernozems predominate in the northern part of the study area, while in the central and southern parts mainly Luvic Phaeozems are developed. Both soil types show a very dark brown to black mollic A-horizon, loamy to clayey textures and humus contents around 2.0-3.5 % (Grigoraş et al., 2004). Soil profiles in the environs of Corneşti-Iarcuri usually show typical features of Calcic Chernozems with calcrete horizons of different development stages at depths ranging between 50 and 110 cm as described by Sherwood (2013). Indications for the formation of paleosols of presumably Pleistocene age are assumed for the area of the high plain in the environs of Corneşti-Iarcuri (Sherwood, 2013). Eroded Chernozems characterize the hillslopes of the valleys and colluvial deposits, in terms of slope sediments that are linked to human activity causing soil erosion (cf. Leopold and Völkel, 2007), are formed at the foot slopes. Fluvic-gleyic Chernozems prevail in the alluvial plains of the valleys (Grigoraş et al., 2004; Sherwood, 2013).

Low slope gradients and west-oriented aspects determine the general northeast-southwest alignment of the valley network that drains the surface of the Vinga Plain (Grigoraş et al., 2004). The archaeological site of Corneşti-Iarcuri is crossed by two creeks that flow at a distance of about 1 km in wide saucer-shaped valleys (nomenclature according to Leser and Stäblein, 1985) from northeast to southwest (Micle et al., 2006). Numerous tributaries have cut their beds into the loamy material of the hillslopes (Fig. 38c and d) and formed well-pronounced alluvial fans at the foot slopes.

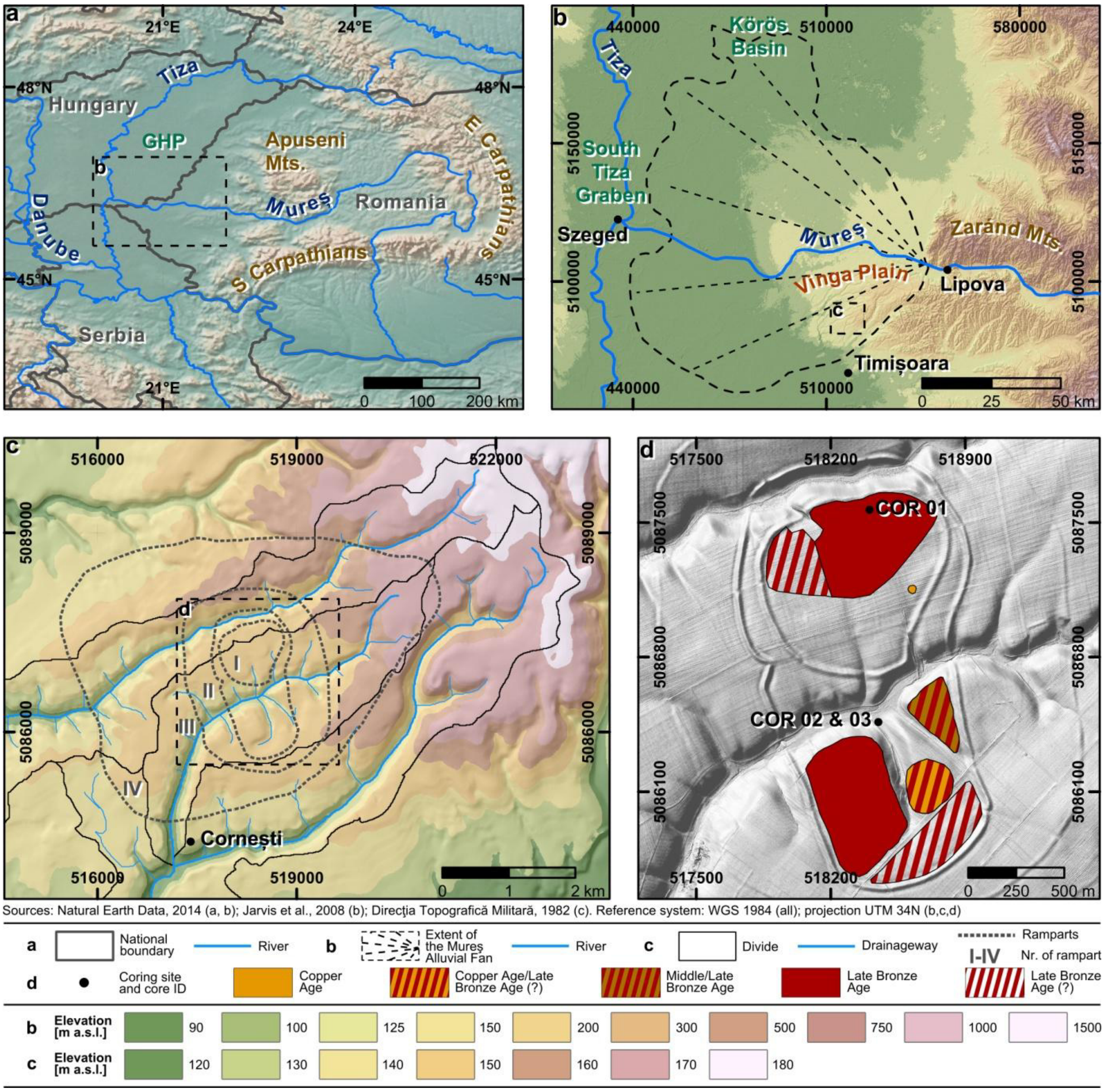

Fig. 38. (a) Overview of the Pannonian Basin with the Great Hungarian Plain (GHP) in the center (vector and raster data from Natural Earth Data (2014)). (b) Location of the study site within its regional setting. Extent of the Mureş alluvial fan modified after Kiss et al., 2014, location of the South Tiza Graben and the Körös Basin after Kiss et al. (2015) and Nádor et al. (2011), location of the Vinga Plain after Grigoraş et al. (2004), (vector and raster data from Natural Earth Data (2014) and Jarvis et al. (2008)). (c) The archaeological site Corneşti-Iarcuri north of the modern village Corneşti. The four ramparts are numbered I to IV from inside out (elevation data from Direcţia Topografică Militară (1982)). (d) Location of the coring sites and the known settlement areas within the inner two ramparts according to their corresponding cultural epoch. Locations of the settled areas and assigned cultural epoch according to Nykamp et al. (2015); the shaded relief is based on a LiDAR DEM with 0.5 x 0.5 m² ground resolution.

5.3.2.3. Archaeological background

The archaeological site Corneşti-Iarcuri is the largest known enclosure of European prehistory. The structure consists of four earth-filled wooden ramparts (Szentmiklosi et al., 2011) with a circular to ellipsoid shape. Altogether, the four ramparts have a length of more than 33 km and enclose an area of 17.2 km^2 (Fig. 38c). Despite intensive agricultural activities that took place over millennia, these constructions are partially preserved to heights of up to 4 m above the surface and represent significant obstacles in the landscape of the Vinga Plain (Szentmiklosi et al., 2011; Heeb et al., 2012; Sherwood, 2013).

The first archaeological excavations in Corneşti-Iarcuri were carried out in 1933 and 1939, but the results were never published (Heeb et al., 2008). Since 2007, the site was re-investigated with modern archaeological methods. New insights regarding the construction of the ramparts and their chronology as well as the internal settlement structures have been achieved. The rampart of the innermost enclosure (rampart I) has been radiocarbon dated to the Late Bronze Age (c. 1500-1300 cal. BCE/3450-3250 cal. BP) and the outermost one (rampart IV) to the transition of the Late Bronze Age to the Early Iron Age (c. 1300-1000 cal. BCE/3250-2950 cal. BP). As all four enclosures are related and do not cut each other, it is argued that the, so far undated, enclosures II and III were built at the same time period as enclosures I and IV (Szentmiklosi et al., 2011; Heeb et al., 2012). The results of systematic field walking confirm the predominance of Late Bronze Age artifacts. In the northern part of enclosure I and in the southern part of enclosure II ceramic concentrations provide evidence for Late Bronze Age settlement areas of varying density. However, the settlement history in the vicinity of Corneşti-Iarcuri started in the Copper Age (Fig. 38d) as indicated by survey results and magnetic prospections (Szentmiklosi et al., 2011; Heeb et al., 2012; Nykamp et al., 2015).

5.3.3. Material and methods

During two field campaigns in the summers 2013 and 2014 the present-day morphodynamic conditions were recorded according to the guidelines of geomorphological mapping by Leser and Stäblein (1975). Additionally, LiDAR data was used to derive topographic profiles of selected areas in the study site. The LiDAR data was acquired and processed by ArcTron Airborne Sensing in spring 2013. Sediment cores with 5 cm diameter were obtained by vibra coring using a petrol driven Cobra (Atlas Copco) hammer. The sediments were described macroscopically according to Ad-Hoc-AG Boden (2005) and Schoeneberger et al. (2011) and sedimentary units were identified according to their characteristics. Color determination was done on non-dried sediments using the Munsell soil color charts. Samples for chemical and physical analyses were taken in 10 cm intervals and processed at the Laboratory for Physical Geography of the Freie Universität Berlin. Initial sample preparation comprised sub-sampling, air-drying, crushing of aggregates in an agate grinder and separation of coarse components with a 2 mm sieve. The sub-samples used to determine chemical elements and carbon contents were homogenized in a vibrating disc mill followed by drying at 105 °C.

The grain size distribution for the fraction ≤ 1 mm Ø was determined using a laser diffraction particle size analyzer (Beckmann-Coulter LS13 320). Sample preparation included removing of organic carbon using 10 % H_2O_2 and placing the samples for several days in a water bath at 50 °C. For the removal of carbonate 17 % HCl acid was used. Thereafter, the samples were washed and bi-distilled water together with about 0.5 g $Na_4P_2O_7$ as anti-coagulation agent was added. The samples were placed in an overhead shaker for 24 hours and treated with ultrasonic for 5 minutes directly before the measurement. The prepared samples were given to a liquid sample divider and two control samples were measured with three independent runs each. All six measurements per sample were averaged to obtain the grain size distribution (Vogel et al., 2016). Mie-theory was applied as the optical model using a refractive index (RI) of 1.55 and an absorption index (AC) of 0.1 as suggested by Özer et al. (2010) to avoid the underestimation of the clay fraction relative to the silt fraction (Eshel et al., 2004). Particle sizes were defined according to Ad-Hoc-AG Boden (2005).

Magnetic susceptibility (MS) at low frequency (0.46 kHz) was measured on air-dried weighted samples using the MS2B sensor (Bartington Instruments) with 10 cm^3 sample containers. The bulk density of the samples was used to calculate the mass specific susceptibility (Dearing, 1999).

The total carbon (TC) contents were determined using the TruSpec CHN (Leco) analyzer. The samples were dry combusted at 950 °C in an O_2 atmosphere and carbon fluxes were quantified by infrared spectroscopy. A multi-point calibration curve was created using certified reference materials (CRMs) (Leco 502-309; 12.29 ± 0.37 mass.-% C; Leco 502-308; 3.6 ± 0.29 mass.-% C) and applied to calibrate the measured sample values. The RSD of the measurements of all CRMs was < 2 mass.-% for the TC. The total inorganic carbon (TIC) contents were analyzed conductometrically using the Carmhograph C-16 (Wösthoff) carbon analyzer. The samples were treated with 42.5 % H_3PO_4 acid at 80 °C and the CO_2, evolving from the digested carbonates, was quantified through the change of conductivity of a 0.05 M NaOH solution. $CaCO_3$ (12.01 ± 0.14 mass.-% C) was used as a calibration standard and the RSD was < 2 mass.-%. By subtracting the TIC from the TC the total organic carbon (TOC) contents were calculated (Müller et al., 2014).

The loss on ignition (LOI_{550}; LOI_{900}) was determined following the procedure of Dean (1974) and calculated according to the equations in Heiri et al. (2001). The dried samples were placed in a muffle furnace and heated for four hours at 550 °C and 900 °C, respectively. The results of the LOI_{550} and LOI_{900} measurements were tested on their linear relationship to the TOC and TIC contents applying the Pearson product-moment correlation (Crawley, 2007). The correction factor achieved by applying a multi-point calibration curve is used to calculate the TOC contents from the LOI_{550} and the TIC contents from the LOI_{900} measurements. The tests on linear relationship between the LOI_{500} and the TOC and the LOI_{900} and the TIC reveal strong positive correlations that are highly significant ($\alpha < 0.01$). The correlation of the LOI_{550} and the TOC ($n = 124$) shows a correlation coefficient of $r = 0.912$ ($\alpha < 0.05$) and a slope of 1.906. The correlation of the LOI_{900} and the TIC ($n = 124$) results in a correlation coefficient of $r = 0.941$ ($\alpha < 0.05$) and a slope of 3.331.

A selection of chemical elements (Al, Si, Ca) were determined using a portable energy dispersive X-ray fluorescence (pED-XRF) analyzer (Thermoscientific Niton XLt3) on powdered and dried samples that were placed in 32 mm sample cups and covered with a mylar foil (0.4 µm) (Simandl et al., 2014). Four certified reference materials (CRMs: GBW 07312; NSC DC 73325; NSC DC 73387; NCS DC 73389) were used to create a multi-point calibration for each element (De Vleeschouwer et al., 2011). The measurements were carried out by applying the previously achieved calibration. To assess accuracy and reproducibility of the analyses the CRMs were re-measured after every ten sample measurements. The accuracy is an indicator of relative proximity of the measured values to the certified values and is expressed as percent difference (% diff). The repeated measurements of the CRMs under identical conditions allow achieving the reproducibility by calculating the relative standard deviation (% RSD) (Simandl et al., 2014). The high accuracy (Al = 5.13 % diff; Si = 3.52 % diff; Ca = 2.71 % diff) and good reproducibility (Al = 1.72 % RSD; Si = 0.74 % RSD; Ca = 2.63 % RSD) demonstrate the reliability of the sample measurements. However, only elements that show mean values larger than four times the 2 sigma error of the measurements were taken into account for the analyses. The major elements were converted into their oxides. All oxides, including the LOI_{550}, were summed up and standardized to 100 % (Schütt, 2004a).

