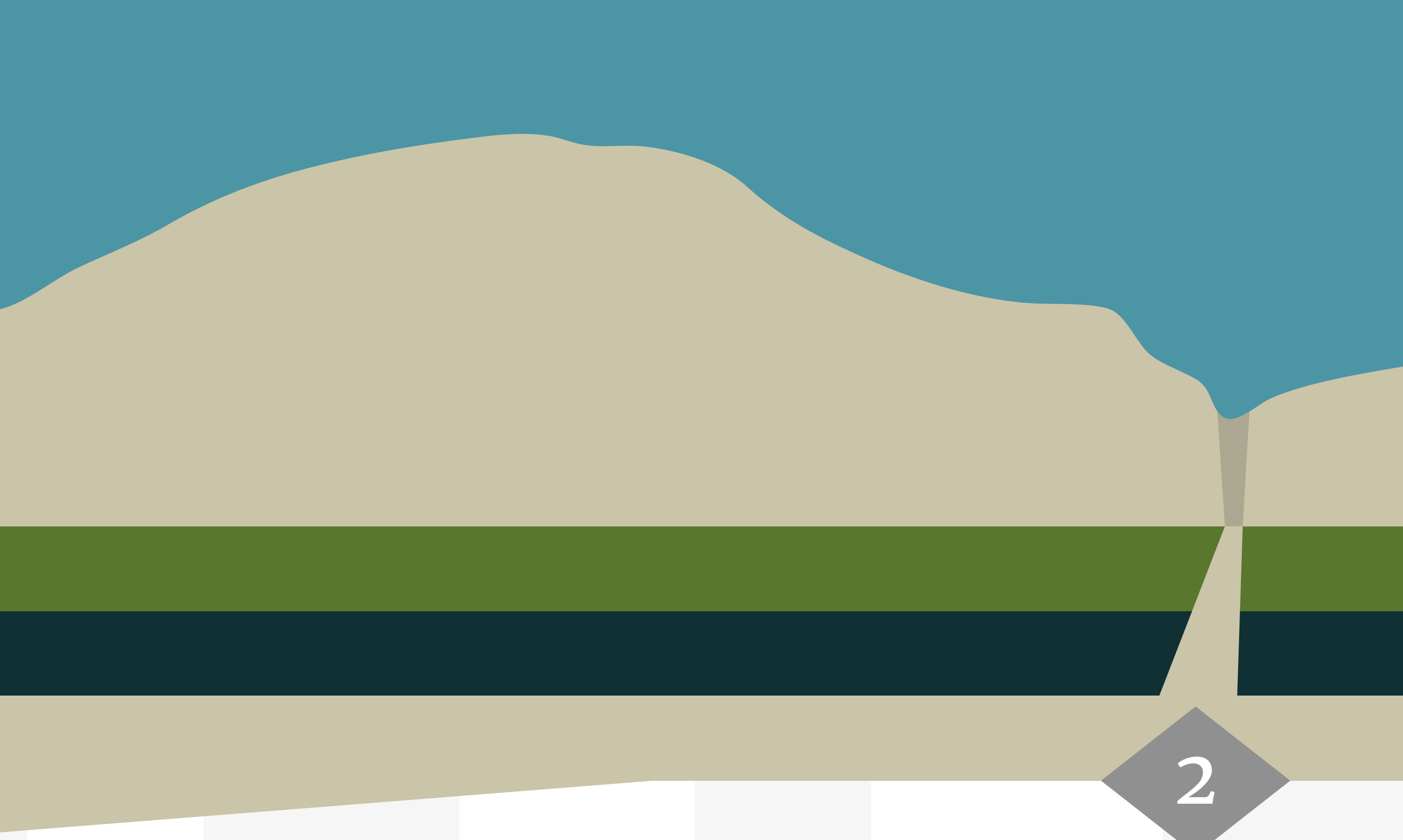

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RaganelloBasinStudies

Soils and Soil Landscapes of the Raganello River Catchment (Calabria, Italy)

Jan Sevink
Michael den Haan
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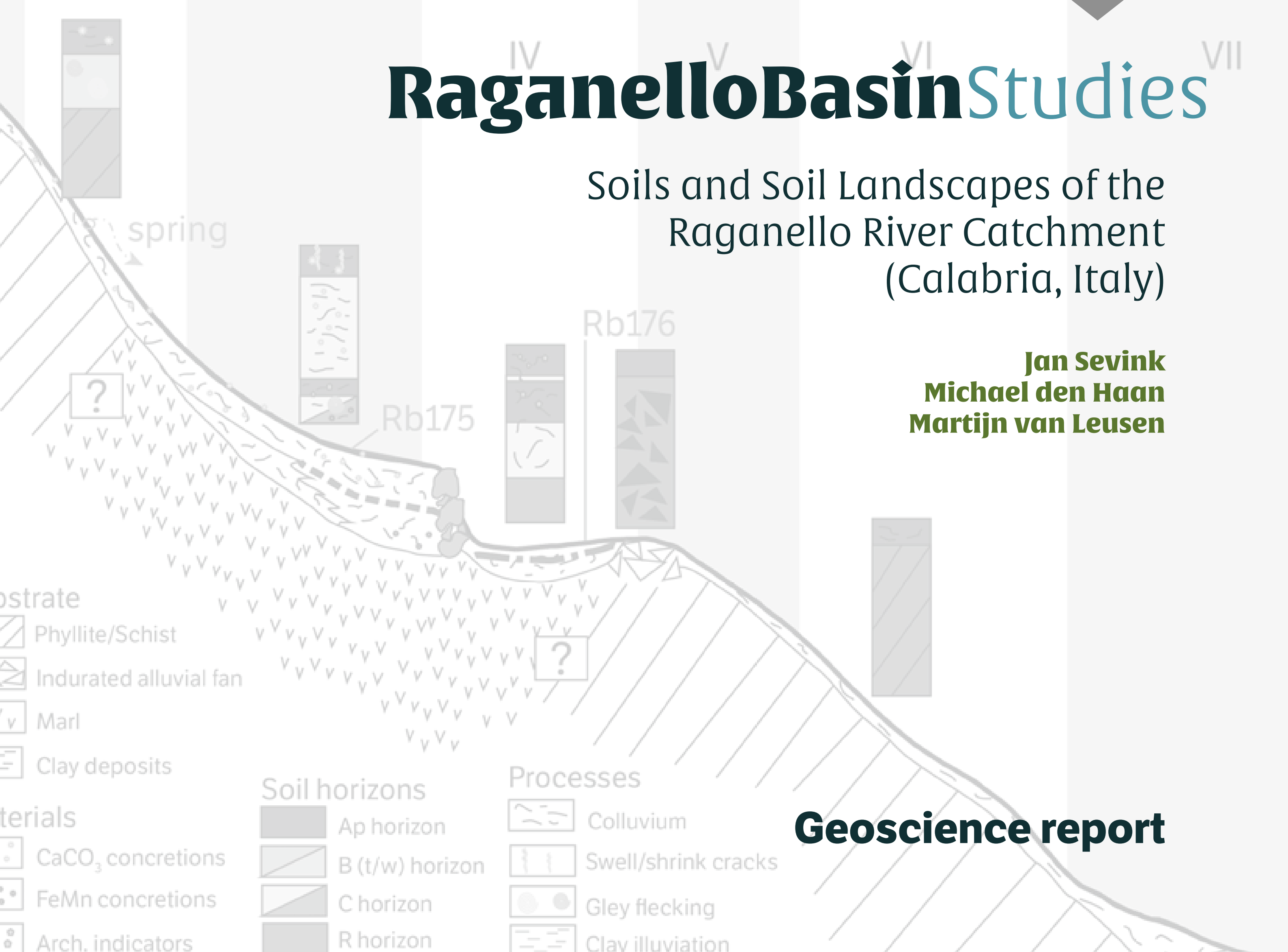

Geoscience report

RaganelloBasinStudies

Soils and Soil Landscapes
of the Raganello River Catchment
(Calabria, Italy)

RaganelloBasinStudies

Volume 2

Editor:
Dr. P.M. van Leusen
Groningen Institute of Archaeology

Volume 1 (in prep.):
Raganello Basin Sites
and Finds Catalogue

Volume 2:
Soils and Soil Landscapes
of the Raganello River Catchment (Calabria, Italy)

For further planned volumes
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Jan Sevink
Michael den Haan
Martijn van Leusen

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CONTENTS

RAGANELLO BASIN STUDIES
SERIES INTRODUCTION

The Raganello River drains a small part of the southern Apennines, for the most part now inside the Pollino National Park, into the Ionian Sea. Like many Italian rivers it is relatively short at 34.5 km but has a high gradient as it drops from the upper watershed boundary at 1500m asl, through two dramatic gorges, to a more sedate pebble bed at the exit of the lower gorge. Now regulated, the many braided channels testify to the seasonal character of the stream – nearly dry in summer but occasionally in full flood from late autumn to early spring.

Where the Raganello leaves the narrow strip of foothills stands the Timpone della Motta, a ridge backed hill in Early Pleistocene conglomerates fringed with several younger fluvial terraces and fans. Archaeological research was carried out here from the 1960s onwards to study the indigenous-to-Greek-colonial temple complex on its summit, and the associated settlement and necropolis on its lower plateaus. At the invitation of the then director of the National Archaeological Museum at Sybaris, professor of Classical Archaeology at the University of Groningen Marianne Kleibrink and her students resumed these excavations in the early 1990s; under her successor professor Peter Attema this was extended in 2000 with a systematic and intensive field walking survey that would eventually cover some 13 square kilometers from the edge of the plain to the upper watershed boundary.

Starting in the early 1980s, the archaeological record of several Italian valleys and basins (e.g., those of the Biferno, Sangro, Gubbio, Liri and Cecina) was studied through survey, and in many cases the physical and social landscape context was taken into account. The work by the Groningen Institute of Archaeology teams in the Raganello Basin is, however, exceptional because it produced detailed and systematic records during multiple seasons over a full decade. The results of this work are published as Volume 1 (Raganello Basin Site and Finds Catalogue 2000-2009) of this series.

Another exceptional characteristic of the Groningen Raganello Basin studies has been its emphasis on methodological rigour and innovation. For this reason its directors, Peter Attema and Martijn van Leusen, were consistently able to fund the research from grants won in free competition before the Netherlands Foundation for Scientific Research (NWO) Humanities Board: in 1997-2001 for the 'Regional Pathways to Complexity' project that compared the archaeological surface records of three marginal regions of south and central Italy; in 2002-2005 in the Raganello Archaeological Project that introduced modern field mapping technology and focused on unobtrusive finds categories; in 2005-2010 in the 'Hidden Landscapes' project that tested a range of geoarchaeological approaches for understanding how landscape change affects the archaeological record; and in 2010-2015 for the 'Rural Life in Protohistoric Italy' project that focused a battery of complementary approaches – from geophysics via coring to test pits – on the widespread but ephemeral surface evidence of protohistoric settlement and land use in the Raganello Basin.

Volumes 2 – 4 in this series are a direct outcome of the last of these, the Rural Life Project. Volume 2, the Geoscience report (Soils and soil landscapes of the Raganello river catchment), was prepared by Michael den Haan and prof Jan Sevink of the University of Amsterdam IBED and focuses on the characteristics and genesis of the physical landscape, with emphasis on its soils. Volume 3, the Geophysics report (Rural Life in Protohistoric Italy: geophysical studies) describes the extensive investigations carried out under the direction of dr Kayt Armstrong into the use of noninvasive prospection methods to complement traditional field walking surveys in 'difficult' Mediterranean landscapes. Volume 4, the Archaeology report (Rural Life in Protohistoric Italy: archaeological studies) details the interlocking series of noninvasive and invasive studies conducted on and around protohistoric pottery scatters by PhD student Wieke de Neef. These form the basis for her PhD thesis, which appears as Volume 5 in this series. A second PhD study, by Francesca Ippolito, looks in detail at the cultural and typochronological affinities of a subset of more substantially documented protohistoric sites in the Raganello Basin – including the Timpone della Motta – and constitutes Volume 6. A final Volume 7, by Martijn van Leusen, synthesizes all of the Dutch research that has taken place in the Raganello Basin since the year 2000.

The volumes in this series are all organized in a similar fashion, namely by 'landscape type', and reflect the two guiding principles of the Groningen approach to Mediterranean archaeology – first, that a joint methodological framework is needed for *systematic* interdisciplinary research in landscape archaeology, and second, that the characteristics and history of homogeneous landscape units must lie at the basis of such a framework.

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Many people and organizations have over the years helped to make the archaeological study of the Raganello Basin a success. We thank the mayors, councilors and support staff of the municipalities of Francavilla Marittima, Cerchiara di

Calabria, San Lorenzo Bellizzi and Civita for their interest and logistical support of the field teams, and the inhabitants of these villages for their unfailingly welcoming attitude – many have become friends over the years. The Department of Physical Geography of Leuven University prepared an exceedingly useful detailed elevation model from an airborne LIDAR data set flown by EUFAR; Antonio ('Nino') Larocca made us aware of the protohistoric landscape hidden in caves and uplands of the Raganello Basin and took us on many memorable field trips; Jan Delvigne (†) first taught us to look closely at change and stability in the physical landscape, and we have been very lucky to find Jan Sevink of IBED (University of Amsterdam) prepared to join the team as our resident physical geographer; we owe all of them a great debt of gratitude.

The research on which these studies are based was funded by the Netherlands Organization for Scientific Research NWO, Humanities Board, under grant nrs 250-09-100 (RPC), 276-61-002 (HLP) and 360-61-010 (RLP); we thank the Board for maintaining a transparent and efficient system, as well as for its forbearance when project timetables inevitably slipped.

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PREFACE

To an archaeologist conducting field walking surveys in a Mediterranean landscape it is impossible not to notice the geographical and geological contexts of the surface archaeological remains. Freshly ploughed-up sherds are accompanied by darker, anthropogenic subsoil; sherds that circulate in a wet plough layer are much less noticeable because they are caked in soil until sun and wind clean them; patterns of soil colour and variations in soil texture across fields seem to correlate in some as yet indefinite manner with the density and quality of the archaeological finds. Driving through a study area, dips in the road indicate that entire slopes are on the move albeit slowly; one encounters the occasional extreme and dramatic example of erosion after a drenching rain has cut a gully, washed away a culvert, or put rock falls in the path of the car. In the modern landscape, farmers may be the most visible agents of change but all the while natural processes modify the earth's land surface – slowly and episodically but with major effect over time. To an archaeologist attempting to understand the meaning of the archaeological record constructed with so much effort for a given study area, a thorough understanding of these anthropogenic and natural processes is crucial. Does the absence of archaeological remains at the surface reflect an absence of past human activities, or are there mechanisms at work that keep such remains hidden from the view of the passing archaeologist? If archaeological remains are present on the surface, what processes have preserved those remains through the ages and are presenting them to us at precisely the right moment to be observed?

Evidence of anthropogenic processes affecting the archaeological record in the Raganello Basin is plentiful, two of the more potent being the construction of agricultural terraces and the ploughing of arable fields. Terrace construction is an important feature of Mediterranean agricultural regimes and may well date back to the Bronze Age, but the vast majority of terraces now in evidence are likely to date to much more recent (Classical and modern) episodes of agricultural expansion. Their construction changes the preceding slope profile, preserving older soil surfaces in some locations and destroying them in others. Ploughing, especially after the mechanization of agriculture in the 1970s, reinforced these effects.