Based on the identified sediment units and their geochemical and sedimentological properties the different core sections were delimited. Geochemical and sedimentological variations among the individual core sections were tested on significance ($\alpha < 0.05$) applying the Wilcoxon rank-sum test, because not all sample distributions met the requirement of normality to apply the t-test (Crawley, 2007).

Radiocarbon datings (^{14}C AMS) were performed on charcoal remains at the Poznan Radiocarbon Laboratory. The ^{14}C ages were calibrated with OxCal 4.2 (Bronk Ramsey, 2009) and the IntCal13 calibration curve (Reimer et al., 2013). The yielded results provide an estimation of the maximal age as reworking of the material could not be excluded (Chiverrell et al., 2007).

5.3.4. Records of sediment dynamics

5.3.4.1. Morphodynamics

The present-day morphodynamics in the area of Corneşti-Iarcuri appear to be rather weak and are mainly controlled by vegetation cover and land use practices. Most parts of the high plain, as well as some of its hillslopes, are intensively used for arable farming and bare surfaces are left behind after the harvest. In some areas of the high plain and its hillslopes steppe vegetation persists, which is used for animal husbandry, primarily sheep herding. The alluvial plains are densely covered by grass; here erosion by water was not observed, and even in the channelized water courses fluvial erosion does not occur. However, on most parts of the surface different relief forming processes occur and diagnostic forms document former dynamics (Fig. 39a). Denudative processes dominate on harvested fields on the high plain. Here, material is relocated by splash erosion and, in areas with sufficient relief, by sheet wash. Deflation prevails during the warm and dry summers on the bare surface of the harvested fields; predominantly caused by dust-devils. Even though the areas of the high plain, which are covered with steppe grass that is used for sheep herding show frequent damage by trampling, these areas lack signs of present-day sediment removal. More intensive sediment dynamics compared to those on the high plain are found on its hillslopes. Agriculturally used hillslopes mainly experience sheet wash, while the ones covered with steppe grass show signs of soil creep and trampling. Colluvial deposits are formed at the foot slopes (Fig. 39a). Water, which is collected in extensive shallow depressions on the high plain generates run-off that results in fluvial erosion in the dell-like valley heads (for illustration see QP 01; Fig. 39d) on the fields and along the field tracks causing the formation of gullies and sunken roads. At the foot slopes of the hollows and sunken roads the active formation of alluvial fans can be observed after rainfall events. In contrast to the erosive run-off on the bare surfaces, the vegetated tributaries show non-erosive run-off, even after heavy rainfall, and alluvial fan formation does not take place at present. However, the presence of alluvial fans downslope of now inactive thalweg and valley-bottom gully systems document former relief forming processes (Fig. 39a). Present-day aggradation of alluvial loam might take place to some extent, but is regarded to be rather small, because the water on the inundated flood plain remains almost clear even after continuous rainfall.

The profile QP MV (Fig. 39b) represents a typical cross profile across the saucer-shaped main valley. Even though the elevation of the high plain is similar on both sides of the valley the southern shoulder lies about 5 m above the northern one. Around 300 m, a pronounced convex knickpoint marks the southern shoulder. The profile of the southern hillslope shows a very slight concavity. The alluvial plain, in between the two marked concave knickpoints, is relatively flat. The profile of the northern hillslope is straight and the shoulder is somewhat smoother than that at the opposed side of the valley. The remains of the innermost rampart that are preserved up to a height of 2 m at this location become clearly visible in the profile. Towards the end the profile turns from straight to slightly convex (Fig. 39b).

The upslope catchment areas of the tributary valley that feeds the alluvial fan from which COR 02 and COR 03 were extracted (Fig. 39a) show settlement remains originating from the Copper Age to the Late Bronze Age (Fig. 39d). The longitudinal profile along this tributary valley (LP TV; Fig. 39c) shows a slightly inclined dell-like valley head in the upper course that is representative for the valley heads in the study area. About 350 m, a distinct knickpoint marks the position where the relief merges into a concave-straight valley profile that was shaped by the erosive action of running water. At around 550 m, a valley-bottom gully is formed. It becomes apparent by comparing the profiles of the valley bottom with the one of the thalweg and indicates a younger incision. From around 700 m onwards, the profile becomes progressively straight and passes over to the convex downstream section indicating an area of fluvial aggradation. Without a clear transition in the course of the slightly convex profile the associated alluvial fan follows at about 900 m. The transition to the nearly flat flood plain after around 1000 m is rather smooth (Fig. 39c).

The morphology of this tributary valley is also documented by a series of topographic cross profiles (QP 01-QP 05; Fig. 39d). The first profile (QP 01) runs across the dell-like valley head showing the shape of a wide shallow depression 220 m downstream of the divide. The profiles QP 02 and QP 03 are located 408 m and 501 m downstream of the divide. They are v-shaped with smooth convex shoulders and rather straight mid-slope sections. The profiles QP 04 and QP 05 are located 700 m and 837 m downstream of the divide showing saucer-shaped valley morphologies. At their foot slopes, distinct convex knickpoints indicate the formation of terraces due to the incision of the valley-bottom gully (Fig. 39d).

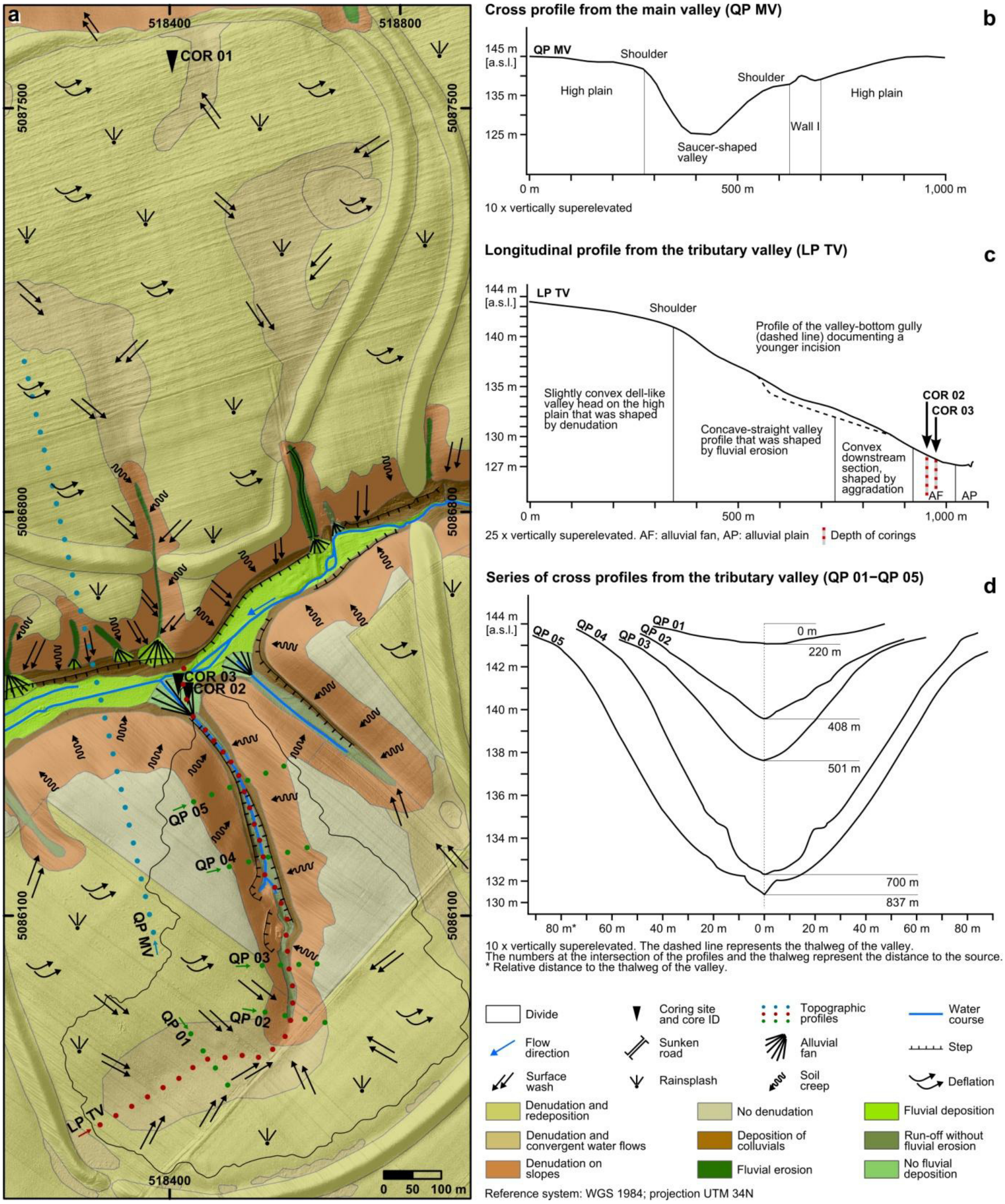

Fig. 39. (a) Geomorphological map indicating the main geomorphic process areas and the dominating relief forming processes. The coring sites and the locations of the topographic profiles are included. (b to d) The topographic profiles illustrate the general relief characteristics in the environs of Corneşti-Iarcuri and in the tributary valley in particular.

5.3.4.2. Sediments

5.3.4.2.1. Core COR 01

The coring site of COR 01 (518402 E, 5087567 N; UTM 34N) is located at an altitude of 140 m a.s.l. on the high plain within the innermost enclosure (Fig. 39). The coring has a total length of 300 cm and was obtained in close vicinity to the archaeological excavation of a Late Bronze Age rectangular structure.

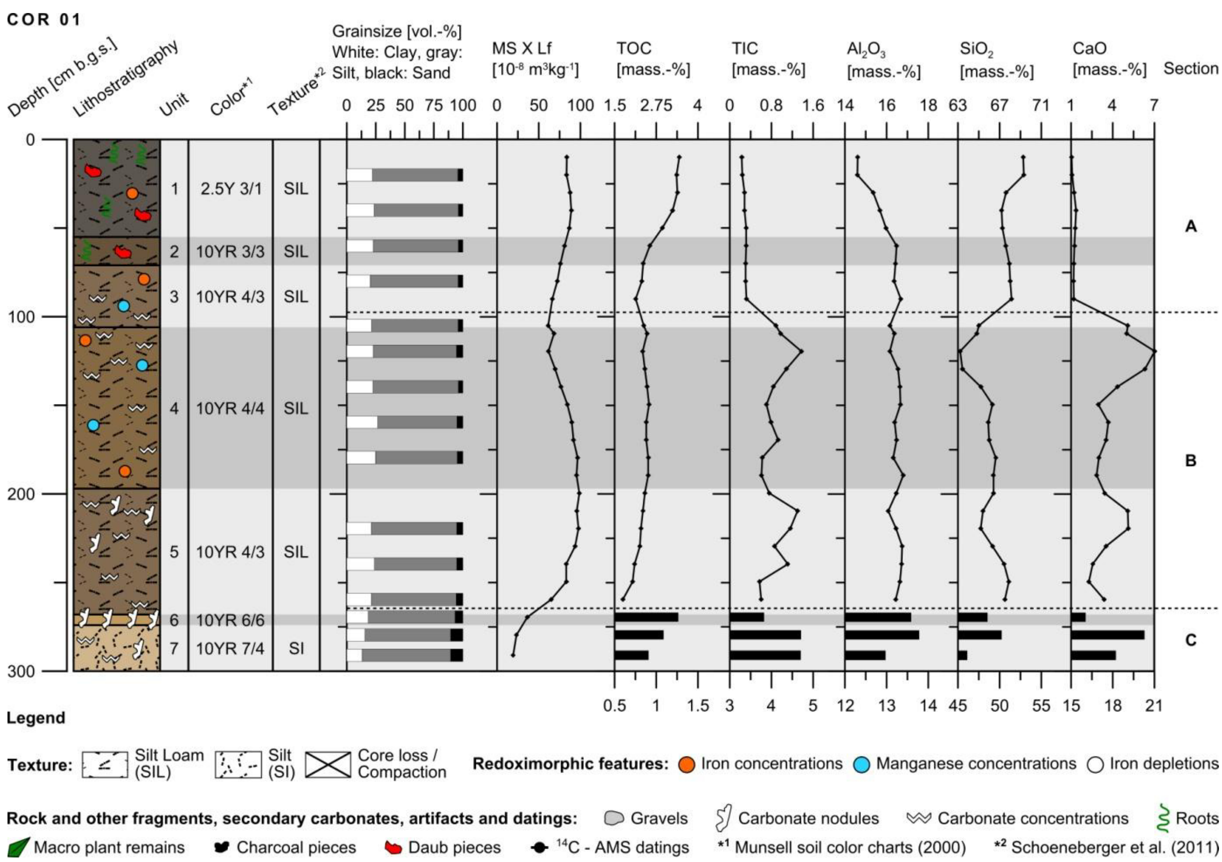

Fig. 40. Sediment description and geophysical and -chemical characteristics of COR 01 (MS x Lf = mass specific magnetic susceptibility, TOC = total organic carbon, TIC = total inorganic carbon; please note that it was necessary to split the scales of the TOC, TIC, Al_2O_3, SiO_2 and CaO in section C in order to enhance the comparability among the sections A and B and the cores COR 02 and 03. The bars in section C refer to the lower scales).

The sediments of COR 01 are slightly moist, free of coarse rock fragments (Ø > 2 mm) and show a firm to very firm consistence with little variations in texture (Fig. 40). The basis (unit 7; 300-274 cm depth) is formed by very pale brown, carbonate rich silt with abundant carbonate concentrations and common medium sized carbonate nodules. The overlying unit 6, distinctly delimited, shows a massive nodular calcrete of about 6 cm thickness with little matrix. The units 5 to 3 (268-71 cm depth) show dark brown to dark yellowish brown colors, a silt loam texture and varying frequency of secondary precipitated carbonates that decrease from bottom to top. Between 190 and 71 cm depth oxidation features in the form of iron and manganese mottles are present. The colors of the units 2 and 1 (above 71 cm depth) are darker and more grayish, fine roots and daub pieces increase towards the top and secondary precipitated carbonates are absent (Fig. 40).

Based on their physical and chemical characteristics, the sediment units of COR 01 are aggregated into three sections. The sediments from the lowermost section (C) are characterized by higher sand and minor clay contents with silt as the dominating grain size fraction. The MS values as well as the TOC, Al_2O_3 and SiO_2 contents are significantly lower than in the overlying two sections while the TIC, and accordingly the CaO contents, are significantly higher ($\alpha < 0.05$). The transition of section C to section B is characterized by a rapid increase of the MS, Al_2O_3 and SiO_2 values and a rapid decrease of the TIC and CaO contents (Fig. 40; Table 4). The middle section (B) shows the highest mean MS values among the three sections. The high TOC and Al_2O_3 contents remain rather stable throughout section B, whereas the TIC, SiO_2 and CaO contents change to a greater extent showing several major variations (Fig. 40; Table 4). The uppermost section (A) shows slightly reduced clay contents in comparison to section B (Table 4). The MS values remain at a high level. The TOC contents continue to increase in section A and exhibit a significantly higher mean value than in the lower sections ($\alpha < 0.05$). The concentrations of Al_2O_3 decline towards the top and show a significantly lower mean value ($\alpha < 0.05$). A marked decrease of the TIC and CaO contents appears at the transition from section B to section A resulting in significantly reduced mean TIC and CaO values ($\alpha < 0.05$). The marked decrease of the CaO content is mirrored by a marked and significant increase of the SiO_2 concentrations ($\alpha < 0.05$) (Fig. 40; Table 4).

Table 4. Descriptive statistics of the geophysical and -chemical properties for the three sections of COR 01 (MS x Lf = mass specific magnetic susceptibility, TOC = total organic carbon, TIC = total inorganic carbon).

Core	Section		MS x Lf [10^{-8} m^3 * kg^{-1}]	Clay [vol.-%]	Silt [vol.-%]	Sand [vol.-%]	TOC [mass.-%]	TIC [mass.-%]	Al_2O_3 [mass.-%]	SiO_2 [mass.-%]	CaO [mass.-%]
COR 01	A	n	9	4	4	4	9	9	9	9	9
		Mean	80.74	22.30	73.78	3.92	2.86	0.29	15.8	68.0	1.2
		SD	7.66	1.44	1.34	0.24	0.52	0.03	0.8	0.8	0.1
		Min	66.39	20.27	72.72	3.73	2.13	0.23	14.6	67.2	1.1
		Max	89.28	23.55	75.74	4.24	3.45	0.32	16.7	69.3	1.4
	B	n	17	8	8	8	17	17	17	17	17
		Mean	83.12	23.15	72.06	4.80	2.34	0.90	16.5	65.8	4.1
		SD	13.45	1.94	2.07	0.65	0.21	0.25	0.2	1.3	1.3
		Min	61.23	21.23	68.33	3.76	1.75	0.57	16.1	63.2	2.3
		Max	98.53	26.68	74.62	5.52	2.54	1.38	16.8	67.9	7.0
	C	n	3	3	3	3	3	3	3	3	3
		Mean	26.26	15.96	72.81	6.86	1.09	4.41	13.4	48.3	18.2
		SD	8.95	2.57	2.53	2.89	0.18	0.51	0.4	2.1	2.1
		Min	19.30	13.47	69.92	4.42	0.91	3.83	13.0	46.1	16.0
		Max	36.36	18.61	76.08	10.45	1.26	4.71	13.8	50.2	20.3

5.3.4.2.2. Core COR 02

The core COR 02 (518448 E, 5086462 N; UTM 34N) was obtained from the central part of the alluvial fan dumped by a tributary valley at an elevation of 128.5 m a.s.l. (Fig. 39). Its total length is 410 cm and it is divided into five units with an almost uniform texture (Fig. 41). The basal unit 5 (410-275 cm depth) is formed by a rigid, grayish brown silt loam that is commonly spotted with iron and manganese mottles and exhibits nodules and scattered medium sized gravels. The color of unit 4 (275-225 cm depth) is slightly darker, and gravels are absent. Secondary precipitated carbonates up to pebble size are spread throughout the unit and dominate between 255 and 260 cm depth. The sediments of unit 3 (225-145 cm depth) consist of dark brown silt loam. Few iron and manganese mottles and common charcoal as well as daub pieces are intercalated. Secondary precipitated carbonates occur in the lower part, whereas the sediments above 210 cm depth are free of carbonates. Unit 2 (109-53 cm depth) is formed by very dark grayish brown silt loam that contains very few daub pieces in the lower part but an increasing content of fine roots in the upper part. Above 53 cm depth (unit 1) the color is slightly more brownish and the root content further increases. The core loss sections at 324 and 311 cm depth, 145-109 cm depth and 27-0 cm depth are the result of compaction while coring these sediments (Fig. 41).

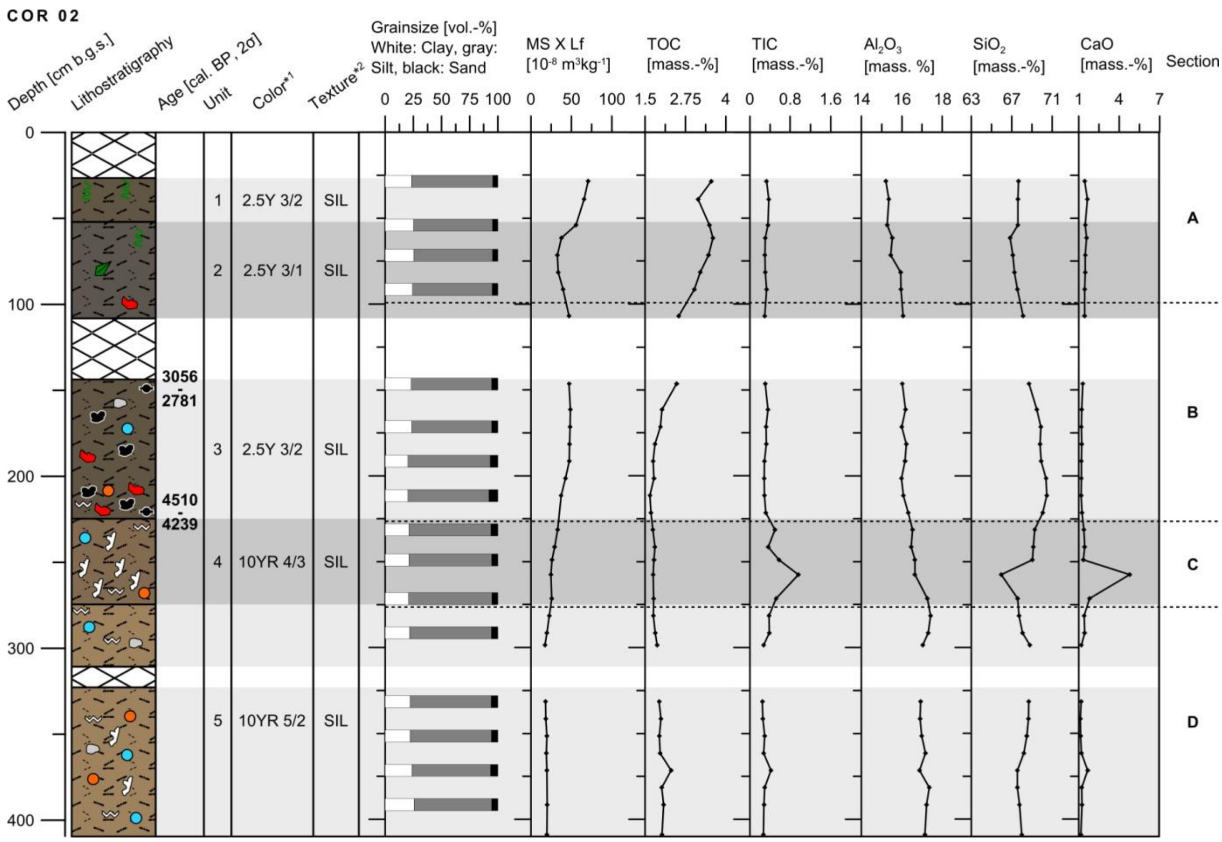

Fig. 41. Sediment description and geophysical and -chemical characteristics of COR 02 (MS x Lf = mass specific magnetic susceptibility, TOC = total organic carbon, TIC = total inorganic carbon; please note that the legend is the same as in Fig. 40).

Table 5. Descriptive statistics of the geophysical and -chemical properties for the four sections of COR 02 (MS x Lf = mass specific magnetic susceptibility, TOC = total organic carbon, TIC = total inorganic carbon).

Core	Section		MS x Lf [10^{-8} m^3 * kg^{-1}]	Clay [vol.-%]	Silt [vol.-%]	Sand [vol.-%]	TOC [mass.-%]	TIC [mass.-%]	Al_2O_3 [mass.-%]	SiO_2 [mass.-%]	CaO [mass.-%]
COR 02	A	n	7	4	4	4	7	7	7	7	7
		Mean	47.99	24.61	70.97	4.76	3.36	0.33	15.5	67.4	1.5
		SD	15.75	0.99	1.03	0.34	0.22	0.03	0.3	0.3	0.1
		Min	32.77	23.34	69.92	4.42	3.03	0.30	15.2	66.8	1.4
		Max	70.52	25.52	72.25	5.30	3.61	0.38	16.0	67.7	1.6
	B	n	8	4	4	4	9	9	9	9	9
		Mean	45.76	21.79	71.95	6.26	1.97	0.31	16.1	69.6	1.2
		SD	3.89	1.78	0.94	1.17	0.33	0.02	0.1	0.8	0.1
		Min	37.26	20.22	70.93	5.30	1.66	0.29	16.0	68.1	1.2
		Max	48.72	23.68	73.20	7.78	2.54	0.36	16.3	70.5	1.4
	C	n	5	3	3	3	5	5	5	5	5
		Mean	27.68	21.16	72.94	5.59	1.77	0.58	16.7	68.2	2.2
		SD	3.38	0.31	0.77	0.35	0.03	0.23	0.3	1.4	1.5
		Min	24.70	20.81	71.98	5.19	1.74	0.36	16.5	66.0	1.3
		Max	32.93	21.35	74.00	6.02	1.81	0.96	17.3	69.3	4.8
	D	n	10	5	5	5	11	11	11	11	11
		Mean	19.43	23.17	71.67	5.80	1.98	0.31	17.1	68.1	1.3
		SD	1.42	1.65	1.26	0.32	0.15	0.06	0.2	0.5	0.2
		Min	17.45	21.70	69.83	5.52	1.76	0.25	16.9	67.5	1.1
		Max	22.55	25.72	72.69	6.24	2.31	0.42	17.4	68.8	1.7

According to their chemical and physical properties the sediment units of COR 02 are combined into four sections. However, the texture of the sediments only shows minor variations among the four sections (Fig. 41; Table 5). The MS values, TIC, and CaO content of section D are very low with significantly lower concentrations compared to the overlying section C ($\alpha < 0.05$). By contrast, the TOC contents are significantly increased in comparison to section C ($\alpha < 0.05$). The highest mean Al_2O_3 concentration occurs in section D. The Al_2O_3 and the SiO_2 values show little variation (Fig. 41; Table 5). Section C is characterized by significantly increased TIC and CaO contents ($\alpha < 0.05$) forming a marked peak at 258 cm, which is also documented in decreased SiO_2 concentrations. The mean values of MS increase, whereas the mean concentrations of Al_2O_3 decrease significantly ($\alpha < 0.05$) with both values showing a continuous trend (Fig. 41; Table 5). The mean MS value and the mean SiO_2 content of section B show a significant increase ($\alpha < 0.05$). A constant increase of the TOC content occurs but the TIC and CaO concentrations remain at a low level without variations. The Al_2O_3 contents decline constantly and show a significantly lower mean value ($\alpha < 0.05$) (Fig. 41; Table 5). The Al_2O_3 and SiO_2 concentrations of the uppermost section (A) continue to decline constantly having significantly reduced mean values ($\alpha < 0.05$). The TIC and CaO contents remain low without alterations. Greater variations occur in the MS and TOC values; the TOC shows a significantly higher mean value than in section B ($\alpha < 0.05$) and a distinct variation in the uppermost 50 cm. The mean MS value is not significantly higher than in section B (α > 0.05) and alteration occurs below 50 cm depth (Fig. 41; Table 5).

5.3.4.2.3. Core COR 03

The coring site of COR 03 (518440 E, 5086478 N; UTM 34N) is located in the distal part of the same alluvial fan, about 20 m northwest of COR 02, at an altitude of 128 m a.s.l. (Fig. 39).