It goes against the grain of many archaeologists to regard humans as geological, rather than cultural, agents. Yet people gather materials from around the landscape and deposit them in and around their settlements; they remove the natural vegetation and break up the soil to make it suitable for their food crops allowing more scope for other geomorphological agents such as wind and water; they interfere with natural geomorphological and pedological processes by draining, irrigating, reinforcing or undercutting slopes, assisting gravity in some places and fighting it in others. Likewise, we find it unnatural to regard the cultural remains found in a surface survey as 'geological' materials. Yet a pottery fragment, however small, worn and nondescript it may be, cannot magically have appeared where we found it. It must have been brought there by a combination of anthropogenic and natural processes, both depositional and post-depositional. It is subject to the same physical and chemical processes that currently affect natural deposits. It cannot have *no* meaning. What could we learn by looking at the landscape with earth scientist's eyes?

One thing we could learn is to describe the relevant processes and characteristics in a systematic and sufficiently detailed manner. Soil scientists can systematically describe soil types, but also how and why specific soils locally deviate from these types, and what this tells us about the post-depositional history and current state of any archaeological remains in those soils. Geomorphologists are used to studying and describing geomorphological processes and their resulting landforms in a systematic manner, albeit at spatial and temporal scales that are generally too coarse for archaeological purposes. But this is just a difference of degree, not of principle. Could we not extend earth scientists' methods of studying the earth's surface to scales relevant to the questions that interest archaeologists – down to the individual archaeological site and the lifetime of individuals?

Past 'geoarchaeological' studies in the context of landscape archaeological research programs have tended to be piecemeal rather than systematic – aimed at understanding specific local situations of interest to the archaeologist directing the project – or were aimed at reconstructing the long-term evolution of particular systems such as coastlines or rivers. This is not sufficient: in modern landscape archaeological projects we want to know how earth surface processes affected the archaeological record everywhere, and in as much detail as possible. Luckily we do not need to study *all* locations in detail because many parts of the landscape have sufficiently homogeneous characteristics for us to make good inferences on the basis of well-studied sample locations!

Although the map, or set of maps, showing continuously varying densities of different types of artefacts as recorded by the fieldwalking archaeologist purportedly reflects the depositional reality – that is, the famous 'palimpsest' or sum of all human traces left in the landscape over time - this is obviously untrue. Current land cover, land use and accessibility determine whether the landscape can be studied at all; the post-depositional history of the landscape determines which (if any) part of the archaeological record will be available for study at the surface; and the interests and abilities of the archaeologist determine which part of the available evidence will be recorded and interpreted.

In earlier research (Feiken 2014) we have explored two 'top-down' approaches to the systematic study of the whole landscape. An extensible landscape classification system, employing landscape units as historically homogeneous entities in terms of affordances and taphonomic history, was developed to guide our sampling strategy; the reader will see this in use in chapter 3. A geoarchaeological process model, CALEROS,[1] developed to explore the possibility that erosion and sedimentation depths over time might be quantified at a sufficiently high spatial resolution to be of practical use to the archaeologist, highlighted a range of shortcomings that will be commented on here in chapter 4. Building on these and other preliminary studies (see publication list below) the Rural Life Project (RLP) has set itself the task of developing systematic approaches to answer the following questions:

1 How do natural and anthropogenic slope processes affect the archaeological landscape in the Mediterranean environment?
2 How has the specific post-depositional history of each landscape unit contributed to its current archaeological surface record? What are the diachronic effects of erosion and sedimentation on the preservation and detectability of archaeological remains in each landscape unit?
3 What is the current state of preservation of archaeological remains as recorded in fieldwalking and near-surface geophysical surveys, and what is the character of the main current threats to this heritage?
4 Which are the prevalent archaeologically exploited soils in the different landscape zones, and what soil characteristics are likely to have determined the type of exploitation?

In this RLP report, extensive information is provided on the soils and soil landscapes of the Raganello river catchment. This information forms an important background for the answers on the questions under 1-3, specifically by describing and quantifying the effects of slope processes occurring on typical slopes of the main landscape units in the Raganello Basin; helping to understand how the formation of agricultural terraces and other sediment traps has affected the archaeological record; and helping to distinguish anthropogenic from natural near-surface geophysical anomalies, so that the latter can be excluded from further study. It also provides a thorough introduction into the history and development of the soils and landscapes of this Raganello catchment, including its various earth surface (geomorphological and soil formation) processes, whether natural or anthropogenic. This forms the basis for identification and quantification of anthropogenic impacts on the original – natural – soils and landscapes, and for discrimination between natural and anthropogenic materials and layers in archaeological sites and sections, in the range of Mediterranean landscape types encountered in the Raganello catchment.

As to question 4, a subsidiary goal of the RLP has been to study the soil properties in and around past settlement zones, in an effort to understand more about past location choice. Do we find a higher settlement density in particular parts of the landscape because the soils there are more suitable for palaeotechnical agriculture? Is the absence of settlement evidence in other parts of the landscape due to the unsuitability of the soils? Landscape classification systems such as those developed by Feiken (2014) should incorporate such information because it helps us to establish a priori hypotheses about settlement and land use. However, systematic and detailed information on relevant soil properties and characteristics is required for a full understanding of the role of soil suitability in early agriculture and settlement patterns, and such information is not yet included in the system developed by Feiken. Den Haan and Sevink therefore developed a simple region-specific soil description and classification scheme that can be operated by archaeologists with limited training, and that includes all relevant pedological and geomorphological phenomena. This scheme will be found in Appendix II.

The first two authors of this technical report are based at the Institute for Biodiversity and Ecosystem Dynamics (IBED), Faculty of Science, University of Amsterdam (UvA), The Netherlands. Michael den Haan holds an MSc in Earth Science from the UvA. He conducted the fieldwork that forms the basis for this study, participating in a series of RLP campaigns. Jan Sevink is full professor in landscape analysis, former director of IBED, and associated member of the Groningen Institute of Archaeology. He is an expert in soil and landscape studies in the Mediterranean, and the principal investigator of this report.

Acknowledgements

Among the students who participated in the Calabrian fieldwork of the RLPI project team, we want to thank especially Nikolaas Noorda for his help with the manual coring. We gratefully acknowledge the specialist

1 The CALEROS model was developed mainly at Utrecht University, by L.P.H. van Beek, H. Feiken, Th.W.J. van Asch and D.M. Smulders. It was applied by Feiken (2014) to quantify the impact of soil forming and gradational processes at 25m resolution and in time steps of 100 years.

contributions of Burkart Ullrich of Eastern Atlas GmbH of Berlin, for conducting the geophysical surveys shown in figure 35c; and of Leo Hoitinga of the IBED soil chemistry laboratory of the University of Amsterdam, for help in soil analysis and interpretation. Finally, we would like to thank the two other members of the RLPI team, Wieke de Neef and Kayt Armstrong, for their logistical support including the supply of location data for corings, for the geophysical data shown in figure 30, and for help in identifying archaeological indicators in corings. We applied the sequence-determines-credit approach for the sequence of authors.

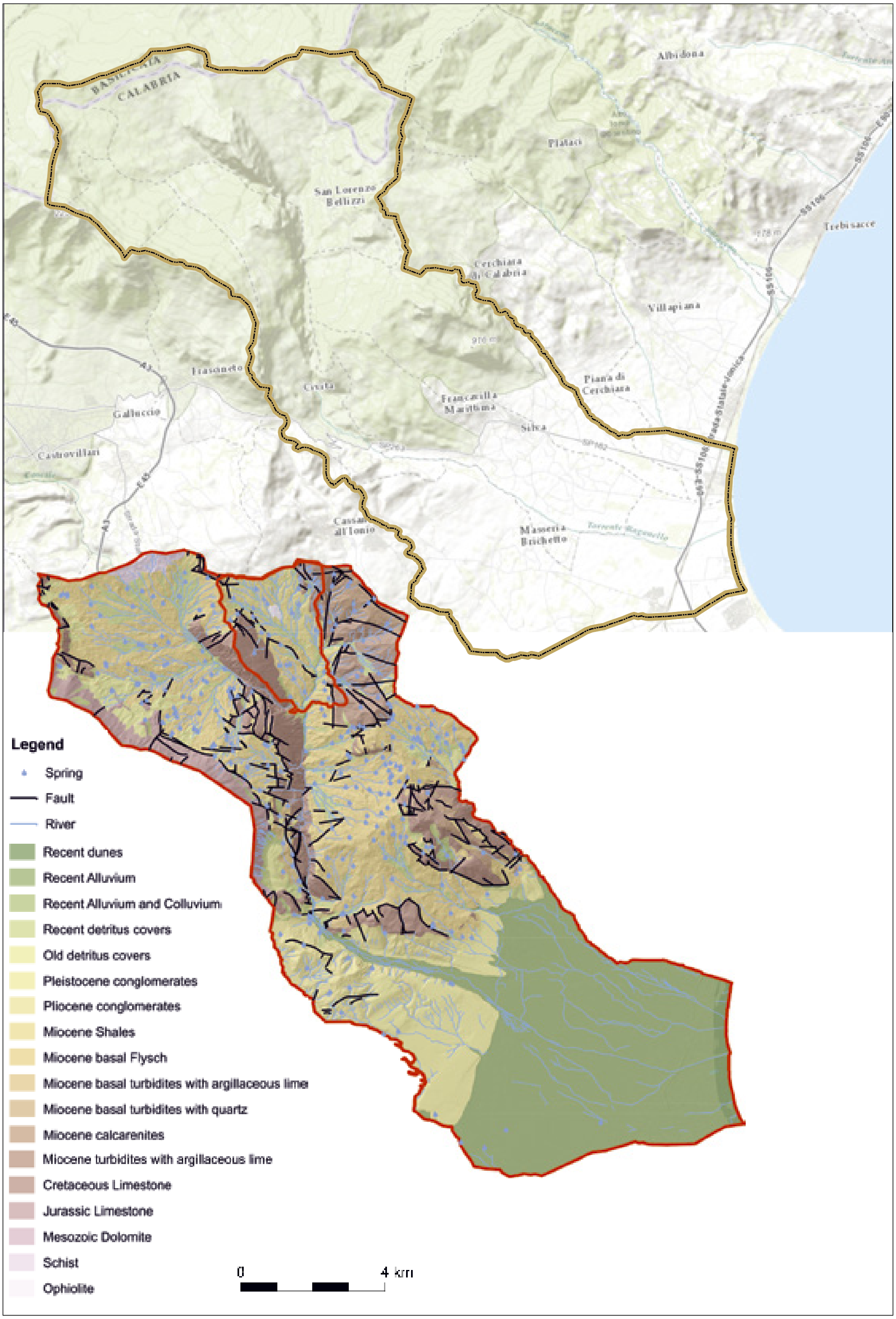

Figure 1. The Raganello River basin in northern Calabria: topography (source: Google Maps) and geology (source: Feiken 2014, fig. 2.6).

1 INTRODUCTION

The Raganello river catchment lies in the North of the Italian Region of Calabria, close to the border with Basilicata (see figure 1). It basically consists of a large coastal plain with Sibari and Francavilla as main centres, and a sparsely populated mountainous inland with the Monte Pollino massive to the West, reaching an altitude of over 2000 masl. Prominent are the more or less North-South running limestone ridges of the M. Sparviere / M. Sellaro, which is the first high ridge from the Ionian Sea going inland and has Cerchiara di Calabria as its main habitation centre, and the Timpa di San Lorenzo / Timpa di Cassano, which is especially steep and has Civita as its main habitation centre. In between these two ridges lies a depression with more gentle relief in which S. Lorenzo Bellizzi is the only significant village. The *Torrente* (seasonal river) Raganello springs in the Pollino massive to the west, cuts through the westernmost limestone ridge (*Gole alte del Raganello*), then turns south, where it again cuts a gorge near Civita (*Gole basse*). The coastal plain starts near Francavilla Marittima, where relief becomes more subdued, while the transitional zone can be described as a landscape with dissected alluvial fans and terraces with very steep and unstable slopes.

Land use varies from relatively large-scale modern irrigated agriculture in the coastal plain, in which olives and citrus play an important role, in addition to animal husbandry (dairy), to more traditional Mediterranean agriculture with mostly small fields and mixed farming in the inland. The ridges are largely barren, particularly where limestone crops out. Forest plantations abound on less steep mountain slopes.

In geological terms, the Raganello catchment is situated between the Southern Apennines to the north and the fold-thrust belt of the Calabrian Arc to the south. Figure 2 illustrates the complex geological structure and history of this part of Calabria, and an overview of the various lithological units encountered in the catchment. Feiken (2014) extensively described its geology and geomorphology, and produced land unit maps at scales of 1:25 000 and, for part of the area, of 1:10 000. For that reason, here only a brief description is given of the geology and geomorphology of the area, and reference is made to his study for a full description, including the processes involved. Limitations of his land unit approach are indicated. A recent interesting topic is the tephrochronology of southern Italy, which unexpectedly appeared to be relevant because of the discovery of ash layers in archaeological contexts in this part of Calabria (den Haan et al. in prep).

Trends in soil formation and weathering processes[2] in the area of study have not yet been described systematically and therefore considerable attention is paid to these processes, as well as to the impact of man on the soils in the Mediterranean.

1.1 Geology and geomorphology

The Calabrian Arc consists of a Hercynian basement,[3] composed of a large variety of mostly Palaeozoic igneous and metamorphic rocks, and partly covered by younger sedimentary rocks (Amodio-Morelli et al., 1976; Van Dijk et al., 2000; Bonardi et al., 2005; Spina et al., 2011). This Calabrian arc represents a continental fragment within the arc-shaped Mediterranean fold and thrust belt (Robustelli et al., 2009). The Southern Apennines, and in particular the Pollino Massif marking the northern border of the study area, consist of Mesozoic and Cenozoic sedimentary rocks of the Ligurid and Sicilid sedimentary basins (Santoro et al., 2009). The Pollino Fault Zone runs through the study area, marking the boundary between the Southern Apennines and the Sila Massif. This results in a complex pattern of geological units (both with regard to age and lithology) that is visible in the geological maps and controls the relief and geomorphology at the scale of the Raganello catchment. For a description of the various units and rock types, see figure 1.

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2 ‘Geomorphological processes’ are processes that cause the earth’s land surface to change in shape, acting over a large range of spatial and temporal scales. They include such relatively small-scale processes as catastrophic landslides or accelerated soil erosion, but also long-term change in the lithosphere related to plate movement and global tectonics. ‘Pedological processes’ or ‘soil forming processes’ refer to processes that are physical, chemical and biological in nature, and lead to the development of soils. They cause the transformation of parent material into soil, often due to vertical transport of soil components (e.g. clay, iron, etc.) released or formed by weathering, and accumulation of organic matter at the surface, and are not necessarily associated with lateral transport processes that would cause the shape of the land surface to change. The overall term employed for all processes that change the shape and nature of the land surface of the earth is ‘earth surface processes’.

3 Collisions of continental plates (plate tectonics) took place during several geological periods and were associated with mountain building (orogenesis), metamorphosis of sedimentary rocks, and large scale emplacement of igneous rocks such as granites. One of these is the Hercynian orogenetic period, dating back to the Late Paleozoic and causing the formation of the Hercynian massifs of Europe, such as the Massif Central, the Eifel-Hunsrück and the Bohemian Massif.

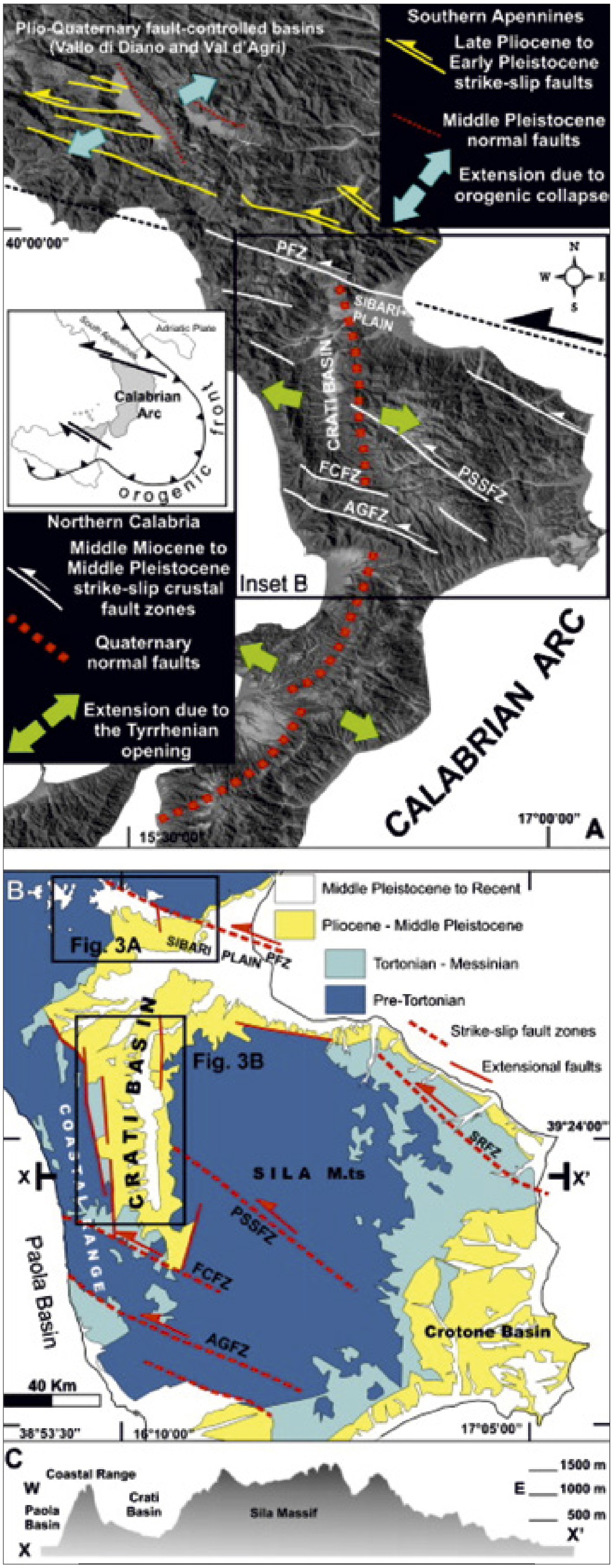

Figure 2. Geology of Calabria (after Spina et al., 2011).
a: Digital elevation model showing main strike-slip faults and extensional basins of the southern Apennines and northern Calabria. The major strike-slip fault in the fieldwork area is the Pollino Fault zone (PFZ).
b: Geological sketch map of northern Calabria.
c: Topographic section across the Crati Basin, the Coastal Range and the Sila Massif.

The lower parts of the Sila Massif and Crati Basin are covered with Middle-Late Pleistocene marine deposits forming the Sibari coastal plain and its inland extensions (Fuchs, 1980; Spina et al., 2011). Together, these marine deposits constitute a set of marine terraces, resulting from the interplay between regional uplift and high-amplitude glacio-eustatic[4] changes, which led to the development of wave-cut platforms covered by shallow-marine deposits and associated marine deltaic fans at progressively lower elevations (Scarciglia et al., 2006; Santoro et al., 2009; Zecchin et al., 2009). Upstream, the marine terraces grade into alluvial fans and fluvial (river) terraces. Fuchs (1980) identified four steps of marine terraces in the study area, whereas Heilmann (1972) and Santoro et al. (2009) identified six steps, which demonstrates the complexity of the genesis and characteristics of the marine terraces. Inferred ages of the various terraces are generally based on a combination of palaeontological evidence (marine fauna), isotopic age estimations, assumed uplift rates and extent of soil development (soil chronosequence approach, see e.g. Sauer, 2013).

An extensive literature exists on the variations in climate during the Quaternary and associated sea level oscillations (glacio-eustatic changes), which are commonly presented in the form of curves for various climatic variables and sea level. Examples of these that provide information that is fundamental for understanding the Quaternary history of the area of research are presented in figures 3 and 4. For the more recent, Mid-to-Late Holocene variations in climate, reference is made to figure 4 (see also Attema and Sevink, in press). This shows that variations were rather limited, even during the first millennium BC of which the early part was relatively cool and humid in Northern and Central Italy. In the south this early cool and humid phase has not been observed and the overall climate trend is described as increasingly dry and more seasonally contrasted over time, starting around 4500 cal BP (Sadori and Narcisi, 2001; Magny et al., 2012). However, in several recent overviews of the available data for the whole of the Mediterranean relatively humid conditions in the South, more or less equivalent to the cool and humid period in the north, are described in the interval 2700-2300 cal BP (Magny et al., 2013) or 2600–2000 cal BP (Magny and Combourieu-Nebout, 2013; Sadori et al., 2013).

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4 'Glacio-eustatic' means linked to glacial (cold) and interglacial (warm) periods, reflected in low sea level and high sea level respectively because of the concurrent changes in the volume of glacial ice caps.

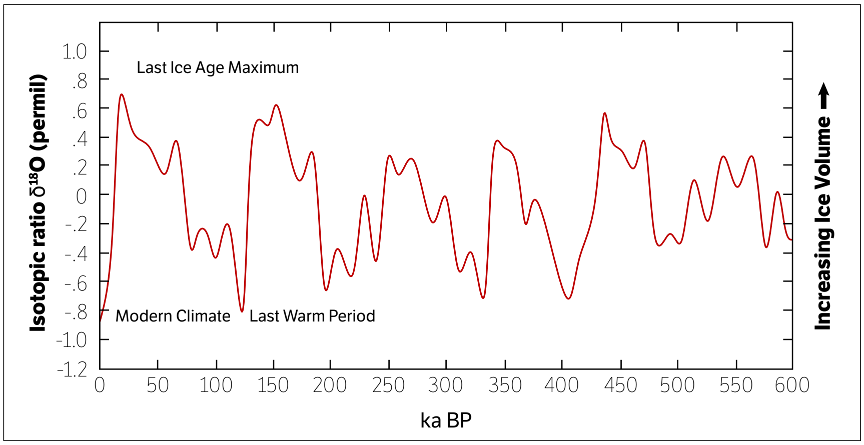

Figure 3. Sea level during the past 600 ka, based on averaged $\delta^{18}O$ in deep sea sediment carbonate (after Schmidt, 1999).

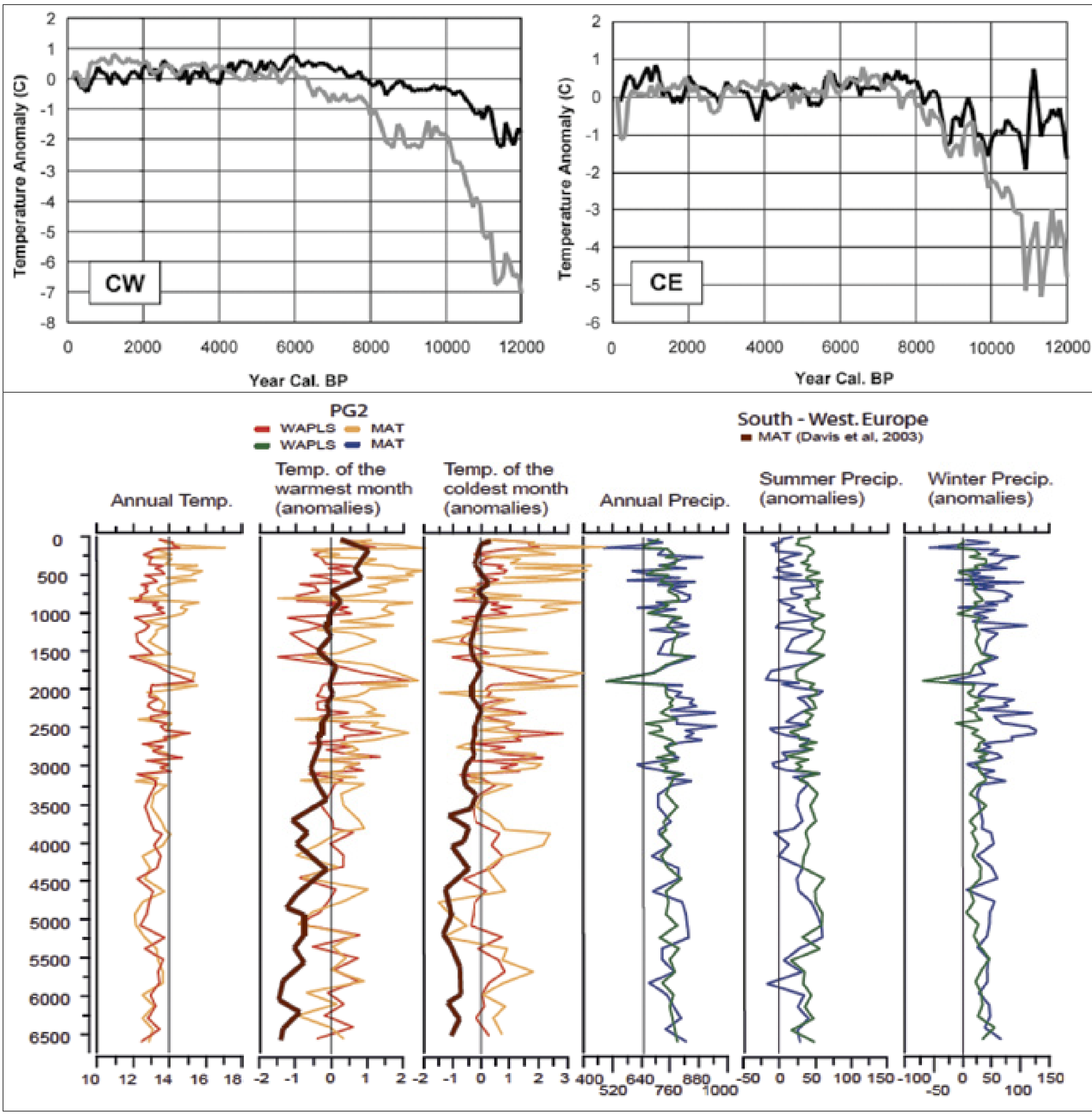

Figure 4. Mid- to Late Holocene climate variations.

a: Reconstructed area-average summer and winter temperature anomalies for Central Western and Central Eastern Europe during the Holocene (from Davis et al., 2003).

b: Fluctuations in precipitation and other climatic variables for Pergusa (Sicily) during the later Holocene (from Sadori et al., 2013 figure 7).

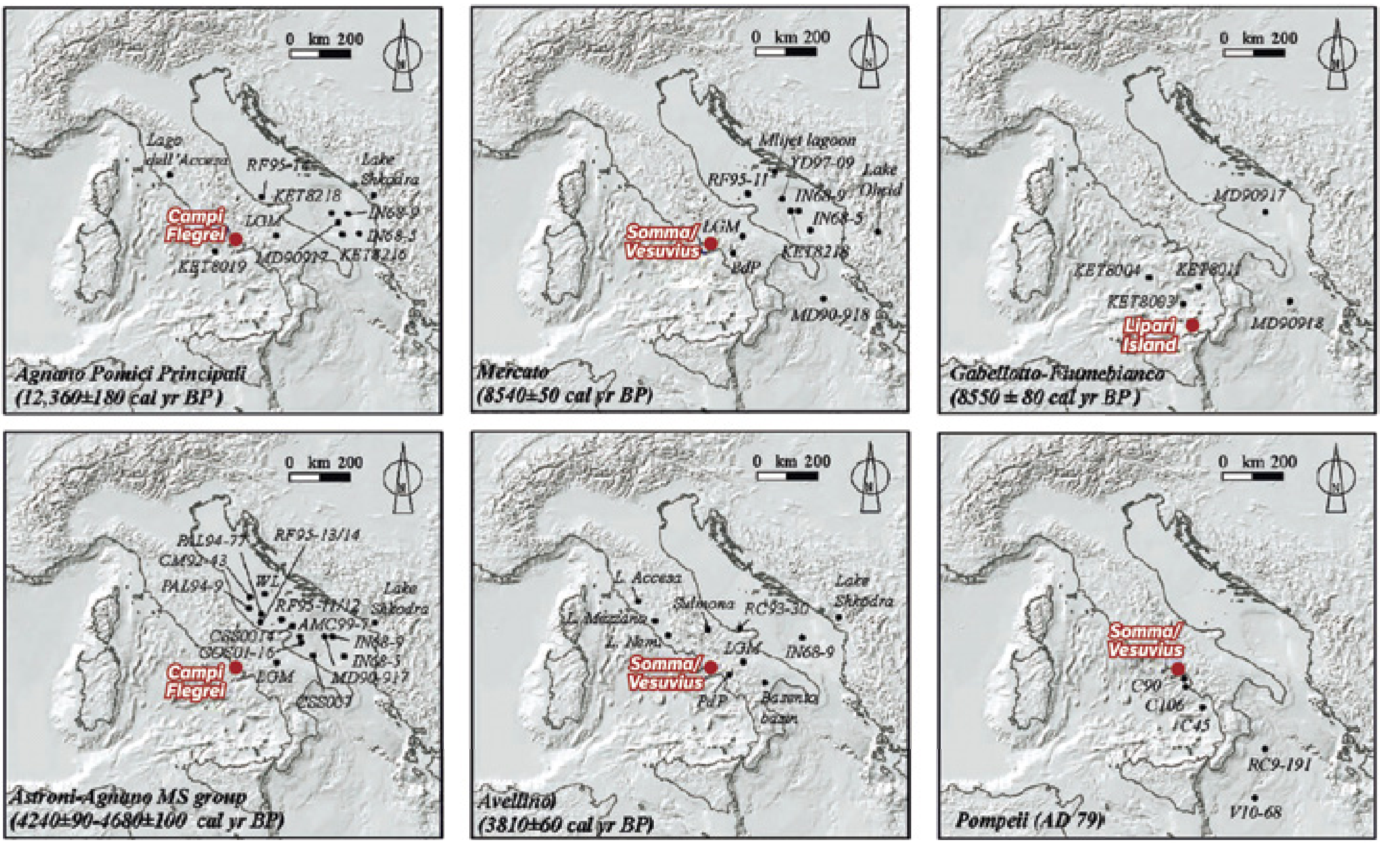

Figure 5. Main Holocene eruptions and sites where their ash was found (after Zanchetta et al., 2011).