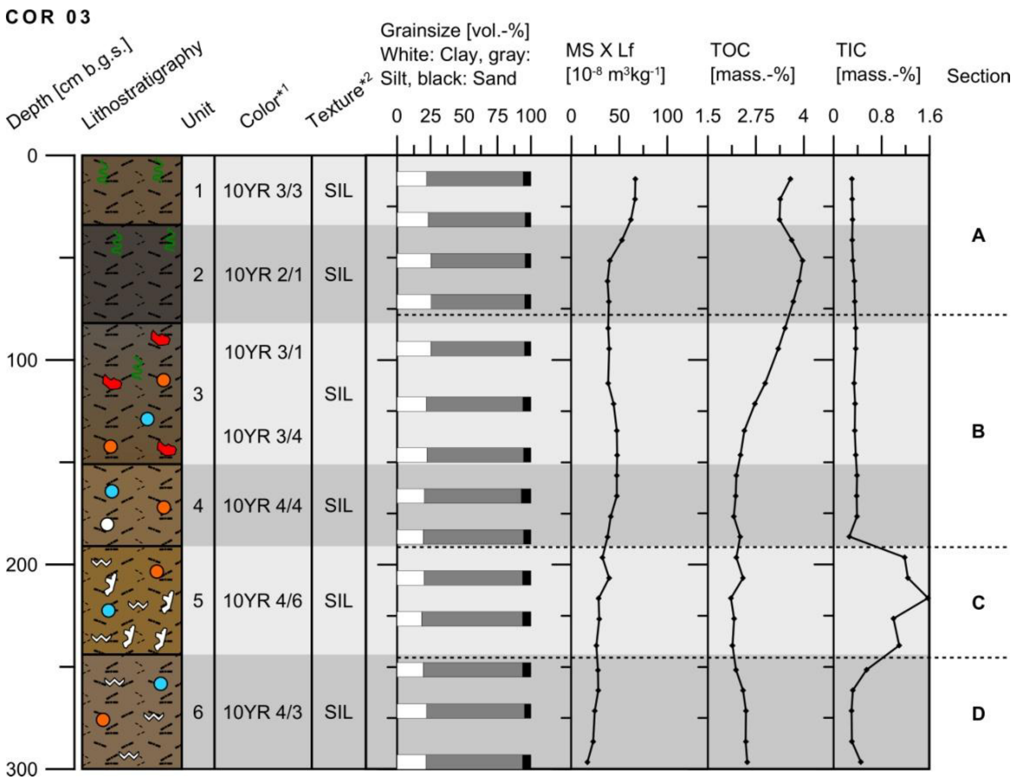

Fig. 42. Sediment description and geophysical and -chemical characteristics of COR 03 (MS x Lf = mass specific magnetic susceptibility, TOC = total organic carbon, TIC = total inorganic carbon; please note that the legend is the same as in Fig. 40).

The total length of COR 03 is 300 cm and it is divided into six units. The sediments are slightly moist; show a uniform texture and a firm to very firm consistence. Coarse rock fragments (Ø > 2 mm) are absent (Fig. 42). The basal unit 6 (300-244 cm depth) consists of dark brown silt loam with few secondary precipitated carbonates, few iron and manganese mottles and small nodules. The content of secondary precipitated carbonates increases considerably in unit 5 (244-191 cm depth) where numerous medium to coarse sized carbonate nodules with few iron and manganese mottles and nodules occur. The color turns into a dark yellowish brown. Sediment unit 4 (191-151 cm depth) is composed of a dark yellowish brown silt loam with few iron and manganese mottles and nodules. Secondary precipitated carbonates are absent. Unit 3 (151-82 cm depth) consists of dark yellowish brown to very dark gray silt loam. Few scattered iron and manganese mottles as well as few fine roots occur. The unit is interfused with fine to medium sized daub pieces. The overlying unit (2; 82-34 cm depth) is free of daub pieces, oxidation features as well as secondary precipitated carbonates. Its color is much darker and the fine root content increases. The uppermost unit (1; 34-0 cm depth) is formed by a dark brown silt loam that shows common fine roots and lacks oxidation marks or secondary precipitated carbonates (Fig. 42).

Based on their physical and chemical characteristics the sediment units of COR 03 are aggregated into four sections. The texture among the four sections shows, as in the case of COR 02, little alteration (Fig. 42; Table 6). The lowermost section (D) is characterized by low MS and TIC values. The average TOC content is significantly higher than in section C ($\alpha < 0.05$) (Fig. 42; Table 6). At the transition of section D to section C, an increase of the TIC contents occurs resulting in a significantly increased mean TIC value ($\alpha < 0.05$). The mean MS value increases significantly as well ($\alpha < 0.05$) whereas the mean TOC content shows a significant decrease ($\alpha < 0.05$) (Fig. 42; Table 6). A marked decrease of the mean TIC content occurs at the transition of section C to section B. The TOC concentrations increase in the course of section B constantly. The mean TOC and MS values are significantly higher than in section C ($\alpha < 0.05$) (Fig. 42; Table 6). The uppermost section (A) shows slightly increasing MS values and a TIC content that remains at a low level. The mean TOC content is significantly higher than in the other three sections ($\alpha < 0.05$) and the alternating values markedly differ in the uppermost 50 cm (Fig. 42; Table 6).

Table 6. Descriptive statistics of the geophysical and -chemical properties for the four sections of COR 03 (MS x Lf = mass specific magnetic susceptibility, TOC = total organic carbon, TIC = total inorganic carbon).

Core	Section		MS X Lf [10^{-8} m^3 * kg^{-1}]	Clay [vol.-%]	Silt [vol.-%]	Sand [vol.-%]	TOC [mass.-%]	TIC [mass.-%]
COR 03	A	n	7	4	4	4	7	7
		Mean	52.01	24.07	71.04	4.65	3.66	0.32
		SD	13.11	1.54	1.13	0.55	0.23	0.02
		Min	37.67	22.23	70.07	4.28	3.36	0.30
		Max	66.55	25.41	72.36	5.59	3.96	0.35
	B	n	10	5	5	5	10	10
		Mean	42.83	21.92	71.72	5.74	2.63	0.36
		SD	4.29	2.22	1.11	1.00	0.48	0.04
		Min	37.67	19.43	70.07	4.65	2.17	0.26
		Max	47.87	25.29	72.40	7.05	3.50	0.39
	C	n	5	2	2	2	5	5
		Mean	30.44	19.43	74.20	5.68	2.22	1.11
		SD	4.91	1.00	1.01	0.73	0.11	0.33
		Min	25.96	18.35	73.25	4.60	2.10	0.55
		Max	39.44	20.32	75.59	6.13	2.41	1.57
	D	n	5	3	3	3	5	5
		Mean	22.90	21.93	72.81	5.27	2.48	0.34
		SD	4.78	0.33	0.62	0.95	0.05	0.07
		Min	16.57	21.69	72.37	4.60	2.42	0.30
		Max	28.03	22.16	73.25	5.94	2.53	0.45

5.3.4.3. Chronology

The chronology is based on two radiocarbon datings of charcoal from COR 02 originating from 222 cm to 146 cm depth (Table 7). Both ages are in stratigraphic order, roughly marking the lower and the upper limits of unit 3 (Fig. 41). The dates show maximum ages of 4510-4239 cal. BP (2561-2877 cal. BCE) at 222 cm and 3056-2781 cal. BP (1107-832 cal. BCE) at 146 cm depth indicating that the charcoal was formed between the Late Copper Age and the transition of the Late Bronze Age to the Early Iron Age. The daub pieces that occur in relation to the dated charcoal pieces are unsuitable for precise archaeological dating. However, their presence is an indication of settlement activities in the upslope catchment area.

Table 7. Results of the ^{14}C dating from COR 02.

Sample ID	Core	Depth [cm b.g.s.]	Laboratory remarks	Dated material	^{14}C age [BP]	Calibrated age [BP, 2σ, from-to]	Calibrated age [BCE, 2σ, from-to]
Poz-59716	COR 02	146	0.4 mg C	Charcoal	2800 ± 50	3056-2781	1107-832
Poz-59718	COR 02	222	0.5 mg C	Charcoal	3920 ± 40	4510-4239	2561-2877

5.3.5. Discussion

The mapping of the morphodynamic processes together with the analyzed sediments and the first rough ^{14}C age determination of the formation of these sediments document the occurrence of Holocene geomorphic activity and stability phases (according to Bork et al.,1998) in the environs of Corneşti-Iarcuri. The high plains, as represented by COR 01 are characterized by geomorphic stability. In contrast the alluvial fan deposits of a first-order drainage basin originating from the high plain, as represented by COR 02 and COR 03 document varying phases of geomorphic activity and stability. The terms of geomorphic activity and stability in the sense of Bork et al. (1998) are applied to landscapes as a whole. We use these terms, however, in relation to geomorphological units, thus downscaling its process-related assignment. Our interpretations are based on the knowledge that different geomorphological units, due to their size, morphometric shape and material composition react with varying sensitivity to changes of land use and climate. Furthermore, due to the scarcity of landscape archaeological and fluvial geomorphological studies in the vicinity of Corneşti-Iarcuri, the discussion of findings refers predominantly to geomorphological processes in comparable situations.

The high plains appear to have experienced rather stable geomorphic conditions, although the forests in the region are typically cleared at least since the Subboreal (Kiss et al., 2015) and the land is intensively used for arable farming since millennia (Sherwood, 2013). This is supported by the preservation of the Copper Age to Late Bronze Age settlement structures in the study area (Szentmiklosi et al., 2011; Heeb et al., 2012; Nykamp et al., 2015). Moreover, the persistence of the Late Bronze Age fortification ramparts, with earthworks that partially run parallel to the main valleys (Fig. 39a and b; Nykamp et al., 2015) in erosion-prone convex upper mid-slope positions (Dikau et al., 2004) demonstrate that the hillslopes experienced rather stable conditions. Thus, geomorphic stability at these sites since at least the Late Bronze Age is expected. Additionally, stability on the high plain persisted beyond the Late Bronze Age. This is reflected in the deeply weathered sediments and the pronounced soil formation as shown by the high TOC contents in the upper ~250 cm of COR 01 (Fig. 40; Table 4). The relationship of geomorphologically stable systems coinciding with phases of soil formation is characteristic for central Europe (Dotterweich, 2008).

Indications for chemical weathering in these loess-derived soils are the solution of carbonates and the corresponding depletion of Ca, also documented in the relative enrichment of less soluble and immobile elements like Al and Si (Nesbitt et al., 1980; Nesbitt and Young, 1982; Schütt, 2004b; Buggle et al., 2011). The element concentrations of the three sections (A-C) of COR 01 are fairly comparable to those reported by Muhs et al. (2001). They reflect intensive chemical weathering of the loess-like deposits resulting in the relative enrichment of Al and Si in combination with an absolute depletion of Ca in section A, and to a lesser degree in section B. The basal section C of COR 01 shows significantly lower Al and Si concentrations together with significantly higher Ca and TIC values than the two overlying sections (Fig. 40; Table 4), thus representing unaltered loess or loess-like deposits.

Carbonates from the overlying sections A and B were precipitated as calcrete at the top of section C (Fig. 40). Pedogenic calcretes are the product of illuvial concentration of calcium carbonate that was solved from the upper soil layers, moved in solution through the profile and precipitated in lower parts where suitable conditions prevailed (Wright, 2007). As pedogenic calcretes generally need a long time and extended periods without significant sediment input to accumulate in the soil (Wright, 2007) the documented calcretes in COR 01 represent another indicator for long-lasting stable conditions on the high plains.

However, the continuously high TOC contents throughout section B (Fig. 40) can also be taken as an indicator for an A-horizon that was built upward due to ongoing weak aeolian accumulation (cf. Mason and Zanner, 2005) pointing to geomorphic activity. Evidence for aeolian activities in the area of the Great Hungarian Plain exists for most phases of the Holocene (Kiss et al., 2015), but no evidence for recurring aeolian accumulation was found in section B. Another explanation for the high TOC content can be bioturbation, whereby the soil is mixed and homogenized by the burrowing activity of animals (cf. Mason and Zanner, 2005; Spaargaren, 2008).

Luvic Phaeozems, frequently occurring in the study area (Grigoraş et al., 2004), have a characteristic dark brown subsoil horizon where clay and humus is accumulated (Gerlach et al., 2006). This translocation of humus could further explain the continuously high TOC content until c. 250 cm depth in COR 01. Luvic Phaeozems can develop from Chernozems as climatic conditions become moister and clay and humus are leached from the mollic A-horizon and translocated to form the argic B-horizon (Gerlach et al., 2006; Eckmeier et al., 2007). Other processes that could affect the formation of Luvic Phaeozems are certain land use techniques, e.g. slash and burn agriculture that leads to a changing soil organic matter composition. Examples from northwest Germany show that the human induced formation of Luvic Phaeozems occurred during several archaeological periods between the Mesolithic and the Middle Ages (Gerlach et al., 2006; Eckmeier et al., 2007; Dotterweich, 2008). First evidence of Neolithic slash and burn agriculture and the associated influences on the landscape development of the Great Hungarian Plain are reported for the Atlantic phase (Kiss et al., 2015). However, until now it remains unclear upon which particular techniques the agricultural economy of the Copper Age and Bronze Age cultures in the study area were based on.

Even though the World Reference Base for Soil Resources criterion of an argic B-horizon (IUSS Working Group WRB, 2007) is not perfectly met in COR 01 (Fig. 40; Table 4), the slightly increased mean clay content in section B points to leaching and illuviation. The assumption of a long-lasting period of intensive soil formation including translocation of clay and humus is further supported by the high MS values that are present in sections A and B (Fig. 40). Magnetizable material is mostly bound to clay and humus (Hanesch and Scholger, 2005), thus leaching and illuviation often cause a relative magnetic enhancement of the illuvial horizon (Jordanova and Jordanova, 1999). It is evident for many soils developed in loess and particularly for Chernozems that the changes of magnetic susceptibility values correspond to the soil horizons, whereas the lowest values occur in the non-weathered loess layers (Maher, 1998; Jordanova and Jordanova, 1999). Magnetic enhancement occurs e.g. during soil formation, whereby well drained soils with intermittent wet and dry periods and a sufficient source of substrate-Fe show highest enhancements (Maher, 1998). The mean MS values obtained for the sections A and B in COR 01 are in good agreement with the soil reference values for Chernozems developed in loess (Hanesch and Scholger, 2005) and with the values achieved for a Chernozem in northeastern Bulgaria (Jordanova and Jordanova, 1999). This, together with the decreasing MS and TOC values and higher TIC contents of section C in COR1, reinforces the hypothesis of intensive pedogenesis in the study area leading to the formation of a Chernozem and the following development to a Luvic Phaeozem by leaching and illuviation processes. Thus COR 01 is regarded to represent Holocene geomorphic stability in the area of the high plain.