Due to the continued regional uplift of Calabria, the Raganello river, its tributaries, and other streams extensively dissected the marine terraces, resulting in steep slopes with scree cones formed by later mass movements and development of small fans by very local tributaries. Such mass movements and alluvial fans abound throughout the Raganello catchment, and are mostly of Late Quaternary age (Post-Würmian) as evidenced by the rather limited weathering and soil formation in the deposits. Alluvial fans can be identified by their low gradient and wide-angle cone shape, and the deposits predominantly consist of rounded and well-sorted gravels. Mass movements can be identified in the field as high gradient, low width cone-shaped landforms. At the foot of steep slopes, scree cones and screes are common. The deposits consist of poorly sorted gravel and stones with minor fine material.

Based on their morphology, genesis, and lithological characteristics, land units can be distinguished and mapped in the field or from remote sensing images. This was the approach used by Feiken (2014), whose land unit maps deliver extensive and rather detailed information on the geology and morphology of the Raganello catchment, in part derived from Lidar data made available by the University of Leuven. However, his combination of geology, morphology, and lithology does not provide systematic and detailed information on the age of the land surface or unit, or on the impact of soil formation. The latter caused more or less significant changes in substrate characteristics and modified the original lithological properties to an extent that strongly depends on the age of the soil. His approach also did not provide detailed information on the extent to which the soils have been affected by human-induced erosion and/or sedimentation, which is crucial for understanding local artefact distribution patterns.[5]

Bouter (2008), who studied the marine and fluvial terraces in the lower reaches of the Raganello catchment, in between Civita and Francavilla Marittima, followed another approach. He studied the geology, geomorphology, and soils of a series of small sample areas, paying particular attention to the relevance of his results for the archaeology in these areas. The latter was described in terms of the potential occurrence and conservation of archaeological remains in relation to the erosional and denudational phenomena observed. His pilot study was limited to a

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5 A typical example is the use of a land unit 'alluvial fans', which may range from very old and deeply weathered gravels with extensive impermeable petrocalcic horizon, which in places is exposed due to serious plough erosion, to very recent hardly weathered and highly permeable stony deposits with incipient soils. Similar differences occur between the various marine terraces, of which soils may range from shallow brown soils to extremely weathered and deep red soils (see e.g. Heilmann, 1972 and Fuchs, 1980).

small part of the catchment and is less systematic than the later study by Feiken (2014).

1.2 Tephrochronology

During the Holocene in central and southern Italy, many volcanic eruptions occurred of which the fine pyroclastic material may have been deposited on contemporary distal land surfaces or in lakes and seas, to be conserved under suitable conditions as identifiable tephra layers. Such preserved ash layers, if identifiable, are described as 'tephrochronological marker beds' and play an important role in the dating of sediment archives that contain such layers. They can be identified by detailed study of their chemical and mineralogical composition, as has been shown recently with regard to the occurrence of Holocene ash layers in the Central Mediterranean (see e.g. Sevink et al., 2011; Zanchetta et al., 2011). Relevant eruptions include the 79 AD eruption by the Monte Somma/Vesuvius, the Avellino pumice eruption from around 4000 calBP, and the Agnano Monte Spina Tephra (AMST) between 4690 and 4300 calBP.[6] The main Holocene eruptions and sites where their ash was found, are given in figure 5.

Recently, ash from the Pompeii eruption of 79 AD was found by den Haan at a site near San Lorenzo Bellizzi, and further indications for the occurrence of tephra were found in the sediment archives from Lago Forano and Fontana Manca (Sevink et al., in prep.). The latter archives were earlier studied for their palaeoecology by Kleine et al. (2005) and Woldring et al. (2006).

1.3 Pedology

Soil formation in the Raganello catchment conforms to the overall trends in soil formation in the Mediterranean, of which the generics are described below. A summary is given of the main pedogenetic (soil forming) processes, soil forming factors, and soil properties. Typical for the Mediterranean is the complex and long continued anthropogenic impact on the soils, which is dealt with in more detail. For an explanation of pedological terms used, reference is made to Appendix I.

The FAO/ISRIC soil classification (2006) is used for characterization of the soils. Because this classification system is relatively hard to apply by non-soil scientists and is meant for use at world scale, we developed a relatively simple 'Soil Key' specifically for classification of the soils in the area of study (Appendix II); this is still based, however, on the principles and definitions employed in the FAO/ISRC classification. This soil key allows for a more easy communication between the various scientists (archaeologists, geophysicists, soil scientists) regarding the soil types encountered during their studies in the area. It is based on three principles: a) the key should allow for distinction between soils on the basis of their extent of truncation/degradation and origin of the material in which they are formed, including colluvial material; b) it should allow for distinction between soils that are markedly different in terms of geophysical properties, i.e. in such parameters as clay content, stoniness, iron content, et cetera; and c) it should allow for distinction between soils on the basis of their suitability for agriculture (soil depth, presence of hard rock, et cetera).

1.3.1 Weathering and soil formation in Mediterranean climate

The Mediterranean climate is characterized by strong seasonal contrast, with a cool, wet season in which a precipitation surplus occurs and the soil is leached, and a dry, warm season in which the soil dries out and solutes may precipitate. An example of the latter is the formation by precipitation of gypsum ($CaSO_4$) from dissolved calcium (Ca^{2+}) and sulphate (SO_4^{2-}).

The role of biota (animals and plants) is most visible in the form of plant growth (both above and below ground) and decomposition of the litter produced (dead plants and roots). This decomposition results in the development of an A horizon containing organic material, giving it a darker colour. The accumulation of organic matter is rather limited as a result of the rapid litter decomposition in the Mediterranean climate. However, the extent of accumulation also depends on the preservation of the decomposition products, which in turn depends on the soil composition. In materials that are not high in finely divided lime ($CaCO_3$), which is the case on most substrates, the A horizon is light coloured and accumulation of organic matter very limited. However, in soils high in fine powdery

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6 Earlier (pre-Holocene) eruptions of major magnitude may also have led to large scale deposition, but remains of these tephra are less likely to have been conserved far from the eruption centres because of adverse climatic conditions (glacials) and thus limited chances for their survival. Würmian or earlier ashes, for example, in order to be conserved, needed to survive periods with very cold, periglacial conditions. In sloping or mountainous terrain this is very unlikely because of the intensive erosion and denudation under such conditions. Thus, the earlier ash eruptions cannot be used to assess the stability of land surfaces and chances of preservation of associated archaeological remains.

Figure 6. Luvisol with local preserved light coloured albic horizon over reddish Bt in marine terrace at site Rb035.

lime, such as in marl substrates, the lime rapidly neutralizes (immobilizes) organic acids produced by microbial breakdown. In such soils, organic matter decomposition is slower, resulting in an increase in soil organic matter and a thicker, darker A horizon.

As a result of the limited leaching and rapid microbial breakdown or neutralisation (on lime-rich substrates) of organic acids produced during litter decomposition, soil acidification is limited (e.g. Duchaufour, 1982). Weathering and leaching of the compounds released, such as basic cations (Na, K, Ca and Mg) and silica (Si), are not very strong. Moreover, Al and Fe, when released upon weathering, remain largely immobile, being virtually insoluble at the pH values encountered. Depending on the extent of leaching, Al and Si combine to form secondary clay minerals of the kandite (1:1 clay mineral) or smectite groups (2:1 clay minerals, in which also Mg and Fe may be included): upon severe leaching (freely drained soils) kandite dominates, whereas limited leaching (in poorly drained soils) produces smectite. Micaceous minerals (muscovite and biotite) present in the parent material are largely preserved in the stable forms of illite and vermiculite ('inherited' 2:1 clay minerals). A more detailed description of the chemical composition and archaeological relevance of clay is given in Appendix III. This relevance largely concerns the reaction of clay to drying and firing, which differs depending on such characteristics as the capacity of clay to swell and shrink, and on the iron content.

Iron released from the primary (original) minerals largely precipitates as reddish brown to reddish goethite (FeOOH) and is strongly bound to the clay. In the presence of organic matter, brown iron-humus-clay complexes will form, with iron in the form of more or less amorphous, brown hydroxides, but such processes only occur in the humic topsoil. Below that topsoil, the soils have typically reddish brown to red colours. The process is described as 'rubefaction' (Fedoroff, 1997), and the overall weathering process leading to these reddish brown, clayey soils is described as 'fersiallitisation' (Fe/Si/Al; Duchaufour, 1982), rubefaction being one of the subprocesses involved. Fersiallitisation leads to the development of differentiated soils, with a more or less leached topsoil and a subsoil in which a smaller or larger part of the eluviated[7] materials and elements accumulate, in addition to newly formed clay. The leaching not only comprises solutes (such as basic cations and bicarbonate), but also clay. The clay is peptized[8] and subsequently washed from the topsoil into an underlying accumulative horizon (argic B horizon), in combination with iron(hydr) oxides, that are tightly bound to the clay particles. This process, described as 'lessivage', is particularly prominent in Mediterranean climates because of the seasonally

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7 Eluviation is the process by which soil components are washed from the topsoil downward to lower horizons or are lost in drainage water, as particles (e.g. clay) or in solution (solutes).

8 Peptization is the process responsible for the dispersion of clay in water. This may occur when rainwater percolates through the soil, diluting the soil solution.

Figure 7. Top: iron-manganese nodules (largest dimension ca. 6-7 cm). Bottom a: soft powdery lime in a soil profile, b: calcium carbonate concretions, c: petrocalcic horizon acting as cap rock.

contrasting precipitation and frequent high intensity rainfall, which both promote the peptization of the clay. Ultimately, it leads to the development of 'impoverished' or 'bleached' topsoils that lack the typical reddish colours due to the absence of iron-clay complexes and have a whitish to greyish colour and low clay content, over a clayey subsoil with prominent reddish colours (see figure 6).

The clayey subsoil is marked by swell and shrink upon seasonal alternate drying and wetting, particularly when containing fair amounts of 2:1 clay minerals. The swell and shrink shows up as severe cracking in the dry season. Kaolinitic soils have a lesser tendency to swell and shrink, and may even completely lack cracks, such as in the old, deeply weathered and red soils of the old marine terraces in the Raganello basin. In soil descriptions, the bleached and impoverished horizon is described as an albic E horizon with the descriptive symbol E for 'eluvial', while the underlying clay accumulation horizon is described as an argic B horizon, for which the symbol Bt is used (t from the German 'Ton' or clay). Irrespective of the intensity of the swell and shrink phenomena, the Bt horizon is marked by the occurrence of clay cutans[9] that form upon illuviation of clay.

In soils that are freely drained, solutes released upon weathering are leached to considerable depth or even completely lost from the soil. However, typical for many sedimentary rocks in the Mediterranean and also in Calabria, is the relatively high primary[10] clay content and low permeability. Leaching in such parent material may be limited to the extent that solutes are not or only partially removed from the topsoil. Weathering under such conditions leads to the formation of smectites, i.e. of strongly swelling and shrinking clay whose properties enhance further stagnation. Iron released upon weathering is largely built into the newly formed clay (nontronite[11]) and thus does not precipitate in the form of reddish brown to red iron(hydr)oxides. Such clayey soils characteristically have a more yellow to greenish yellow colour, often with pronounced swell and shrink features (described as 'slickensides'[12]) and with small, black, rounded iron-manganese nodules (figure 7). Such soils, if well developed, are classified as Vertisols. Where less prominent, soils are described as having 'vertic properties'. Evidently, in such soils decalcification is less or even virtually non-existent and secondary carbonates may abound.

Many parent materials in the Mediterranean area contain primary carbonates (calcite) or calcium-bearing primary minerals such as feldspars. Upon the weathering of these primary minerals or, in the case of carbonate, its dissolution, solutes are leached into the subsoil. Upon the seasonal drying out of the soil these may precipitate as secondary carbonate, often in the form of concretions or even dense layers called 'calcrete'. The depth of

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9 Clay cutans develop when water with dispersed clay particles infiltrates into a relatively dry lower soil horizon. The water is sucked into the dry aggregates and pores, while the clay is left behind on the aggregate surfaces and in the pores in the form of coatings or 'cutans'. It should be stressed that the clay cutans contain a fair amount of iron that is tightly bound to the clay platelets, hence the term ferri-argillans is used for such cutans.

10 Clay may be present in the parent material or be formed by weathering. In the first case it is described as 'primary clay', in the second case as 'secondary clay'.

11 Nontronite is an iron-rich variety of smectite. The iron is present as ferro (Fe^{2+}), which explains the absence of the typical reddish brown colour of ferric iron compounds.

12 Slickensides are a type of cutan produced in soils containing a high proportion of smectitic clays. The seasonal alternation of drying (shrinking) and wetting (swelling) of the clays results in these polished pressure surfaces.

precipitation depends on the extent of leaching, which in turn is governed by a complex of factors such as the net precipitation surplus (intensity of leaching), amount of calcium carbonate originally present, permeability and water holding capacity of the material, and time elapsed. In other words, in old, highly gravelly soils with low amounts of primary carbonates and higher up in the mountains (where a larger precipitation surplus exists), secondary calcium carbonate will be of minor importance. Contrariwise, in the Sibari coastal plain with highly calcareous, relatively fine sediments (e.g. in the older alluvial fans; see figure 1), secondary carbonates abound particularly in older soils.

1.3.2 Time scale of soil formation in Mediterranean climate

Time scales at which soil forming processes operate range from decades to many thousands of years, examples of which will be given below. Soils develop over time, allowing for the distinction of development stages (initial, mature and old) and of soil chronosequences, i.e. series of successive stages in soil development over time. Soil chronosequences offer interesting possibilities for dating soils and soil features and for estimation of ages of land surfaces (see e.g. Sevink et al., 1982), but they generally concern longer time spans and are relevant mainly for the archaeological study of early (Palaeolithic) prehistoric cultures. For more recent periods, our emphasis must be on the relatively short-term pedological sequences, i.e. on the initial stages of soil formation.

'A' horizons develop relatively rapidly, periods of a few hundred years being sufficient to form Ah horizons that show up because of their darker colour and higher organic matter content. This evidently is only possible without ploughing and crop production, since ploughing leads to rapid oxidation of organic matter in combination with a lower litter input as crops are removed and crop remains (litter) burnt. This also implies that at least several centuries of soil formation are required to mask any significant earlier disturbance caused by ploughing (see e.g. Melero et al., 2011; Cuesta et al., 2012).

Accumulation of secondary carbonates, varying from minor accumulation of soft secondary carbonate to thick and massive petrocalcic horizons, takes place at intermediate time scales (see figure 7). The former may occur at the scale of centuries, whereas the formation of petrocalcic horizons of major dimensions requires a glacial/interglacial scale. Since the accumulation of calcium carbonate strongly depends on factors such as climate and amount of primary calcium carbonate present in the parent material, but also on the hydrology of the system, there is no generally applicable measure for the time required for formation of a specific secondary carbonate horizon. Such a relation can only be established on a local scale and for a certain area, and can only be semi-quantitative.