Evidence for present-day geomorphic activity in the environs of Corneşti-Iarcuri is given by the occurrence of most recent and present-day soil erosion and active formation of associated forms and sediments. This is documented by gullying, the formation of sunken roads and the deposition of alluvial fans and colluvial deposits (Fig. 39a). Deflation occurs during the dry season on the tillage areas where the bare soil is exposed to the wind and in particular where particles are lifted artificially, e.g. by ploughing. Wiggs and Livingstone (2004) point out that sediments which are exposed to the wind e.g. by ploughing are highly susceptible to deflation. Tsoar and Yekutieli (1992) emphasize that the artificial lifting of particles considerably contribute to particle entrainment where wind speed is usually too low to allow deflation. Hillslope processes such as sheet wash, rainsplash, tillage erosion and soil creep cause the down slope movement of soil material resulting in eroded soils on the hillslopes (Grigoraş et al., 2004; Lóczy et al., 2012) and the formation of correlative colluvial deposits at the concave foot slopes as documented by Sherwood (2013). In the shallow depressions on the high plain the surface run-off converges and initiates rill and gully erosion in the tributary valleys and hillslope hollows as well as along the field tracks leading to the deposition of alluvial fans. These processes are well documented for various environments e.g. by Tsoar and Yekutieli (1992) for a loess covered region in the northern Negev, by Chiverrell et al. (2007) for Great Britain and by Lóczy et al. (2012) for Hungary. Diagnostic forms, e.g. the now inactive gullies and correlative alluvial fans (Fig. 39) demonstrate the occurrence of former phases of geomorphic activity as pointed out by e.g. Dotterweich (2008) for central Europe and Zygmunt (2009) in the case of alluvial fans formation in southwestern Poland.

The alluvial fan deposits documented in the corings COR 02 and COR 03, located on a presently inactive alluvial fan of a first-order drainage basin (Fig. 39a), provide further evidence and chronometric age control of the Holocene sediment dynamics. The results obtained by macroscopic sediment descriptions and chemical and sedimentological analyses show that the sediment units of COR 02 and COR 03 correlate well with respect to the succession of the units and their associated depth (Figs. 40 and 41). The comparison of the properties of COR 01 to those of COR 02 and COR 03 shows that the alluvial fan is exclusively composed of reworked soil and weathered material. A section with non-weathered loess, as shown at the base of COR 01, was not detected in COR 02 and COR 03 and seems to be unlikely, because the distinct sediment characteristics, e.g. the low TOC, Al and Si values together with the high TIC and Ca concentrations lack in the fan sediments (Figs. 39-41; Tables 3-5).

According to the position of COR 02 and COR 03, between the alluvial fan and the floodplain of the receiving stream (Fig. 39a), it is assumed that the lowermost section (D) represents floodplain deposits (Fig. 43a). These lowermost sections (Figs. 40 and 41) show slightly increased TOC contents indicating their possible origin from a humic A-horizon (Dreibrodt et al., 2010b). The low TIC values in both cores and the low Ca concentrations in COR 02 reflect the decalcification of these sediments while they were situated at higher positions and experienced leaching (Dreibrodt et al., 2013). Furthermore, the high Al and Si contents in COR 02 document a relative enrichment by depletion and formation of clay minerals due to chemical weathering (Heim, 2001; Dreibrodt et al., 2013). These findings point to the formation of a paleosol (Fig. 43b) that has developed in the alluvial deposits, presumably during the Atlantic phase (Kiss et al., 2015). The absence of increased MS values as a further indication of soil formation might result from magnetic depletion of the soil under waterlogged conditions (Maher, 1998).

The onset of fan development (Fig. 43c) is represented by the sections C in the cores COR 02 and COR 03 (Figs. 40 and 41), whereby material with low humus contents buried the humic A-horizon of the sections D in both cores. This depositional phase occurred prior to c. 4400 cal. BP (2450 cal. BCE) (Table 7). The onset of the second phase of fan formation (Fig. 43d) dates to c. 4400 cal. BP (2450 cal. BCE), thus coinciding with the development of the Copper Age settlement landscape in the area. The upper limits of the sections B in COR 02 and 03 (Figs. 40 and 41; Table 7) date to the transition of the Late Bronze Age to the Early Iron Age c. 2900 cal. BP (950 cal. BCE). This second phase of fan formation coincides spatially and temporally with archaeological evidences for the Copper Age to Late Bronze Age settlements in the environs of Corneşti-Iarcuri (Szentmiklosi et al., 2011; Heeb et al., 2012; Nykamp et al., 2015).

The characteristics of the sections C in the cores COR 02 and COR 03 indicate a weakly developed nodular calcrete whereas the overlying sediments, up to a depth of about 2 m, lack signs of secondary precipitated carbonates. Assuming that the secondary precipitated carbonates in COR 02 and COR 03 were formed by leaching and illuviation, as in the case of

COR 01, two implications can be drawn. First, the precipitation of the carbonates must have occurred after c. 4400 cal. BP (2450 cal. BCE), because this marks the maximum age of the onset of the fan formation. Second, the comparison of the depth of the uppermost occurring secondary precipitated carbonates in COR 01 (at ~ 90 cm depth) with the depths in COR 02 and COR 03 (Figs. 39 to 41) shows that the overlying carbonate-free sediments in the alluvial fan are about twice as thick as on the high plain. Thus, a period in which the fan formation ceased and soil formation took place (Fig. 43e) is assumed to have occurred after the deposition of the sections B. According to Barta (2011) larger and well-cemented nodules of secondary precipitated carbonates are older and smaller concretions point to shorter periods of pedogenesis. Taken this into account, the smaller nodules found in COR 02 and COR 03 are regarded as an indicator for a shorter phase of soil formation in comparison to COR 01. Further indication for a phase of soil formation under stable geomorphic conditions is indicated by the constantly increasing TOC values starting at depths of more than 150 cm (Figs. 40 and 41).

The youngest phases of fan formation (Fig. 43f) occurred after c. 2900 cal. BP (950 cal. BCE) and are represented by the sections A in the cores COR 02 and COR 03 (Figs. 40 and 41; Table 7). The more brownish colors of the sediments of the units 1 in both cores that overlay in both cases considerably darker material (units 2) together with the irregularly increasing TOC values that vary in both sections A point to a young burial of a humic A-horizon (cf. Boettinger, 2005).

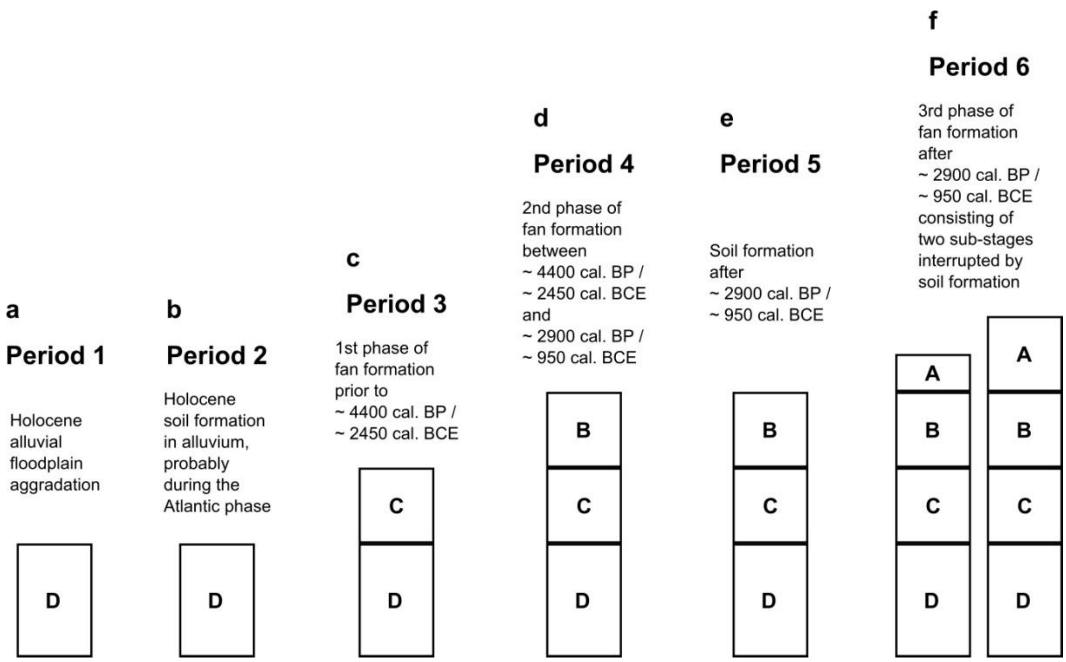

Fig. 43. Simplified model of Holocene floodplain aggradation and fan development at the mouth of a tributary that originates from a small-scale catchment. The development periods 1-6 are named a-f in the text.

Gully erosion and the corresponding fan formation are threshold-dependent processes that are controlled by various factors (Valentin et al., 2005). Among these factors local land use and frequency of extreme rainfall events are considered to be the main driving forces (Bork et al., 1998; Valentin et al., 2005; Chiverrell et al., 2007; Dotterweich, 2008; Zygmunt, 2009; Dreibrodt et al., 2010b; Dotterweich et al., 2012). Human activities often cause that geomorphic thresholds are exceeded either enabling gully erosion to occur on the hillslopes or creating the precondition for gullying subsequent to extreme events (Chiverrell et al., 2007). Forest clearings and agricultural expansions are regarded to be common factors enabling geomorphic thresholds to be exceeded and thus controlling historic soil erosion (Dotterweich, 2008; Dotterweich et al., 2012).

However, for many archaeological sites it is reported that the repeated passage of humans and animals can foster the development of path-oriented gullies through retrogressive erosion along ancient paths (Tsoar and Yekutieli, 1992; Wilkinson, 1993). Ramisch et al. (2012) demonstrate for the vicinity of a pyramid, constructed during the 4th Dynasty of the Old Egyptian Kingdom that gullies developed along the regular footpaths between the settlement at the rim to the Nile floodplain and the construction area in the hinterland. The erosion process is due to soil compaction and resulting reduced infiltration capacity, so that increased surface runoff leads to gully formation (Schütt et al., 2005). The location of the tributary valley that feeds the fan from which COR 02 and COR 03 were extracted – with the headwater area located between Copper Age to the Late Bronze Age settlements (Szentmiklosi et al., 2011; Heeb et al., 2012; Nykamp et al., 2015) and a possible watering pool at the perennial creek of the receiving stream – suggests that similar processes occurred between the Copper Age and the Late Bronze Age in the studied catchment, too. Wilkinson (1993) emphasizes that the formation of linear hollows, which are associated with archaeological sites occurs contemporaneously with the occupation period of the site. The results of Nykamp et al. (2015) show that several tributaries in the built-up area of Corneşti-Iarcuri are related to either archaeologically verified gates to the fortification or to settlement areas within e as it is the case for the small-scale catchment of this study. Taking this into account the obtained maximum ages for the deposition of the fan sediments from COR 02 are in good agreement with the suggested formation period of the path-oriented gully. Thus, it is assumed that the deposition periods of the fan sediments were closely related to the human impact in the upslope catchment area, namely the repeated passage of humans and animals along regular footpaths between the settlement areas and the perennial creek of the receiving stream.

5.3.6. Conclusions

Our study provides a first glimpse into the Holocene landscape development in the surroundings of the fortification enclosure of Corneşti-Iarcuri in western Romania, considering the Copper Age to Late Bronze Age settlement history. We link geoscientific records of present and past morphodynamics with archaeological evidences to decipher potential anthropogenic impact on the landscape development. Our results suggest that the Holocene morphodynamics on the high plains were rather weak, as the Copper Age to Late Bronze Age settlement and fortification structures are partially still well preserved. Further indication of long-lasting geomorphic stability is provided by the deeply weathered aeolian sediments and the pronounced soil formation that is present on the high plain. However, the investigated alluvial fan that is fed by a first-order tributary valley sourcing close to the

Copper Age to Late Bronze Age settlements documents the occurrence of varying active and stable geomorphic conditions throughout the Holocene. Here, indications for the development of different paleosols were found pointing to geomorphic stability in the catchment, whereas the fan sediments point to phases of activity. The ^{14}C datings obtained from reworked soil sediments of the alluvial fan revealed maximum ages between the Copper Age and the transition from the Late Bronze Age to the Early Iron Age. The temporal concurrence of the obtained ages and the documented settlement phases suggest that human impact caused intensified fan formation, considering that linear hollows that are associated with archaeological sites develop contemporaneously with the site, mainly as path-oriented gullies and hollow ways.

Acknowledgements

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5.4. A landscape archaeological approach to link human activities to past landscape change in the built-up area of the Late Bronze Age enclosure Corneşti-Iarcuri, western Romania

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Key words: Human–environment interactions; Hollow ways; Interdisciplinary research; Landscape archaeology; Conceptual model

Abstract

This study exemplifies the theoretical and methodological process of integration of disciplinary results, the joint development of new hypotheses and its interdisciplinary interpretation in the framework of landscape archaeological research. A conceptual model is introduced to visualize the integration process. The findings of two recently published studies and the archaeological state of the art regarding the largest known prehistoric enclosure in Europe – Corneşti-Iarcuri – are used as exemplary data to demonstrate the applicability of the conceptual model. The presented discussion shows how integration of disciplinary findings leads to a more holistic and more rigorous interpretation and opens the opportunity to jointly develop new hypotheses that can be integrated subsequently.