Clay translocation ('lessivage') is a far slower process that occurs at and beyond the millennium scale. For thick and prominent argic B horizons to form, periods in the order of hundreds of thousands of years are required. Thus, differences in the development of argic horizons, in terms of contrast in clay content between topsoil and subsoil, in maximum clay content of the Bt horizon, and in redness of the illuviated clay, can be used to date at the scale of glacial/interglacial cycles.

In the Mediterranean, the absence of strong periglacial erosion and denudation during Pleistocene glacial periods has led to the relative abundance of older stable (non-eroded) surfaces (e.g. in marine terraces), and thus to relatively common old and strongly developed soils. Such soils are marked by prominent features of fersiallitisation and secondary carbonate accumulation, which give rise to marked differentiation in soil horizons. The extent of soil development depends on the age of the soil, but a further complication is that earlier during the Quaternary the climate was warmer and more humid than today, resulting in a soil formation that comes closer to 'ferrugination'. This is a more pronounced leaching, leading to formation of kandite minerals and a stronger weathering of the micas, resulting in a more kaolinitic soil that is higher in residual iron/manganese minerals. In such soil, instead of goethite (FeOOH) the more reddish hematite (Fe_2O_3) formed. Such ferruginous soils lack the swell and shrink features of fersiallitic, more smectitic soils, and are often deeply decalcified.[13] The overall result is that with increasing age, as in the series of marine terraces encountered along the Italian coast, soils exhibit a marked change in properties: from a reddish brown clay-loam soil with shallow secondary carbonate horizon in Late Pleistocene deposits to a deep, red soil that is deeply decalcified and very clayey (figure 8). These chronosequences have been extensively studied and form the basis for the current theories on soil forming processes in the Mediterranean as for example described by Duchaufour (1982), Cremaschi and Sevink (1987), Yaalon (1997) and Torrent (2004). Such soil chronosequences also have been described for the Calabrian terraces (Heilmann,

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13 Identification of the iron(hydr)oxides in terms of the mineral species involved can only be achieved in the laboratory with infrared and/or electron spectroscopy (Scheidegger et al., 1993) and thus cannot be readily used to characterize soils. Hence the wide use of a redness rating for characterising sequences of soils that developed over the Quaternary, based on colours from the Munsell Color Charts and not on their mineral composition (e.g. Torrent et al., 1980).

Figure 8. Red Bt horizon of high marine terrace behind Francavilla, with deeply decalcified Bt horizon.

1972; Sauer et al., 2010), and this information can be used to 'predict' the characteristics of soils in such terrace sequences and, in particular, to understand and assess the extent to which these soils have been eroded.

1.3.3 Humans as a soil forming factor

Under natural conditions, when erosion and sedimentation generally play a very minor role given the presence of a protective vegetation cover, the main effect of topography is the transport and redistribution of water and solutes contained in the water. This results in patterns of 'loss' and 'accumulation' that show up as differences in soil properties. Thus upper slopes and summits, where losses prevail, will impoverish in bases and be higher in kanditic materials than lower slopes and basins, where clay and solutes accumulate to form smectitic soils with abundant lime (see also 1.3.1). Surface transport processes and redistribution of soil materials become much more prominent upon deforestation and other anthropogenic disturbances (such as ploughing) that lead to a major increase in surface transport of soil materials by e.g. overland flow. This produces a much more intricate pattern of erosion and accumulation at slope scale, and eventually leads to such phenomena as terraced slopes with an alternation of eroded soils and colluvium-covered, more or less preserved original soil. Particularly in old anthropogenized landscapes such as those of the Mediterranean, the anthropogenic topography-related redistribution processes of erosion and sedimentation had a major impact on the original soils, and largely determine their current properties and pattern (see e.g. Bintliff, 1992; Bergkamp, 1996). In steep and dissected landscapes, surface horizons generally have been completely removed and the soil is rejuvenated, resulting in shallow soils with bedrock close to the surface, classified as Leptosols. With more or less flat topography or on footslopes and man-made terraces, runoff is reduced and colluviation (accumulation of soil material derived from overlying slopes) becomes a prominent feature. This colluvium often protects the underlying 'natural' soil against erosion.

In the context of a single slope, local variation in the topography and/or anthropogenic influences in the form of terracing results in a complex pattern of erosion and colluviation, and corresponding soils. It should be emphasized that this complex pattern results not just from the complex of processes that together can be termed 'transport by overland flow', i.e. by water running over the surface. Often, equally important or even dominant is the effect of ploughing and other forms of soil labour that lead to downslope mechanical transport of soil material. In the Mediterranean, with its extremely long history of crop production and intensive soil labour, the effect of so-called 'plough erosion' may far exceed that of overland flow, particularly where soils are coarse textured and water readily infiltrates, as on coarse textured alluvial fan deposits. In such cases, overland flow will be of very minor importance and will not lead to massive downslope transport of material over the soil surface. Instead of water erosion it is the 'plough erosion' that often was and still is responsible for the development of agricultural terraces. A further implication is that current topsoils of more or less sloping lands that are or have been under prolonged cultivation should be seen as 'layers in transport'.

Plough erosion became particularly effective with the introduction of modern mechanised ploughing, enabling far deeper ploughing than was possible with animal traction. Devastating impacts are known from modern vineyards and olive groves that have been deep ploughed to improve drainage and enhance deep rooting (see e.g. Borselli et al., 2002). Mediterranean agricultural areas with modern farming systems involving mechanised ploughing therefore should be seen as landscapes 'in transition', rapidly changing with regard to their soil cover and soil archive, and subject to intense degradation by plough erosion.

Differences in accumulation of organic matter that are due to differences in soil composition (parent material), drainage, and (micro or meso) climate will be visible in soils that are under more or less natural vegetation and have been so for a prolonged period. However, land use, in particular when accompanied with intensive soil labour, leads to lesser inputs of litter and consequently to declining organic matter contents and development of the Ah horizon. Thus, soils that have been ploughed and cropped for prolonged periods of time, without adequate periods of fallow, generally are very low in organic matter. Such soils, because of the resulting poor aggregation of the topsoil, are prone to erosion.

A last aspect to be discussed is the difference between 'natural' and 'anthropogenic' slope deposits. 'Natural' slope deposits include, for example, scree deposits and talus slope deposits, but in the humid Mediterranean environment do not comprise fine textured humic deposits since under a closed, natural vegetation cover overland flow and transport of soil material is very unlikely (see e.g. Cerda, 1998). Such relatively fine textured, humic deposits only result from detachment of soil aggregates and their downslope transport by splash erosion or overland flow on slopes that lack such protective vegetation cover, and accumulate on a lower slope or slope discontinuity (e.g. a lynchet). Such fine textured, humic slope deposits are therefore directly caused by anthropogenic disturbance.

The term 'colluvium' is often used as a broad term involving all slope deposits, whereas the term 'anthropogenic colluvium' is reserved for those slope deposits that formed as a result of human land use. In this text, however, we will use the term 'colluvium' in a stricter sense, in line with the definition given by Leopold (2003), being the more or less humic, anthropogenic slope deposit that formed as a result of accumulation of soil material (mainly soil aggregates) that was eroded from slopes above or ploughed down the slope. Natural colluvium is referred to here as 'slope deposits'.[14]

1.3.4 Soil as indicator for the extent of erosion

Over time, parent material (rock or sediment) is changed into soil material. Soil material has lost the characteristics of the parent material to the extent that its colour has changed (by for example soil organic matter, weathering with release of iron, manganese or other components), soil structure is formed, soil texture changes e.g. by formation of clay, and calcium carbonate is lost by leaching. This change of 'parent material' into 'soil material' coincides with the development of the 'solum', which is the part of the soil profile that has changed into soil material. This solum consists of horizons described as A, E or B horizons, while the underlying parent material is described as C horizon (soft rock) or R horizon (hard rock). The solum and the underlying parent material together form the 'soil profile'.[15] Clearly, the depth of the solum (the combined pedogenetically altered horizons) in a specific parent material depends on the intensity and duration of soil formation, and on the extent to which the soil has been eroded (or 'truncated'; this assumes that the original soil had a deeper solum, but as a result of land use and concurrent erosion or of natural processes has lost part or all of its topsoil).

In the section on weathering and soil formation (see section 2), the descriptions basically concern non-eroded soils and their various pedogenetic horizons. The extent of anthropogenic erosion can be estimated by comparison of the depth of the solum of non-eroded soils with the observed depth of the solum in a soil under study. Thus a rough but fairly accurate estimate can be obtained for the thickness of the topsoil layer that was lost through erosion. The soil key (see Appendix II) serves as an aid in such estimation since it recognizes stages in the truncation of the various soil types. For example: soils in marl typically have a brown clayey B horizon that is about 30-40 cm thick; hence a soil in marl with an Ap over C horizon must have lost a layer of soil that was at least 30-40 cm thick. Careful study of the extent to which soils have been truncated, and of spatial patterns in such truncation, may be extremely helpful in the identification of potential reservoirs of in situ archaeological material. Evidently, in severely truncated soils chances of finding such in-situ reservoirs are nil, and where they do occur they must be attributed to dug-in features.

1.3.5 Soil and its suitability for agriculture

To grow, plants require nutrients, water and a foothold from soils. Soil properties ('qualities') linked to these requirements can be defined, such as depth of the solum (for water holding capacity and foothold), texture (water holding capacity), reaction (nutrients), etc., and together these reflect the agricultural capacity of the soil. For example, shallow soils (thin solum over hard rock) are fairly unsuited, while well-developed soils with a deep, loamy to clayey solum with fair amounts of organic matter are generally well suited. The soil key (Appendix II), which was developed for characterisation of the soils in the Raganello basin, can be used to rank the various soils with respect to their suitability for certain types of land use, though this generally requires further experience in the application of land evaluation techniques. However, local soil maps employing the key may form the basis for such land evaluation by experts (see e.g. Finke et al., 1994; van Joolen, 2003; Feiken, 2014).

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14 For a full treatment of the definition of colluvium, see Leopold and Völkel (2007).

15 For a more extensive description of the various terms, reference is made to the worldwide used 'FAO Guidelines for profile description' (2006) and to Appendix I.

2 SOILS IN THE RAGANELLO BASIN

In the Raganello catchment a large variety of geological formations occurs, the soils in the various parent materials (rock types) often exhibiting a specific set of pedogenetic features. General trends in pedogenesis are presented first, after which soils in the various major parent materials are described in more detail.

2.1 General trends

In the characteristic intact Mediterranean soil, the upper horizon is a thin, dark Ah horizon, where the mineral and organic matter are intimately mixed. The E horizon below is the zone where the soil is depleted of weatherable minerals, iron, and clay. Because of the resulting predominance of quartz and similar residual minerals this E horizon is (slightly) bleached, for which reason it is called an albic (whitish) horizon if the bleaching is distinct. The depleted material accumulates in the Bt horizon, which can be recognized by its high clay content. The clay (and iron) is visible as a film surrounding soil aggregates (or 'peds'[16]). In some cases even slickensides - scratched and polished planar surfaces or slide planes in clay - can be recognised, which are formed because of the high clay content of this Bt horizon and concurrent strong swell and shrink. The Bt horizon ends where the unconsolidated parent material starts. This zone is called the C horizon and has a significantly lighter colour compared to the B horizon. In the rainy season $CaCO_3$ (calcium carbonate) is leached from the topsoil by dissolution and is transported deeper into the soil by the infiltrating rainwater; this water is sucked into the dry subsoil and taken up by plant roots. Thus dissolved carbonate precipitates and accumulates to produce secondary calcium carbonate. Over time such process may lead first to formation of soft powdery lime, followed by the development of a calcic horizon with abundant calcium carbonate nodules, or even to a completely cemented petrocalcic horizon (see figure 7). Accumulation often occurs in the contact zone between the B and the C horizon, but its depth and magnitude will vary depending on the age of the soil and the nature of the parent material.

16 In soil science the term 'ped' is used for natural soil aggregates and relates to the aggregation of soil material.

The foregoing implies that calcium carbonate concretions are formed at some depth in the soil, and only occur at the surface or in the plough layer if the topsoil has been eroded or severely disturbed by ploughing.

Relatively well-developed soils in the Raganello catchment, i.e. soils that were not seriously eroded because of the steep slope or intensive land use, consist of an incipient E horizon (if present at all) and an underlying Bt horizon. For the development of an E horizon, the substrate should contain sufficient resistant minerals, such as quartz, to allow for the development of a residual layer. These horizons thus may be encountered on the older marine terraces. In substrates dominated by limestone or marls (clay) such residual accumulation is very unlikely to occur, and E horizons do not exist. A horizons (and E horizons, if present at all) are very sensitive to erosion and are easily washed away, and therefore are often absent. Bt horizons are more stable due to their high clay content and strongly developed structure. The presence of calcium carbonate concretions at the surface might indicate that the upper parts of the soil (A and E horizons) are eroded, most likely inclusive of the upper part of the B horizon, but concretions at the surface may also originate from eroded soils in nearby topographically more elevated areas.

2.2 Soils on limestone

Soils on limestone are mostly residual, i.e. they consist of the weathering residue (non-carbonate minerals) left behind upon dissolution of the limestone over prolonged periods of time, and thus are generally subjected to intense weathering, explaining their distinctly red colour (see section 1.3.1). They are classified as Luvisols with calcic and chromic properties, and more rarely as Vertisols. Soils are classified as Luvisols when clay illuviated from the topsoil into the subsoil and formed a distinct argic Bt horizon, which is primarily identified as such by its marked clay illuviation features (cutans). Due to erosion the impoverished topsoil is rarely preserved and the A horizon is developed in the Bt horizon, leading in the field to a gradual transition from A to Bt. Vertisols are soils with high clay content throughout the soil profile that additionally exhibit prominent swell and shrink features. During dry periods Vertisols show clear shrinking as cracks on the surface. The residual soils on limestone, though all high in clay, lack the high smectite content characteristic for the marls and are more kaolinitic. Thus swell and shrink is generally not well expressed and Luvisols prevail.

In the Raganello area, well-developed residual limestone soils are scarce and very shallow because of the strong relief of the limestone areas and the resulting severe erosion, and rocky soils prevail with only minor amounts

Figure 9. Top: thin red/brownish soils present in pockets in between the limestone. Bottom: prominent residual limestone soil, also described as terra rossa, with pronounced karst relief.

of clayey residuum. These soils are therefore unsuited for agriculture (see figure 9a). Deep residual soils are rare, but where present show the characteristic features of such soils, inclusive of their highly irregular boundary with the underlying limestone, as evidenced by figure 9b. These kaolinitic dark reddish clays, which are the classic 'terra rossa',[17] are well suited for production of ceramics.

17 In the Mediterranean, residual limestone soils are quite common, limestone being one of the most common parent materials. The clayey red soils, which consist of residual material that accumulated through dissolution of the limestone over very long periods (millions of years) and are found as a continuous layer or, more commonly, as infill of karst pockets and fissures, were described as 'terra rossa' from early on. More recently the term 'terra rossa' has been used for all old red soils irrespective of the origin of the parent material, but because of the large variety of soils that were grouped under the term and the poor definition of their characteristics, this term is no longer used in soil classification and in fact became obsolete.

2.3 Soils on marl, shale and phyllite

This substrate ranges from greyish fine-grained rocks with some quartzitic beds to whitish/yellowish very fine-grained rocks that are largely composed of silt and clay. Calcium carbonate contents vary, the carbonate occurring as finely divided lime or as calcite veins. Overall the marls are silty to clayey textured, smectitic and fairly high in lime (see figure 10a and b), but local variability is considerable. They may be rather low in calcium carbonate and high in clay and silt, and are described as shales if they exhibit clear foliation (figure 10c). The far less frequent, harder and less clayey rocks, described as 'phyllites', can be recognized by their platy structure and darker colour (figure 10d). They contain more mica (silt size) and less smectite than the marls and shales.

If not weathered (no dissolution of calcium carbonate), the clay in the marls, shales and phyllites remains 'inactive', and swell and shrink is absent. However, even upon slight

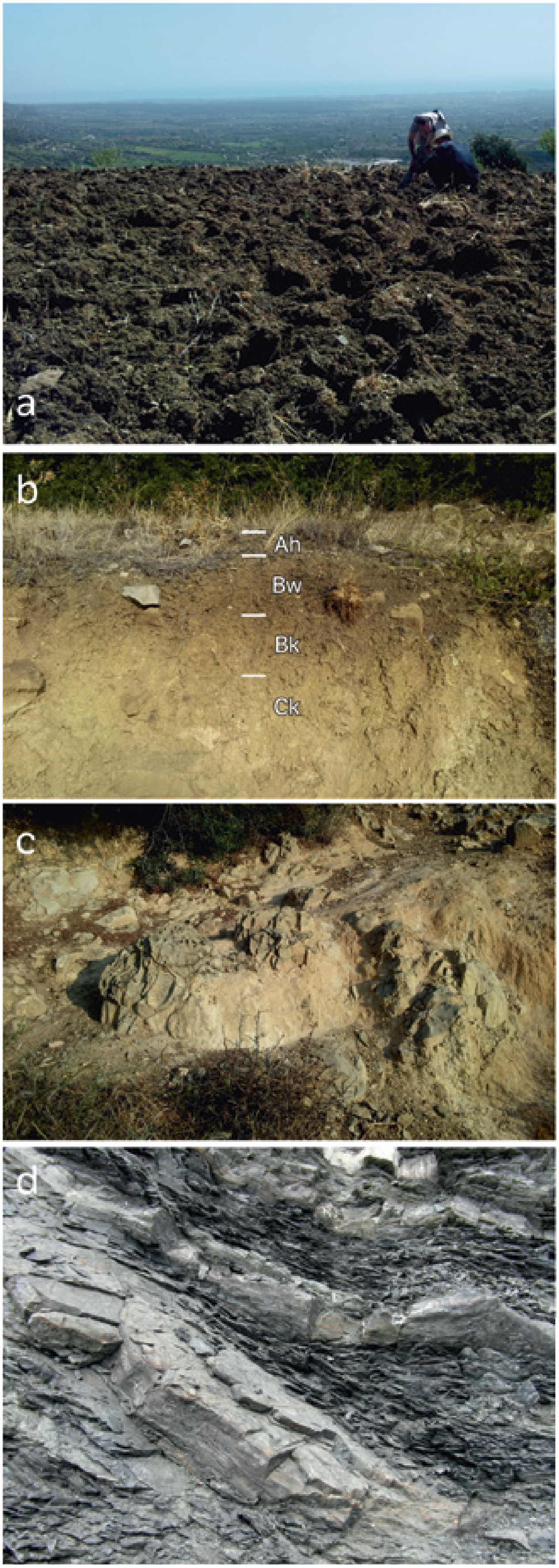

Figure 10.
a: Marl surface with dark topsoil. Characteristic dark coloured Ap horizon of soil in marl near site Rb094.
b: Soils in marl with dark Ah horizon and cambic B horizon, with abundant soft powdery lime.
c: Outcrop of shale band in overall marly rock.
d: Phyllite.

weathering the clay becomes active (swell and shrink) and reduction phenomena (grey and brown iron mottles) develop, particularly in the marls and shales, with phyllites being least sensitive to weathering. The high silt and clay content and the smectitic clay mineralogy cause the soils to swell upon wetting, limit percolation of water, and make the soil rather impermeable. This prevents the iron released by weathering from being transported and results in the formation of nontronite,[18] giving the soil its characteristic brown/yellow colour.

At the contact between the permeable limestone and the less permeable marl, shale and phyllite, groundwater stagnates and seepage is common. This makes the marl and shale soils very sensitive to erosion, whereas phyllite because of its higher content of angular rock fragments tends to be more resistant. Moreover, due to their poor internal drainage and strong swell and shrink, conditions for olive trees and other tree crops are poor, for which reason fruit trees are rarely found on these soils.

18 Smectite is the name for a group of minerals with a specific structure (swelling 2:1 clay mineral). Smectites consist of a central layer with Al^{3+}, Mg^{2+} or Fe^{2+}between two layers with Si - hence the name '2:1 layer clay mineral'. If the central layer is largely filled with Fe^{2+} (ferrous iron) the smectite species is called 'nontronite'; other species include montmorillonite, saponite and beidellite.

Figure 11. Eroded marly soil with abundant fine lime concretions on the Monte San Nicola north lobe. The yellowish colour of the soil is clearly visible in the foreground.

The marl and shale soils, if not seriously eroded, have a relatively well developed Ah horizon with dark colour, due to the abundant presence of finely divided lime which limits microbial breakdown of the organic matter, thus increasing soil organic carbon (SOC) contents (see figure 10a). This Ah horizon is underlain by a brownish B horizon that commonly contains small secondary lime nodules and soft powdery lime. The thickness of this B horizon is generally limited to a few decimetres only (see figure 10b). Where relatively well developed, i.e. with a solum of up to 1 metre, it exhibits clear clay cutans and is described as an 'argic Bt' horizon. If without distinct clay cutans, it is diagnosed as a 'cambic B' horizon. The presence of clay cutans may be identified in the field with a 10x magnifying lens.

All soils in marls and shales have a yellowish/brown to yellow colour (figure 11) and a fine texture. They are classified as Cambisols and, more rarely, as Luvisols with vertic and calcic properties. Soils developed in shale, which occurs as intermittent bands within the marls, resemble the marl soils but are more stony and permeable, and less calcareous, with less common secondary carbonates. Soils in phyllites are far less common and are largely restricted to the higher uplands in the Contrada Maddalena, where phyllites are encountered as mostly narrow and irregular intercalated bands in marls and shales. These soils are mostly Cambisols with a weakly developed brown cambic horizon or Regosols, and have a texture of gravelly to stony loam.

In some areas, in particular in the Contrade Maddalena and Damale, limestone boulders fell down onto the slopes below that have soils in marl, shale, or phyllite. These boulders act as a local buffer preventing the adjacent upslope areas from being eroded, thus inducing the local preservation of relatively well developed soils.

The clays from marls are unsuited for pottery, since smectitic clay is far too unstable (shrinking when drying and cracking upon baking) and the finely divided lime causes the pots to be very porous. Clays from phyllites might be more suited for pottery.

2.4 Soils on terrace deposits

Terraces within the Raganello basin can be differentiated into Pleistocene marine terraces with a specific internal sedimentary structure and sediment composition, and fluvial terraces (or river terraces). The latter mostly consist of large, Late Holocene alluvial fans and fluvial deposits with coarse textured gravels and very weakly developed soils (Fluvisols). Older (Pleistocene) river terraces do occur, but have soils and sediments that strongly resemble the coarser members of the marine terraces. The genesis of the various marine terraces and fluvial deposits is described first, paying particular attention to their sedimentary structure. This is followed by a description of the soils and soil chronosequences.

2.4.1 The marine terrace sequence and sedimentary structure

The Quaternary marine terraces result from the interplay between regional tectonic uplift and high-amplitude glacio-eustatic changes, leading to the development of wave-cut platforms at progressively lower elevations, covered by deposits that formed in a shallow marine environment. These deposits have a characteristic sedimentary composition and structure, being very well sorted and composed of topsets, foresets and bottomsets (figure 12). The finer materials have been deposited as bottomsets,

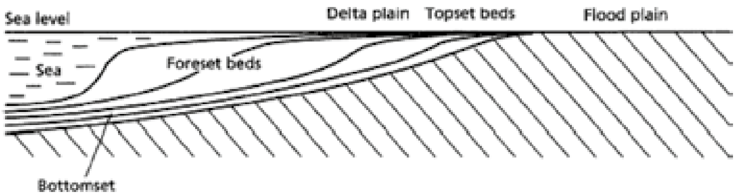

Figure 12. Topsets, bottomsets and foresets.

whereas the coarser materials have been deposited as topsets and related flood plain deposits. Examples of the various deposits are given in figure 13.

Within the area several stages of marine terracing are clearly recognizable as a stepwise pattern resulting from successive palaeoshorelines. This history is schematically represented in figure 14. In figure 15 the terrace sequences on either side of the Raganello river are presented. Terraces (T8, T7 and T6) occur on both sides at 340, 290 and 225-237 m asl and therefore can be linked.

2.4.2 The soils

The highest (and oldest) marine terraces are the most eroded. The deposits of these highest terraces are strongly cemented with secondary carbonates (petrocalcic horizons), the severe erosion resulting in very thin soils (Leptosols). The conglomerate beds are most resistant to erosion and act as a protective cap against erosion of the underlying marly layers. Soils are yellow where they are in largely marl derived silty sediment, and red if in (largely limestone derived) conglomerates. Soils on the lower marine terraces are generally deeper because of the lesser induration by secondary carbonates and the lesser erosion, and are classified as Luvisols with calcic horizon and, locally, vertic properties. In the transitional zone between the terraces (below the terrace scarps) slope deposits abound, partly of anthropogenic origin, and in these deep brown soils occur (Luvisols).

Trends in soil development in the fluvial terraces and alluvial fans resemble those in the gravelly members of the marine terraces, since the fluvial deposits rarely contain finer textured beds. Older terraces have deep red soils with decalcified argic Bt horizon (Luvisol with calcic horizon); younger terraces and fans have more brownish argic Bt. Secondary lime is common, including petrocalcic horizons in older terraces and fans. General trends in the formation of thick Bt horizons, decalcification and increase in pedogenetic iron with increasing age can be assessed via soil chronosequences, i.e. the development of soils of different age from similar parent material and under comparable climatic conditions and vegetation cover. Previous studies on soil chronosequences of the Calabrian terraces showed clear differences in soil development with increasing age (Sauer et al., 2010; figure 18).

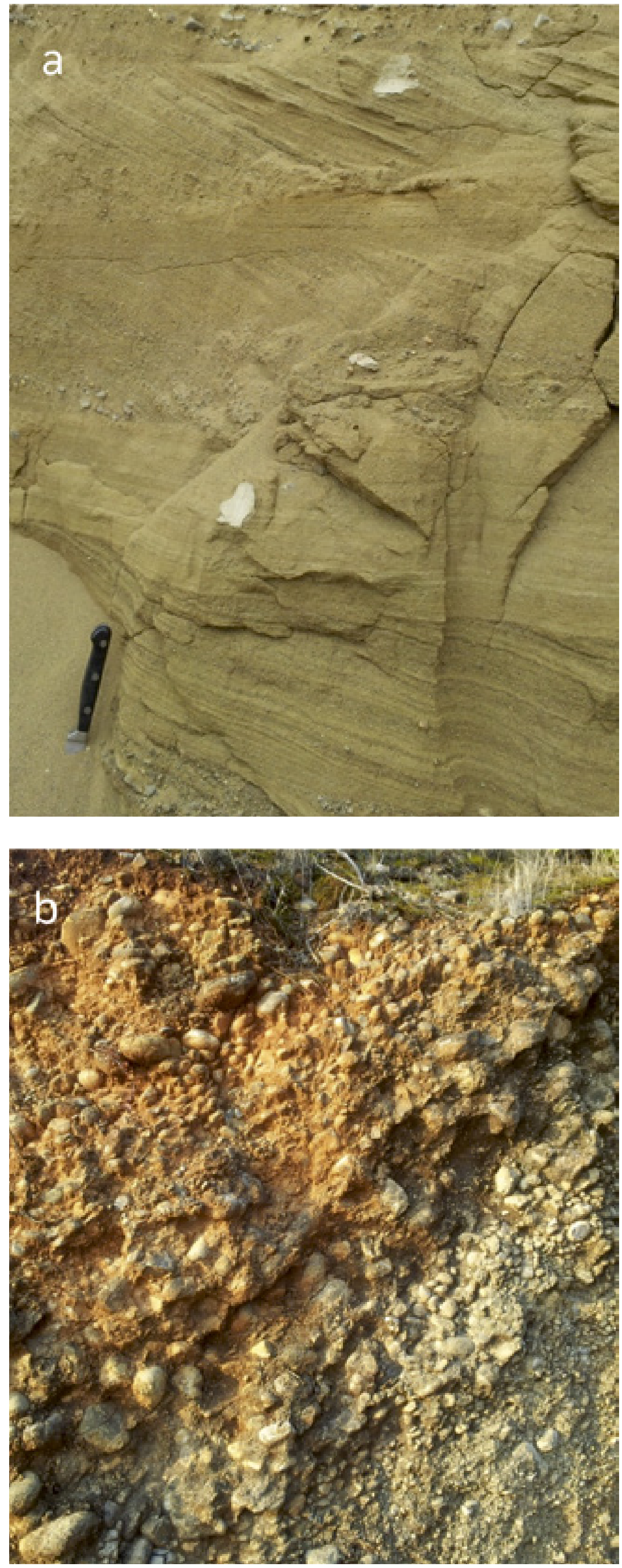

Figure 13. Examples of the various marine terraces deposits.
a: the fine textured bottomsets,
b: the coarsely textured topsets.

This provides a framework for understanding the relation between terrace age and soil characteristics that can be used in the assessment of the gradational history of areas in which archaeological sites or materials are encountered,

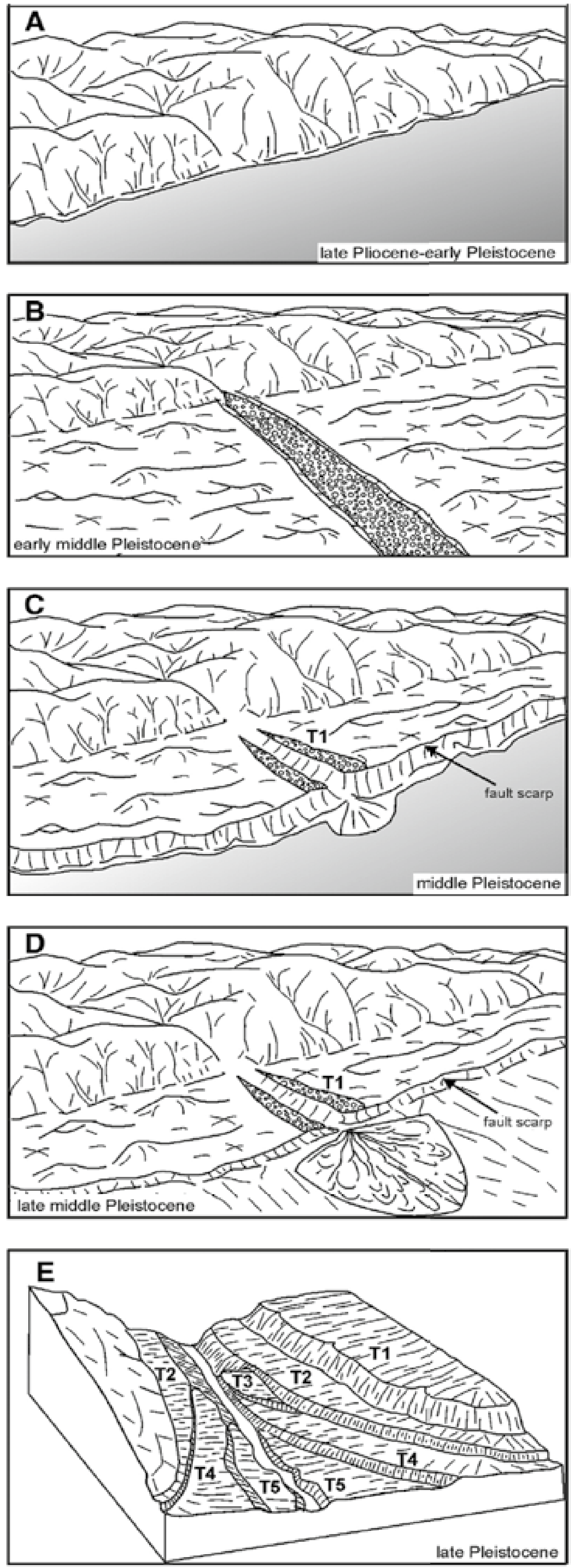

Figure 14. Schematic representation of the Plio-Pleistocene evolution of the marine terraces (after Robustelli et al., 2009).