5.4.1. Introduction

Landscape as a – by itself – transdisciplinary term (Legler, 2012) offers more than the opportunity to simply combine disciplinary results in order to achieve a multidisciplinary interpretation (Meier and Tillessen, 2011; Meier, 2012). It offers the possibility to perform interdisciplinary research (Meier, 2012) including the joint interpretation of findings, the re-formulation of hypotheses and the joint development of new questions.

We understand landscape as a physical phenomenon that is modified by economical and socio-cultural utilization, which causes a constant transformation of the landscape and which is followed by a changing perception and the assignment of a new meaning (Gramsch, 2003; Legler, 2012). Thus, in the context of our study, the term landscape has two primary meanings: First, landscape is seen as a geographically delimited area whose natural factors can be investigated using scientific methods. Second, landscape is seen as a social construct of an area which owes its existence to the human assignment of meaning and which needs to be investigated hermeneutically (Kluiving et al., 2012; Legler, 2012).

This study aims to draw conclusions on the value of an interdisciplinary approach from the field of landscape archaeology. This is realized by: i) summarizing the main findings presented in two recently published studies (Nykamp et al., 2015; Nykamp et al., 2016) in connection with the archaeological state of the art (Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2014; Heeb et al., 2015), ii) discussing the applied work flow, which allowed the integration of results achieved by the disciplines of archaeology and physical geography, and iii) emphasizing the importance of a mutual discussion of disciplinary findings across the disciplines, the joint development of hypotheses and their interdisciplinary interpretation.

The two recently published studies deal with the human–environment interactions in the environs of the Late Bronze Age enclosure Corneşti-Iarcuri in western Romania.[1] The findings indicate the degree and the kind of human impact related to Copper Age and mainly Late Bronze Age settlement activities and the large-scale Late Bronze Age enclosure. A series of hollow ways were identified that could relate to the developing Copper Age and Late Bronze Age structures. They were formed due to compaction and reduced infiltration capacity (Goudie, 2006) along regular footpaths fostering gully development due to retrogressive erosion (Tsoar and Yekutieli, 1992). Hence, the prehistoric human impact on the development of the local relief and drainage network can be inferred. Moreover, first ideas regarding the network of Late Bronze Age intra-site pathways that connect settlement clusters can be developed.

Our example illustrates how integration leads to a more holistic interpretation, which is more rigorous than a purely disciplinary research could be in this regard, and how new hypotheses can be jointly developed and interpreted.

[1] The studies of Nykamp et al., 2015 and Nykamp et al., 2016 are realized in the context of the Excellence Cluster (EXC 264) Topoi project A-6-8 and in close cooperation with the DFG project WE4596/5-1.

5.4.2. The environs of Corneşti-Iarcuri and its archaeological background

Corneşti-Iarcuri is located at the eastern rim of the Great Hungarian Plain, in the area of the Romanian Banat, c. 20 km north of the city of Timişoara. The surroundings of Corneşti-Iarcuri belong to the Vinga Plain that is geomorphologically characterized by loess covered interfluves and wide saucer-shaped valleys that generally drain southwestwards (Fig. 44; Grigoraş et al., 2004; Nykamp et al., 2015). The hillslopes of these valleys are commonly dissected by hollows and gully-like first order tributaries that frequently form well-pronounced alluvial fans at their outlets (Nykamp et al., 2015; Nykamp et al., 2016). The prevailing climate is moderate temperate with mean annual precipitation of 550 mm (Grigoraş et al., 2004). Today, most of the area is intensively used for arable farming; some smaller areas where steppe grass vegetation persists are used for sheep herding (Nykamp et al., 2016).

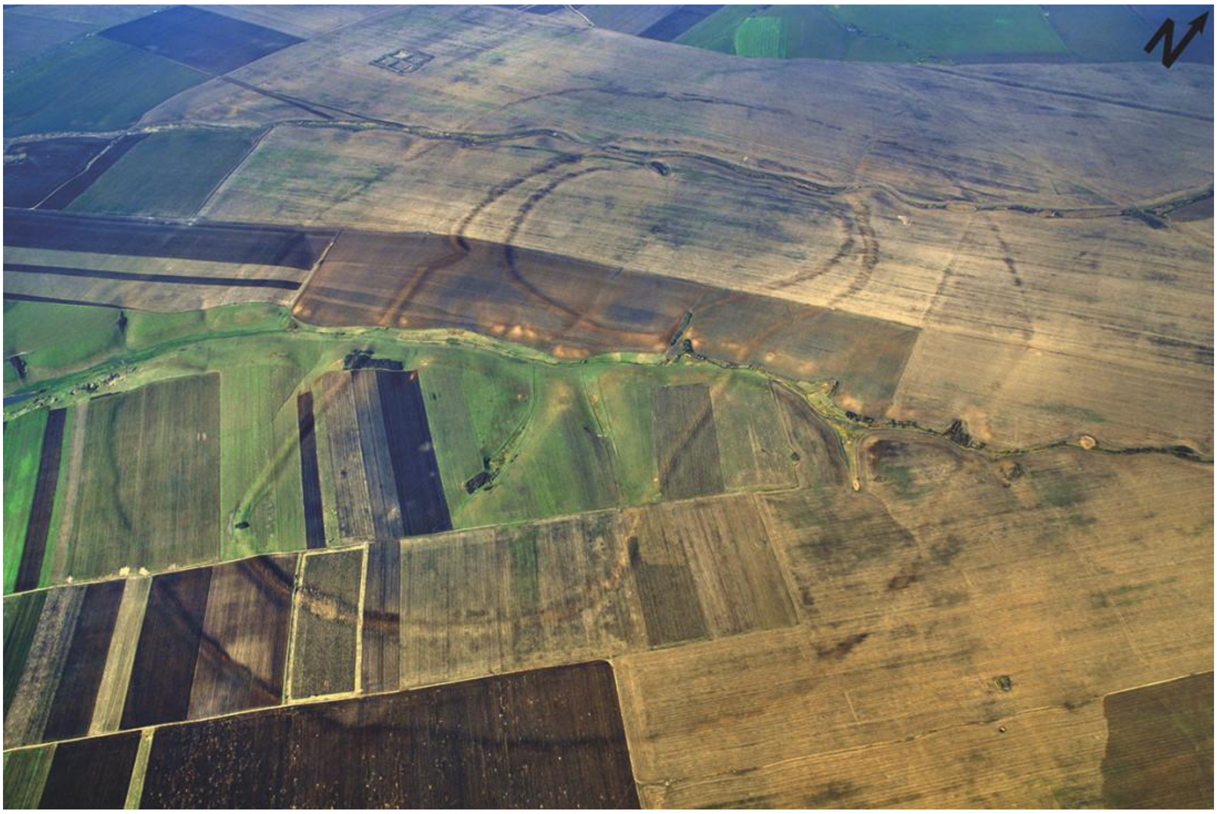

Fig. 44. Oblique aerial view on Corneşti-Iarcuri. The photograph gives a good overview of the prevailing landscape; three of the four enclosing ramparts are clearly visible. The innermost rampart I (in the upper central part of the picture) measures c. 1 km in diameter. Photograph taken by: Daniel Baltat, Bucharest, 2009.

With its four earth-filled wooden ramparts Corneşti-Iarcuri (Fig. 44) is the largest known enclosure of the European prehistory (Szentmiklosi et al., 2011). The enclosed area totals c. 17.6 km² and the four ramparts have a total length of more than 33 km (Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2015) and at least ten gates (Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2014; Nykamp et al., 2015). Settlements with varying density have been identified within the two innermost ramparts (Fig. 45; Heeb et al., 2012; Nykamp et al., 2015). Based on a series of radiocarbon dates it is known that the ramparts of the enclosure date to the Late Bronze Age until the transition to the Early Iron Age. The two innermost ramparts I and II date to c. 1500-1300 cal. BCE (3450-3250 cal. BP) at 2σ and the outermost rampart IV to c. 1300-1000 cal. BCE (3250-2950 cal. BP) at 2σ. Rampart III is undated so far, but it is assumed that it dates to the same period of time, because the ramparts do not cut each other (Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2015). To date, ten gates (Fig. 45) have been identified by the combination of excavation and the interpretation of satellite and aerial images and LiDAR and magnetic data (Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2014; Nykamp et al., 2015). The interpretation of magnetic data and extensive systematic field walking also allowed identifying subsurface settlement structures and estimating the density of settlement areas within the two innermost ramparts I and II (Fig. 45; Szentmiklosi et al., 2011; Heeb et al., 2012; Nykamp et al., 2015). Based on the chronology of documented artifacts, mostly pottery sherds, it turned out that its predominant majority date to the Late Bronze Age (Cruceni-Belegiş I-III). Besides, fewer quantities of Copper Age (Tiszapolgár), Early Bronze Age (Makó), Middle Bronze Age (Vatina) and Iron Age (Gornea-Kalakatča) artifacts have been identified, too (Szentmiklosi et al., 2011; Heeb et al., 2012).

The archaeological research conducted since 2007 allows differentiating areas within the two innermost ramparts I and II that were densely settled during the Late Bronze Age in comparison with other areas that show substantially lower settlement densities (Fig. 45; Heeb et al., 2012). Other areas, in turn, show higher densities of Copper Age settlements (Fig. 45; Szentmiklosi et al., 2011; Heeb et al., 2012). It turned out that the southern part within rampart II shows the highest Late Bronze Age settlement densities of the total investigated area (Fig. 45). Another area that shows signs of dense Late Bronze Age settlements is located in the northeastern part within rampart I (Fig. 45). However, the comparison of the obtained amount of pottery sherds per square meter shows that the assumed Late Bronze Age settlement density within the southern part of rampart II is much higher than in the northeastern part of rampart I (Heeb et al., 2012; Heeb et al., 2015). In the southeastern part of rampart II a round enclosure of four ditches and settlement structures have been identified. Based on the shape and orientation of the houses and the clear concentration of Tiszapolgár pottery sherds this area is regarded to represent a Copper Age settlement (Fig. 45; Szentmiklosi et al., 2011).

5.4.3. Summary of complementary studies

The archaeological state of the art demonstrates that the picture of settlement locations from the different cultural epochs becomes more and more explicit within the two innermost ramparts I and II. However, many questions remain open, e.g. how did people move through the enclosed area and the adjacent landscape, where were the main trajectories of movement and how did the regular movement of people transform the landscape at a certain time.

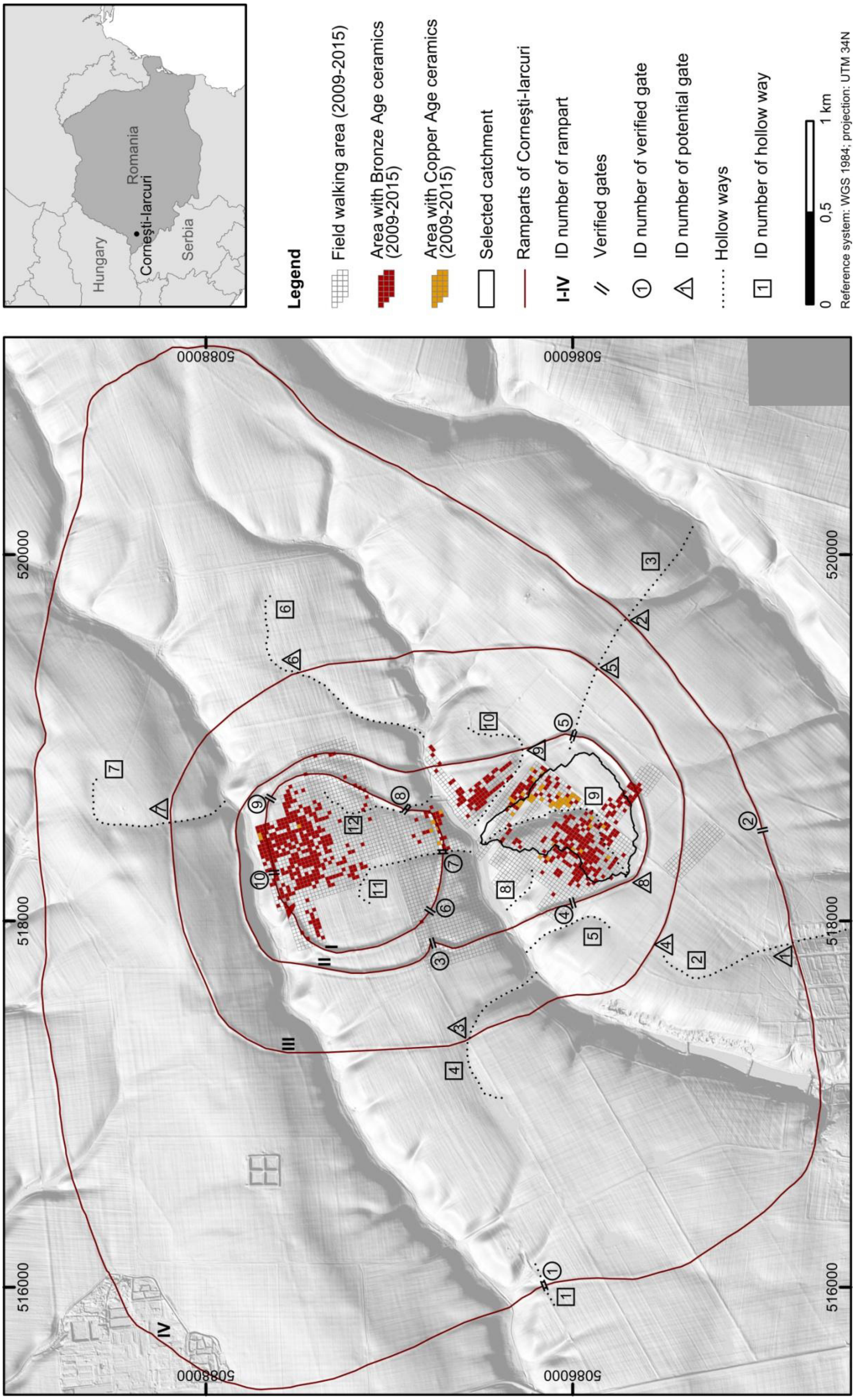

Fig. 45. Results map indicating the Bronze Age and Copper Age settlement clusters, the gates in the ramparts and the identified hollow ways in the built-up area of Corneşti-Iarcuri.