(A) Depicts the situation in the Early-Middle Pleistocene with high sea level.

(B) The marine regression during the Early and Middle Pleistocene resulted in the extension of a river system into the marine deposits. Incision of the river into the marine sediments led to the deposition of fluvial sediments on its banks and in the stream channel currently seen as cemented conglomerates.

(C) Tectonic uplift resulted in the oldest marine terrace to be raised above sea level. The steps between the terrace levels (fault scarp) indicate this movement. After the uplift the marine deposits were deeply incised by rivers, and deltaic and shallow marine deposits formed at the basement.

(D) During glacial periods sea levels dropped causing the formation of fluvial deposits on top of the deltaic deposits.

(E) The sequence of uplift, fluvial incision, marine deposition, sea level changes and alluvial deposits continued through the Pleistocene, resulting in the clear sequence of marine terraces as identified today.

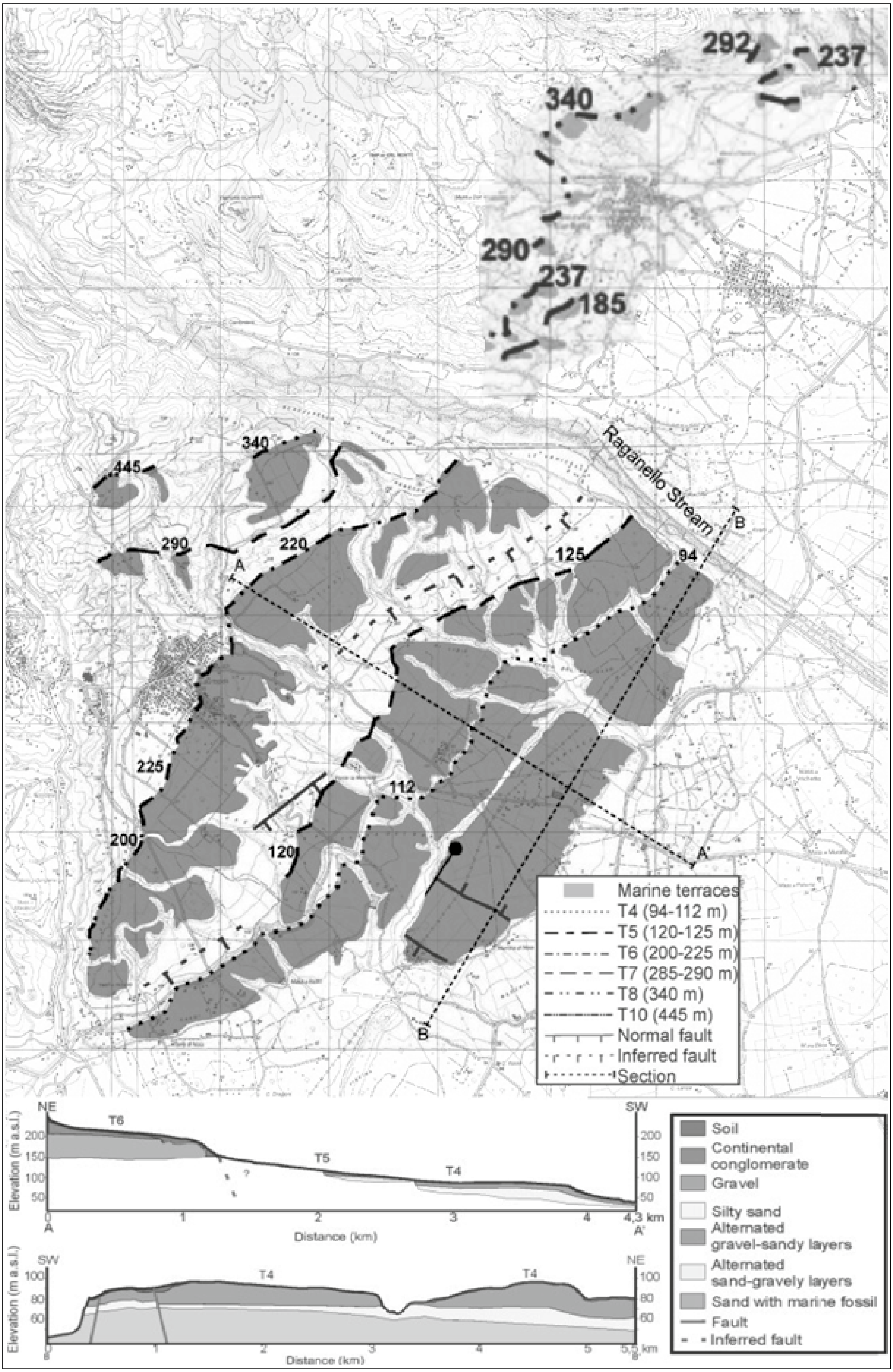

Figure 15. Sequences of marine terraces on both flanks of the Raganello river (after Santoro et al., 2009). Differences between northern and southern series of marine terraces demonstrate the differences in geological history between the two areas, which are separated by a major fault (see fig. 2b).

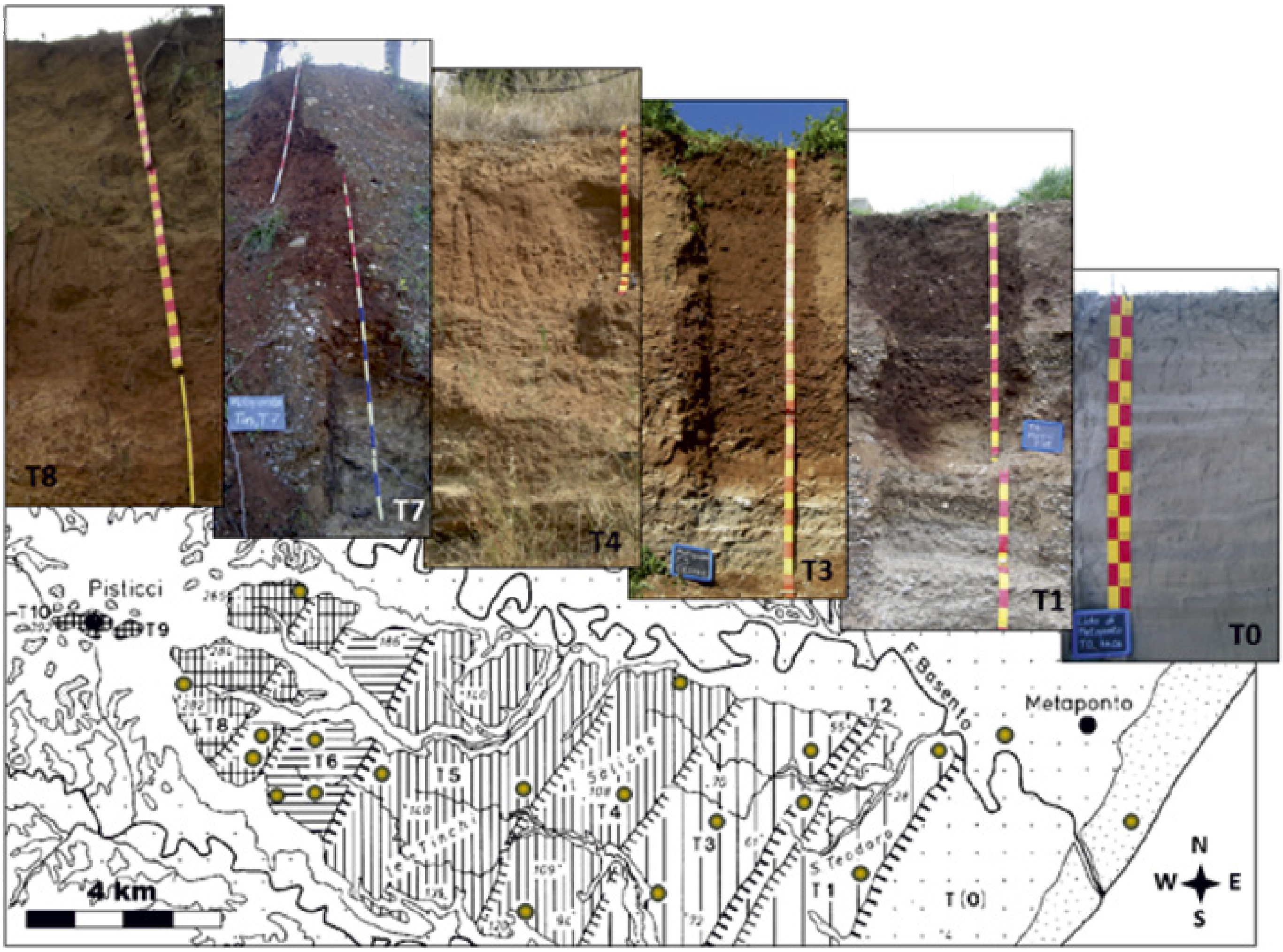

Figure 16. Profiles of soil chronosequences of terraces with different ages in the Metaponto area, Basilicata, southern Italy (after Sauer et al., 2013).

and of their 'original' suitability for prehistoric land use (see e.g. section 3.2.2., site Rb035).

Several techniques exist for relative age determination of soils on the various terraces in a sequence, one of them being a colour rating system of soils developed by Torrent (1980) on the basis of the extent of rubefaction. This redness rating, or RR, is based on the Munsell color scale hue, chroma and value of the soils.[19] This trend in redness of the soils in the marine terraces is not perfect, because the sedimentological situation differs among the different sites and terraces and the sediments forming the land surface are often younger than the respective marine terrace due to colluviation and slope processes. The fresh sediments (C-horizons) already contain very variable amounts of smectite, vermiculite, and kaolinite so that clay minerals cannot be used as age indicators.

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19 The redness of a soil is closely linked to the nature and amount of iron (hyr)oxides present. Pedogenetic iron (Fe_d) in the solum increases with prolonged weathering. When (Fe_d) is divided by the total iron (Fe_t) a ratio is obtained. The older terraces in the Metaponto study area of Sauer et al. (2010) showed increasing Fe_d/Fe_t ratios suggesting increasing terrace ages from the lower to the upper terraces. This trend has been confirmed by similar decreasing trends of the molar total element ratio of (Ca+Mg+K+Na)/Al and silt/clay ratio. The (Ca+Mg+K+Na)/Al ratio reflects progressive silicate weathering, accompanied by Ca, Mg, K and Na release and subsequent leaching, while Al is not leached. The decreasing silt/clay ratio with soil depth represents the subsequent washing of clay into the lower parts of the solum.

2.5 Soils on conglomerates

Conglomerates are mass movement, alluvial, and marine deposits composed of gravels and stones that are more or less cemented with calcite. In the field, conglomerates can be identified as rounded gravel and stones, cemented by secondary carbonates. If smaller materials such as gravel, sand and clay fill the holes between the larger boulders the conglomerate is said to be 'matrix supported'. If it is only the secondary carbonate holding the larger boulders together, the conglomerate is non-matrix supported.

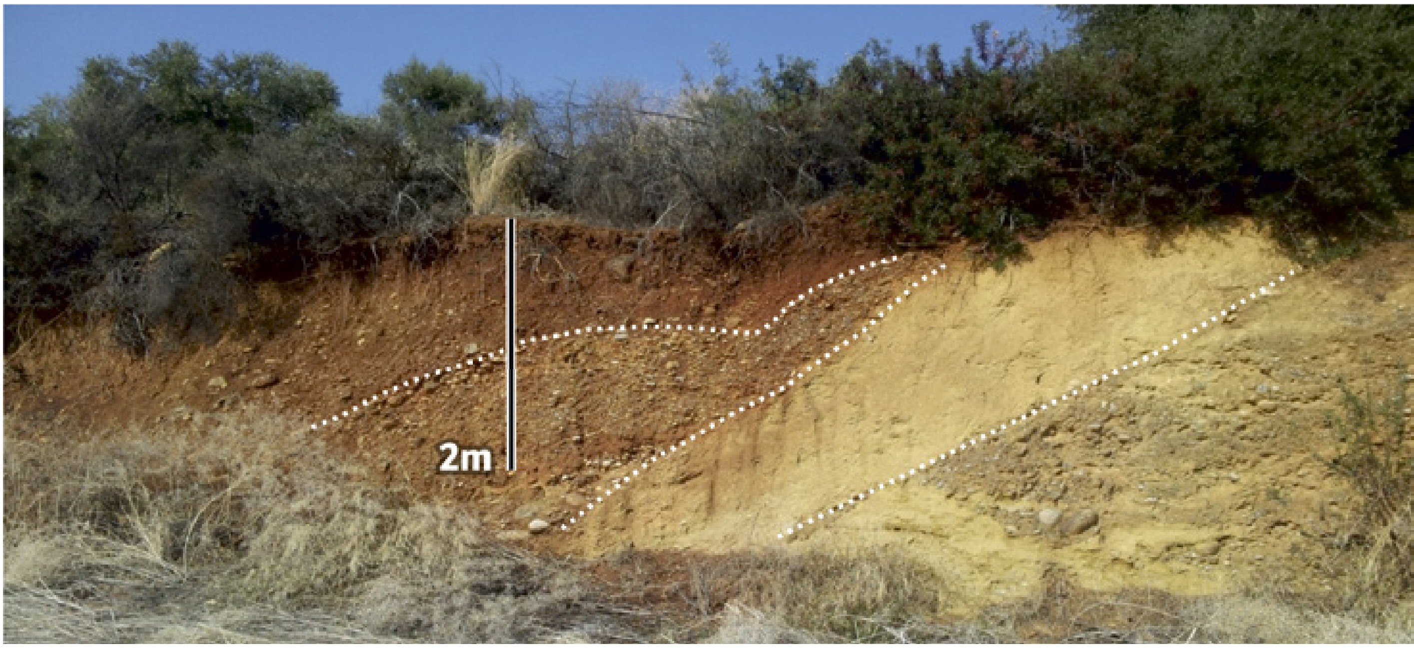

Figure 17. Paleo-incisions filled with colluviated material in the conglomerates. Soils in the later incisions (left) are highly porous and therefore intensively weathered, resulting in deep red soils. The early incisions (right) contain high amounts of silt, are less porous and are therefore yellow with shallow soils.