A complementary landscape archaeological study deals with these questions for the first time. Amongst others, GIS techniques are applied to link hydro-morphological relief anomalies to archaeological evidences regarding settlement distribution in the built-up area of Corneşti-Iarcuri (Nykamp et al., 2015). The results show that in the wider settlement area of Corneşti-Iarcuri substantially more first order tributaries bend unnaturally in comparison to three reference-catchments in the close vicinity but beyond the Late Bronze Age settlement area (Nykamp et al., 2015). Some of these tributaries have a short, strongly bending section in their course (i.e. hollow way ID nr. 2, 4, 5, 7, 9 and 10 in Fig. 45) or a section that runs reverse to the direction of the general surface gradient (i.e. hollow way ID nr. 4, 5, 9 and 11 in Fig. 45; Nykamp et al., 2015). Natural factors, such as the local climate, geological underground, catchment geomorphology and soils, can be excluded largely to play a role on the occurrence of unnaturally bending first order tributaries. It is argued that the presence of the enclosure, the settlements within and an interconnecting intra-site path network are the determining factors for this phenomenon (Nykamp et al., 2015). Moreover, the study reveals that the unnaturally bending tributaries tend to cluster in the central part of the enclosure (Fig. 45), partially run through verified gates in the ramparts (i.e. gate ID nr. 5, 7 and 8 in Fig. 45) or seem to link the areas where signs of dense settlement structures occur (i.e. hollow way ID nr. 9, 10, 11 and 12 in Fig. 45).

Paths that developed to hollow ways due to increased surface runoff triggered by soil compaction caused by the repeated passage of humans and animals are well known (Brice, 1966; Denecke, 1969; Piest and Ziemnicki, 1979; Tsoar and Yekutieli, 1992; Wilkinson, 1993; Ur, 2003; Wilkinson et al., 2010) and it is suggested that similar processes occurred in the time when Corneşti-Iarcuri was occupied (Nykamp et al., 2015). In this regard, the locations where hollow ways run through the gates or seem to link densely settled areas are of particular interest, because by applying the principle of active association (Wilkinson, 2003) the assumption can be made that both features, e.g. the hollow way and the Late Bronze Age gate where it is running through, were in use at the same time. For the principle of active association the following example was given by Wilkinson (2003): "[…] if a feature such as a hollow-way road leads directly to another feature (e.g., a gate) that forms part of a site the occupation phases of which are known, then the hollow way and the gate were likely, but not necessarily, in use at the same time" (Wilkinson, 2003, p. 66).

However, the study of Nykamp et al. (2015) lacks geomorphological and sedimentological evidence and particularly independent age control to further verify the hypothesis of contemporaneous hollow way formation due to soil compaction and reduced infiltration capacity along regular footpaths. In order to overcome this shortcoming complementing geomorphological investigations, geophysical and -chemical sediment analyses together with ^{14}C dating were conducted and presented in Nykamp et al. (2016).

The catchment of a first order tributary showing signs of Copper Age and Late Bronze Age settlement structures in its terrain was selected. Also, this catchment is drained by an unnaturally bending tributary that has a section running reverse to the general surface gradient (i.e. hollow way ID nr. 9 in Fig. 45; Nykamp et al., 2016). The alluvial fan that is deposited at the outlet of the catchment into the receiving alluvial plain was chosen as an archive for complementary sediment analyses. The sediments that built up the alluvial fan are interfused with daub pieces between c. 225 and 100 cm depth and the obtained ^{14}C

datings yielded maximum deposition ages of 2877-2561 cal. BCE (4510-4239 cal. BP) at 2σ in 222 cm depth and 1107-832 cal. BCE (3056-2781 cal. BP) at 2σ in 146 cm depth (Nykamp et al., 2016). Thus, the maximum deposition ages roughly coincide with the development of the Copper Age and Late Bronze Age settlements in the catchment, even though a Tiszapolgár impact is not evident in the sedimentary record. This suggests that the development of the settlements and the formation of the fan sediments – and finally also the initial facilitation of the hollow way formation – were closely coupled.

5.4.4. Integration of disciplinary results

The process of integration of disciplinary results, their interdisciplinary discussion and interpretation and the following re-formulation of the hypotheses or the development of new ones is illustrated and discussed using a conceptual model (Fig. 46). The research objective, i.e. the landscape as a sphere of natural, economical and socio-cultural interactions, represents the basis on which questions are asked, hypotheses are formulated and research is conducted. The two participating disciplines, i.e. archaeology and geography, are represented by two individuals. The conceptual model is read from bottom to top and starts with a disciplinary hypothesis or question (Fig. 46, level one), i.e.: How is the drainage network characterized? Or: Where are settlement clusters located? Each level in the consecutively running model represents a step of data production and interpretation that is dependent on the earlier steps. Thus, each level shows a path dependency, produces results that can enhance the rigor of the interpretations and can lead to new questions or hypotheses.

On level one disciplinary results, i.e. identification of hydro-morphological relief anomalies or the localization of settlement clusters, are achieved (Fig. 46, level one) applying methods from physical geography or archaeology, i.e. the morphometric study of the drainage network or systematic field walking. At this point the two disciplines do not interact, but use their disciplinary methods and concepts to answer purely disciplinary questions. The following integration of the disciplinary results leads to the joint interpretation that the hydro-morphological relief anomalies could represent hollow ways since they seem to link the settlement clusters (Fig. 46, level one). Thus, the interaction between the two disciplines starts at this point, from where on the two individuals start to talk to each other, jointly develop new questions and hypotheses and start to change their positions (Fig. 46, level two).

Gates are not simply a gap in an enclosure, but have the function to direct the passage of people and to control pathways (Heeb et al., 2014). Thus, they have a meaning to people. As a next step, all gate situations in the enclosure of Corneşti-Iarcuri are mapped.

By this means, a new disciplinary dataset, i.e. the spatial distribution of gates (Fig. 46, level two), is produced following the further development of the hypothesis that paths not only link settlement clusters, but that they should run through the gates in an enclosure (Wilkinson, 2003).

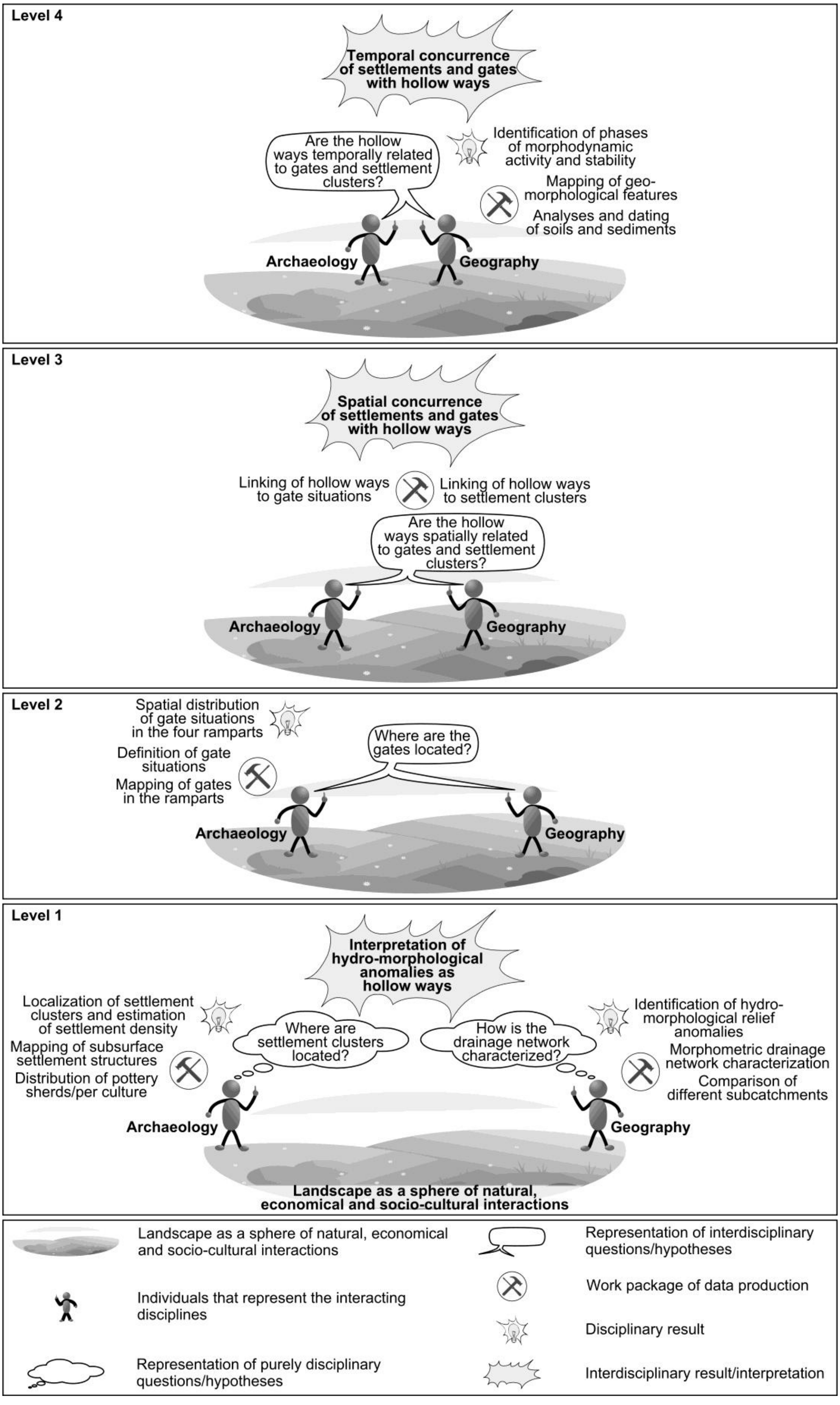

Fig. 46. The conceptual model is applied to the landscape in the environs of the Late Bronze Age enclosure Corneşti-Iarcuri.

At this point a new question arises, i.e. is there a systematic spatial relation between the hollow ways and the gates and settlement clusters? The spatial link of the hollow ways with the, so far, ten verified gates and known settlement clusters (Fig. 45) is examined systematically yielding the new interdisciplinary result, i.e. the spatial concurrence of gates and settlement clusters with the hollow ways (Fig. 46, level three). At this point it even might become possible to state a first idea concerning the formation period of the hollow ways. This can be achieved through active association of archaeological features of a known cultural epoch, e.g. Late Bronze Age gates or settlement clusters, with landscape features of unknown age, e.g. hollow ways, assuming that both were in use at the same time (Wilkinson, 2003).

However, without independent datasets, i.e. sediment analyses and radiometric dating techniques, the interpretation must be viewed as preliminary and the question whether the hollow ways and the gates and settlement clusters temporally coincide cannot be answered convincingly. Thus, a new disciplinary dataset is generated, i.e. in the form of ^{14}C-dated sediment cores, to obtain independent results, i.e. identifying phases of varying morphodynamics (Fig. 46, level four). Through the integration of the newly achieved results into the interdisciplinary interpretation obtained on level three the rigor of the re-interpretation of the hydro-morphological relief anomalies being hollow ways that formed during the Late Bronze Age as path-oriented gullies along frequently used footpaths connecting settlement clusters or running through the gates of the enclosure is substantially enhanced (Fig. 46, level four). Thus, at this point we are able to more far-reaching interpretations than to generally state that phases of intensified morphodynamics in a small-scale catchment often occur as a result of exceeded geomorphic thresholds due to local land use change and intensified human activities in the upslope catchment area rather than as a result of climate change; a concept that is well established for Central Europe (Chiverrell et al., 2007; Dotterweich, 2008; Dotterweich et al., 2012). Among the factors that control threshold-dependent processes such as gully erosion and hollow way formation local land use and frequency of extreme rainfall events are considered to be the main driving forces (Valentin et al., 2005; Chiverrell et al., 2007). Thus, our results might reflect both: the compaction-induced reduction of the infiltration capacity due to trampling along frequently used footpaths and the occurrence of precipitation events that are severe enough to let overland flow develop.

The process of integration and re-formulation of hypotheses not necessarily stops at the point that is reached by the conceptual model in this study. New hypotheses may arise, e.g. if the hollow ways serve to localize, so far, unknown gates (i.e. the potential gates in Fig. 45) or settlement clusters or if the importance of a certain gate or settlement cluster is mirrored by the expression of a hollow way. Thus, on the one hand appropriately targeted measures to identify unknown gates can be applied and, on the other hand, new ideas regarding the socio-economic structure can be deduced from the location of the most important settlement areas or most representative gates in relation to the location of hollow ways showing specific expressions. The conceptual model illustrates that the two interacting individuals that represent the disciplines of archaeology and geography constantly change their positions during the process of integration. These changing positions also represent the feedback of the jointly achieved interpretations back into the disciplines as described by Meier (2012).

The feedback into the discipline of archaeology might be that Holocene geomorphic features such as hollow ways are usable as indicators of settlement structures, while the feedback into the discipline of geography might be that anthropogenic features such as pathways are important features to understand the Holocene origin of hollow ways.

5.4.5. Conclusions

This study summarizes the main findings of current research on the landscape development and human–environment interactions in the environs of the Late Bronze Age enclosure Corneşti-Iarcuri in western Romania. The process of integrating disciplinary results, jointly developing new hypotheses and interpreting the findings interdisciplinarily is illustrated. Our example shows how integration leads to a more holistic and rigorous interpretation that would not have been possible by only one discipline; neither archaeology nor physical geography. The example clearly shows that while studying the same object, the different participating disciplines focus on different phenomena. The interdisciplinary collaboration and intellectual exchange allows putting these disciplinarily examined objects into an integral context. In consequence physical objects, e.g. unnaturally bending first order tributaries, become archaeological artifacts, e.g. hollow ways. Thus, the procedure corresponds to the point made by Wilkinson (1993) that landscape features should not be viewed in isolation, but jointly with other types of evidence so that the interpretations become more comprehensive and plausible. The conceptual model we introduced in this paper opens the opportunity to, either jointly or disciplinarily, develop new hypotheses and to integrate new findings into an interdisciplinary interpretation. The process of integration also results in feedbacks into the participating disciplines. By emphasizing the value of using a landscape archaeological approach we would like to encourage researchers from different disciplines to continue working together on the development of integrated hypotheses and to further improve the discussion of disciplinary findings across the disciplines of archaeology and physical geography.

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6. Conclusions

The theoretical reflection of the approaches of geoarchaeology and landscape archaeology (chapter 2) subsequently allows setting the four case studies into the context of these approaches.

The introduced approach of geoarchaeology is applied in two studies (Nykamp et al., 2016; Nykamp et al., 2017b). The study of Nykamp et al. (2016, chapter 5.3.) combines geomorphological, geochemical, sedimentological, chronometric, and archaeological data to investigate Copper Age to Late Bronze Age hollow way formation in a small catchment in the environs of Corneşti-Iarcuri. The study of Nykamp et al. (2017b, chapter 5.1.) uses a combination of archaeological, historical and geomorphological data to estimate the soil erosion-induced lowering of the surface in historic times and to deduce its implications for the occurrence of archaeological finds. Both studies, although covering different spatial and temporal scales, aim to investigate and quantify the kind and degree of past and present-day human–environment interactions that are involved in the formation of the archaeological context. In both studies landscape is regarded as a physical phenomenon that reacts – according to physical laws – when e.g. land use is altered or geomorphic thresholds are exceeded (Schumm, 1979). Also, both studies are regarded to be more multi- than interdisciplinary as the cooperation among the disciplines mostly happened on the results level.

By contrast, the studies of Nykamp et al. (2015) and Nykamp et al. (2017a) are regarded to be more inter- than multidisciplinary, because the cooperation among the disciplines already started at the hypotheses level. First results regarding the spatial and temporal concurrence of hollow ways with settlement clusters in the built-up area of Corneşti-Iarcuri and with gates in its ramparts, achieved by applying GIS techniques and the principle of active association (Wilkinson, 2003), are presented in the study of Nykamp et al. (2015, chapter 5.2.). The study of Nykamp et al. (2017a, chapter 5.4.) introduces a conceptual model that exemplifies the theoretical and methodological process of integration of disciplinary and interdisciplinary results focusing on the joint development of new hypotheses and its interdisciplinary interpretation. In both studies landscape is regarded as a physical phenomenon, which is transformed by humans for economical and socio-cultural purposes leading to a modified perception. Even though the way prehistoric people have perceived their surroundings is difficult to approach (Popa and Knitter, 2016) first ideas about the meaning of landscape features are presented. In this respect the introduced approach of landscape archaeology is applied in both studies.

The findings of the four case studies contribute to close the gap of i) how past and present-day human–environment interactions have impacted the Holocene development of the landscape in the surroundings of Corneşti-Iarcuri (Nykamp et al., 2017b, chapter 5.1.; Nykamp et al., 2015, chapter 5.2.; Nykamp et al., 2016, chapter 5.3.), ii) in which way past and present-day human–environment interactions were involved in the formation of the archaeological context (Nykamp et al., 2017b, chapter 5.1.; Nykamp et al., 2015, chapter 5.2.; Nykamp et al., 2016, chapter 5.3.) and iii) how the integration of disciplinary results can be achieved successfully (Nykamp et al., 2017a, chapter 5.4.).

The results of Nykamp et al. (2017b, chapter 5.1.) reveal that major changes in the natural environment occurred approximately between the years 1770 and 1865 due to the scheduled resettlement and land reclamation activities in the region including the substantial intensification of arable farming in the study area. Since c. 1865 the surface of the arable fields in the environs of Corneşti-Iarcuri has lowered by between 10 and 40 cm due to the combination of subsurface compaction along field paths and tillage-induced wind-driven soil erosion on the arable fields. This estimated lowering, in combination with the present-day plowing depth of c. 30 cm, implies that archaeological structures must have penetrated to between 40 and 70 cm into the subsurface in order to be preserved. Finally, the study emphasizes that the still intact lower-lying stratigraphy of Corneşti-Iarcuri is seriously threatened by the ongoing lowering of the surface in combination with plowing, as the destructive action of plowing continuously reaches greater depths even when a constant plowing depth is maintained (Nykamp et al., 2017b). The findings are generally in good agreement with the results from the excavation of four Late Bronze Age houses (Heeb et al., 2015) where clearly definable foundation ditches were found, but signs of a floor were lacking. Also, the findings underpin earlier observations that modern agricultural practices in the environs of Corneşti-Iarcuri largely cause the blurring of structures in the magnetograms (Heeb et al., 2015) and the ongoing destruction of the archaeological remains (Szentmiklosi et al., 2011). The findings of this study provide useful explanations for the (re-)interpretation of archaeological evidences and underline – with quantitative data – the need for continuing the research efforts at the largest known enclosure of European prehistory. Thus, with respect to the superordinate goals the findings of this study show that historic to present-day human–environment interactions – namely the plowing of the silt-dominated sediments of the high plains – have a significant impact on the aeolian shaping of the landscape in form of fostering the intensification of wind-driven soil erosion that causes the lowering of the surface. Due to this ongoing surface lowering and the destructive impact of the plow that continuously reaches greater depths this study also shows that the formation of the archaeological context is considerably influenced.

The results of Nykamp et al. (2015, chapter 5.2.) demonstrate that the construction of the ramparts and the development of the settlements during the Late Bronze Age had a substantial influence on the development of the local drainage network causing the formation of unnaturally bending first order tributaries. Some of the tributaries in the built-up area of Corneşti-Iarcuri have a short, strongly bending section in their courses or sections that run reverse to the direction of the general surface gradient. The unnaturally bending tributaries tend to cluster in the central part of the enclosure, partially run through gates or seem to link settlements and natural factors can be excluded largely to play a role on their formation. Thus, it is argued that they formed as hollow ways due to compaction-induced reduced infiltration capacity and accelerated surface runoff as a consequence of trampling along frequently used footpaths (Nykamp et al., 2015). By applying the principle of active association (Wilkinson, 2003), i.e. the assignment of archaeological features of a known cultural epoch with landscape features of unknown age assuming that both were in use at the same time, a preliminary dating for the formation of the hollow ways to the Late Bronze Age is achieved (Nykamp et al., 2015). The results of Nykamp et al. (2016, chapter 5.3.) show that the recorded morphodynamics vary according to the general geomorphic unit. The high plains are characterized by deeply weathered sediments showing signs of pronounced soil formation pointing to long-lasting stable geomorphic conditions. By contrast, the alluvial fan located at the basin outlet of a first-order tributary shows a distinct alternation of phases of sediment accumulation and soil formation, thus, documenting varying active and stable geomorphic conditions throughout the Holocene. The ^{14}C datings obtained from the reworked soil sediments of the alluvial fan revealed maximum deposition ages between the Copper Age and the transition from Late Bronze Age to the early Iron Age, thus, coinciding with the development of the settlements in the upslope contributing area. Considering the results of Nykamp et al. (2015) it is concluded that the Copper Age and mainly the Late Bronze Age human impact in the form of trampling along a frequently used pathway caused the formation of a hollow way and led to the deposition of the fan sediments (Nykamp et al., 2016). Thus, regarding the superordinate goals the findings of these two studies show that prehistoric human–environment interactions – namely the trampling along frequently used footpaths – have a considerable impact on the shaping of the landscape in the form of facilitating the formation of path-oriented gullies. These path-oriented gullies represent Copper Age and mainly Late Bronze Age hollow ways; thus, they ultimately form part of the archaeological context. In this regard the findings of these two studies also show in which way one part of the overall archaeological context is formed by trampling along frequently used footpaths.

The study of Nykamp et al. (2017a, chapter 5.4.) integrates the findings of two previous published studies (Nykamp et al., 2015; Nykamp et al., 2016) into the archaeological state of the art (Heeb et al., 2008; Szentmiklosi et al., 2011; Heeb et al., 2012; Heeb et al., 2014; Heeb et al., 2015). The consecutive integration of disciplinary and interdisciplinary results is realized using a conceptual model. On each of the consecutive levels of the conceptual model the interdisciplinary interpretations become more and more holistic and rigorous and result in new questions and hypotheses that are integrated subsequently (Nykamp et al., 2017a). This study exemplifies the importance and the value of close cooperation among the disciplines of archaeology and geography in the context of landscape archaeological research and how mutual discussions, joint development of hypotheses and intellectual exchange can enhance the holism and rigor of interdisciplinary interpretations. Thus, with respect to the superordinate goals, this study shows how the integration of disciplinary results can be achieved successfully. Moreover, possible feedbacks back into the disciplines, e.g. that archaeology picks up that Holocene geomorphic features such as hollow ways can be used to localize settlement structures or gates in an enclosure or that geography takes into account that anthropogenic features such as settlements or gates can be used to explain the Holocene origin of hollow ways, are demonstrated (Nykamp et al., 2017a). The design of the model allows to subsequently add new levels and to continue the process of integration and development of new hypotheses. Also, it can be easily transferred into other research projects to clarify and illustrate the different disciplinary or interdisciplinary work packages mandatory for achieving robust interdisciplinary interpretations.

The four presented studies – with their wide methodological diversity and the analyses of multi-proxy data sets – contribute with their findings to deepen and to broaden the understanding of the archaeological site Corneşti-Iarcuri in a number of ways. A convincing explanation for different archaeological observations, i.e. the blurring of structures in the magnetograms (Heeb et al., 2015), the ongoing destruction of the archaeological remains (Szentmiklosi et al., 2011), the absence of floors in the four Late Bronze Age houses (Heeb et al., 2015) and the field walking evidence of Iron Age artifacts (Heeb et al., 2015) together with the absence of Iron Age settlement structures, is provided in the study of Nykamp et al. (2017b, chapter 5.1.). The identification of Late Bronze Age hollow ways in the built-up area of Corneşti-Iarcuri provides first evidence of how people moved through the enclosed area and the adjacent landscape and how the regular movement of people transformed the landscape at this time (Nykamp et al., 2015, chapter 5.2.; Nykamp et al., 2016, chapter 5.3.). These evidences lead to new questions, e.g. whether the hollow ways serve to localize, so far, unknown gates or settlements or if the importance of certain gates or settlements is mirrored by the expression of a hollow way, that can be answered applying the conceptual model of Nykamp et al. (2017a, chapter 5.4.). The close cooperation among the disciplines of archaeology and geography, thus, can lead to the implementation of appropriately targeted measures to identify unknown gates or settlements and, on the other hand, new ideas regarding the socio-economic structure among the Late Bronze Age settlements can be deduced from the location of the most important settlements or gates in relation to the location of hollow ways showing specific expressions (Nykamp et al., 2017a).

The detailed consideration of the presented results on human–environment interactions in the area of Corneşti-Iarcuri reveals that in comparable locations on the high plains pathways developed to hollow ways, i.e. morphologic hollow forms, during prehistory, while they developed to dam-like linear features, i.e. morphologic ridge forms, in historic times. The opposite development of pathways during prehistoric and historic times reflects the varying susceptibility of the landscape to the dominating relief forming processes as a consequence of the changing pattern and intensity of land use. While the Late Bronze Age hollow ways mostly formed in the former built-up land that was, beyond the area of the buildings itself, presumably characterized by a mixture of forest and steppe vegetation (Magyari et al., 2010; Kiss et al., 2015), the field paths that developed to dam-like linear features in historic times formed in an environment that is intensively used for arable farming. Thus, in the present-day setting the impact controlled by the degree of openness of the landscape and mainly the tillage-induced intensification of wind-driven soil erosion causing surface lowering on the arable fields exceeds the impact of the compaction-induced reduction of the infiltration capacity that fosters gully formation.

This cumulative doctoral thesis contributes with its findings, presented in four case studies, how past and present-day human–environment interactions have shaped the landscape in the environs of Corneşti-Iarcuri, in which ways these interactions were involved in the formation of the archaeological context at the largest known enclosure of European prehistory and how the integration of results from the disciplines of archaeology and geography can be achieved successfully. Through the application of a wide variety geoscientific methods and well-established concepts from physical geography and by adopting the approaches from the field of geoarchaeology and landscape archaeology the point of view of a hitherto purely archaeological research at the site of Corneşti-Iarcuri is extended considerably.

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Affidavit / Eidesstattliche Erklärung

Hiermit erkläre ich, Moritz Nykamp, dass ich die Dissertation "Human–environment interactions in the environs of the Late Bronze Age enclosure Corneşti-Iarcuri, western Romania" selbständig angefertigt und keine anderen als die von mir angegebenen Quellen und Hilfsmittel verwendet habe.

Ich erkläre weiterhin, dass die Dissertation bisher nicht in dieser oder in anderer Form in einem anderen Prüfungsverfahren vorgelegen hat.

Berlin, den 5. April 2017