Presumably older, heavily indurated conglomerates are found as cap rocks of marine terraces and associated alluvial fans, whereas less indurated and presumably younger conglomerates abound in the lower terraces and associated fans. Because of the induration the conglomerates are impermeable and soil development is very limited, soils being shallow, stony, calcareous, and brownish in colour. Such horizons indurated by secondary carbonates are called 'petrocalcic' horizons or 'calcrete', and may even show secondary dissolution of carbonates ('secondary karst') features in the form of dissolution holes filled with soil material (figure 18). Palaeoincisions filled with colluvial material can be found within the conglomerates, and soils in these incisions are highly weathered, deep, and red (figure 17), providing non-smectitic and non-calcareous material that is suited for pottery.

Figure 18. Secondary karst features in the form of dissolution holes filled with soil material.

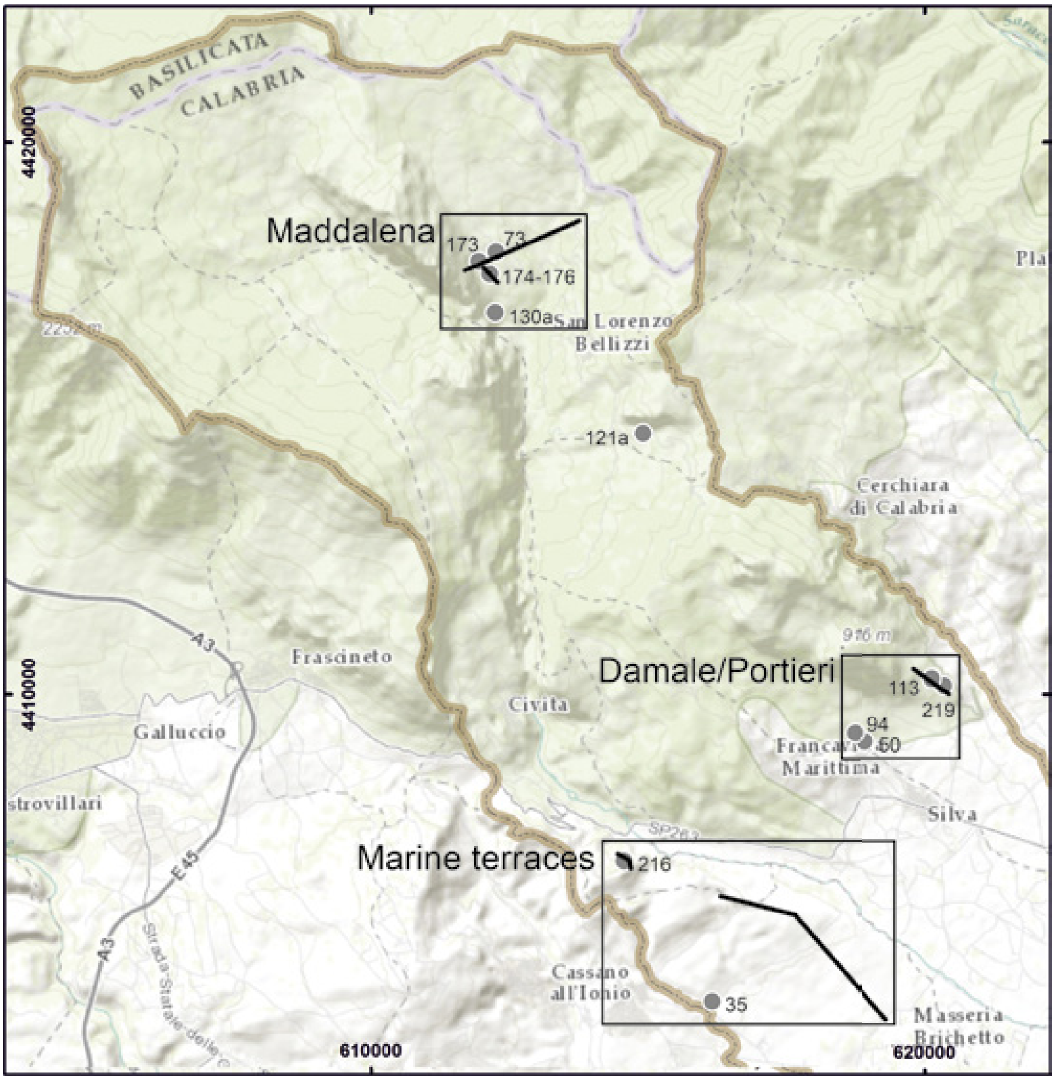

Figure 19. Locations of the sites and transects examined within the Raganello catchment. Background image: Google Maps.

3 DETAILED SOIL SURVEYS AND TRANSECTS

3.1 Introduction

During the field walking surveys in the Raganello catchment more than 150 protohistoric sites were found. These sites are typically small and usually consist of small numbers of poorly preserved finds (mostly fragments of handmade pottery). Such sites are often neglected in archaeological studies, where emphasis is put on large, complex sites or on special finds assemblages. A selection of these small rural sites was studied in closer detail. This included on and off-site non-invasive research (survey and geophysical measurements), followed by invasive research (soil coring and test pits) at selected locations. The purpose of the invasive research was to confirm the presence of archaeological features as detected by geophysical means, to understand how such features give rise to archaeological sites on the surface, and to collect soil samples for further geophysical and geochemical study.

Detailed soil studies were executed in order to gain insight – mostly at the site scale - into the variety of geomorphological and pedogenetical processes that were active at these sites, and to more reliably interpret the archaeological, geophysical and remote sensing data. For these detailed studies, which involved systematic soil observations by hand coring and, where needed, additional observations in profile pits, target areas were selected within the three main landscape zones of archaeological interest within the catchment: the marine terraces, the foothills and the uplands. Results are discussed by landscape zone, starting with the marine terraces.

3.2 Marine terraces

The marine terraces consist of coarse to fine textured sediments of varied mineralogical composition (derived from limestone, shale, sandstone, et cetera). They exhibit a clear soil chronosequence, as extensively discussed in section 2.4.2. One aspect of this is the distinct decalcification, which becomes more prominent with increasing age of the terrace concerned. In the decalcified soil, rock fragments that are more resistant to erosion accumulate residually. Where the terrace deposits are coarse textured (gravels), gravel beds directly underneath the decalcified soil have often been cemented into conglomerate by secondary carbonates, forming a petrocalcic horizon. Other aspects of the soil formation in these terraces concern the redness, development of the Bt and extent of accumulation of iron upon increasing age (see also section 1.3.1). Lastly, with increasing altitude the marine terraces are increasingly dissected and fragmented. Soils on the higher isolated terrace remnants have often been severely truncated, leaving an exposed petrocalcic at the surface, which acts as cap rock and protects the land surface against further erosion.

The lower marine terraces, where not seriously dissected, which is the case particularly to the west of the Raganello river, are truly stable land surfaces that in their surficial layers may hold a very ancient archaeological archive. Thus, Mid-Pleistocene non-eroded terrace soils might in theory hold artefacts ranging in age from the Mid-Pleistocene (Palaeolithic) till recent. Field walking has shown that such soils indeed hold early flint artefacts, but it was not clear whether these were in situ or more or less reworked.

To characterise the soils of the relatively well-preserved marine terraces, a long transect was studied through the terraces to the west of the Raganello river (T4 to T8 as described by Santoro et al., 2009). More detailed studies of specific sites were conducted on a well-preserved middle terrace (distal part of T4) around site Rb035, and at a higher, isolated and dissected terrace remnant (T7) around site Rb216. For the locations of these sites, see figure 19.

3.2.1 Transect along several stages of the marine terraces

The transect studied and its soils are illustrated in figure 21. Soil profiles (figure 22, phases T4 and T6) are consistent with previous studies (Heilmann, 1972; Torrent et al., 1980; Scarciglia et al., 2006; Sauer et al., 2010), and are classified as Luvisols with chromic and calcic properties. They consist of an Ap horizon and an underlying Bt horizon. When of sufficient thickness (at least 7.5 cm, but for details reference is made to IUSS, 2006) this clayey horizon is classified as an argic horizon and the soil is classified as Chromic Luvisol. With a lesser thickness of the clayey horizon the soil is classified as a Cambisol with luvic properties. In relatively flat areas, even an E horizon may occur (T4), formed as a result of prolonged clay translocation and residual accumulation of resistant, quartz-rich sand and gravel. The Bt is often divided into several subhorizons (Bt1, Bt2, Bt3) based on differences in texture as a result of clay illuviation and on the extent of shrinking and swelling of the soil. As discussed in section 1.3.2 the latter was indeed observed to be more prominent in the younger terraces.

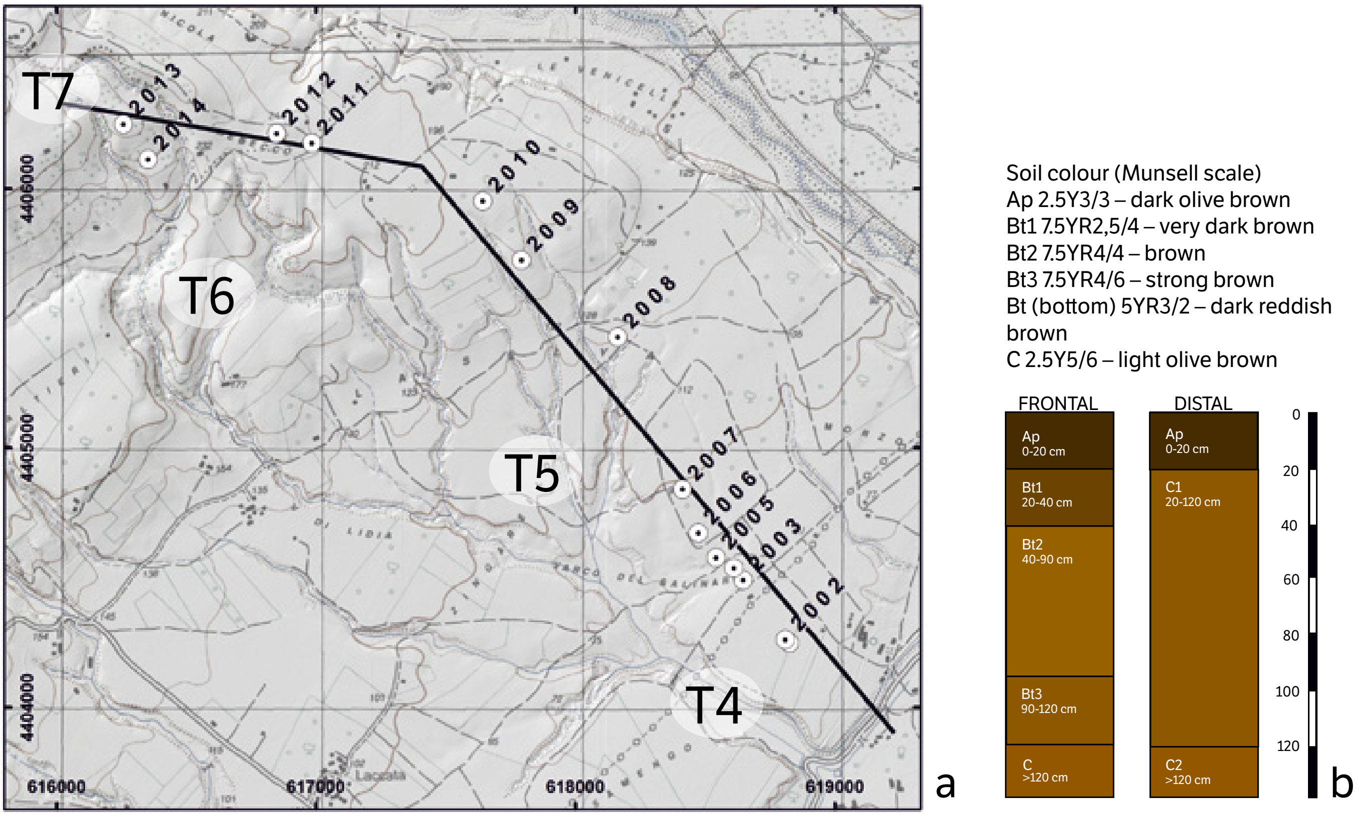

Figure 20. a: Locations of corings and longitudinal transect across the marine terraces, labeled from old (T7) to young (T4) as in Santoro et al. 2009. b: typical soil profiles for the frontal and distal parts of the marine terraces.

The terrace scarps, which form the boundary between the terrace levels and in fact may be fault scarps (see for example Santoro et al., 2009), have steep slopes. These slopes have a thick layer of colluvium overlying the upper part of the underlying terrace and its soil, as can be seen in the cross section at site Rb035 (figure 26). Soils of these upper terrace sections show no colour differentiation between the colluvial material and the in situ soil in the marine terrace. The soils on the more silty deposits are yellow: 2,5Y 6/6 to 6/8 on the Munsell scale.

Soils in the frontal part of the terraces are hardly affected by colluviation and where on relatively flat slopes are largely in situ. These frontal parts mostly consist of topsets of the deltaic fans that constitute the original marine terrace, and are therefore relatively coarse textured (figure 13b). This limited erosion and truncation has resulted in the formation of Bt horizons that exhibit a clear differentiation into different subhorizons (Bt1, Bt2, etc.; figure 20a). The presence of a well-developed Bt horizon leads to a classification of these terrace soils as Chromic Luvisols.

Soils of the distal terrace section (e.g. T5 in figure 20) have been subjected to multiple phases of colluviation. This has resulted in the mixing of several stages of soil formation/horizons, making individual phases very hard to distinguish in the field (figure 20b). The colluvium is clayey but due to the limited age of the deposits pedological features are not yet fully developed and therefore these horizons are classified as C material; hence their characterisation as 1C (parent material lacking distinct soil features). The prefix 1 in front of the C indicates the colluvial (non-marine) origin of the material. The lack of soil formation within these soils leads to their classification as Fluvisols, but in older profiles clay illuviation may become visible leading to a classification as Luvic Cambisols. Figure 21 shows the cross section of the transect with the elevation of the terraces, the general trend in soil formation with increasing age, and the typical frontal and distal situations within marine terraces.

In summary, soils of the marine terraces studied are red (7,5 to 10 YR 3/4) and their argic horizon (Bt) becomes thicker, more clayey and redder with increasing age/altitude (Heilmann, 1972; Torrent et al., 1980). Soil depth is least on the highest terraces as a result of truncation and erosion, until only the cemented conglomerate caprock remains.

3.2.2 Site 35 Vallone Franceschiello

Site Rb035 lies at the top of marine terrace T4, below the scarp of the next higher terrace T5, and is protected against serious erosion by the colluvial cover originating from the latter. It adjoins the Vallone Franceschiello, which permanently carries water at this location (figure 22a), and has thus most probably been one of the more attractive areas for habitation over a prolonged period. The RAP surveys initially found material from the Archaic and Hellenistic periods in this field but, in a special-purpose

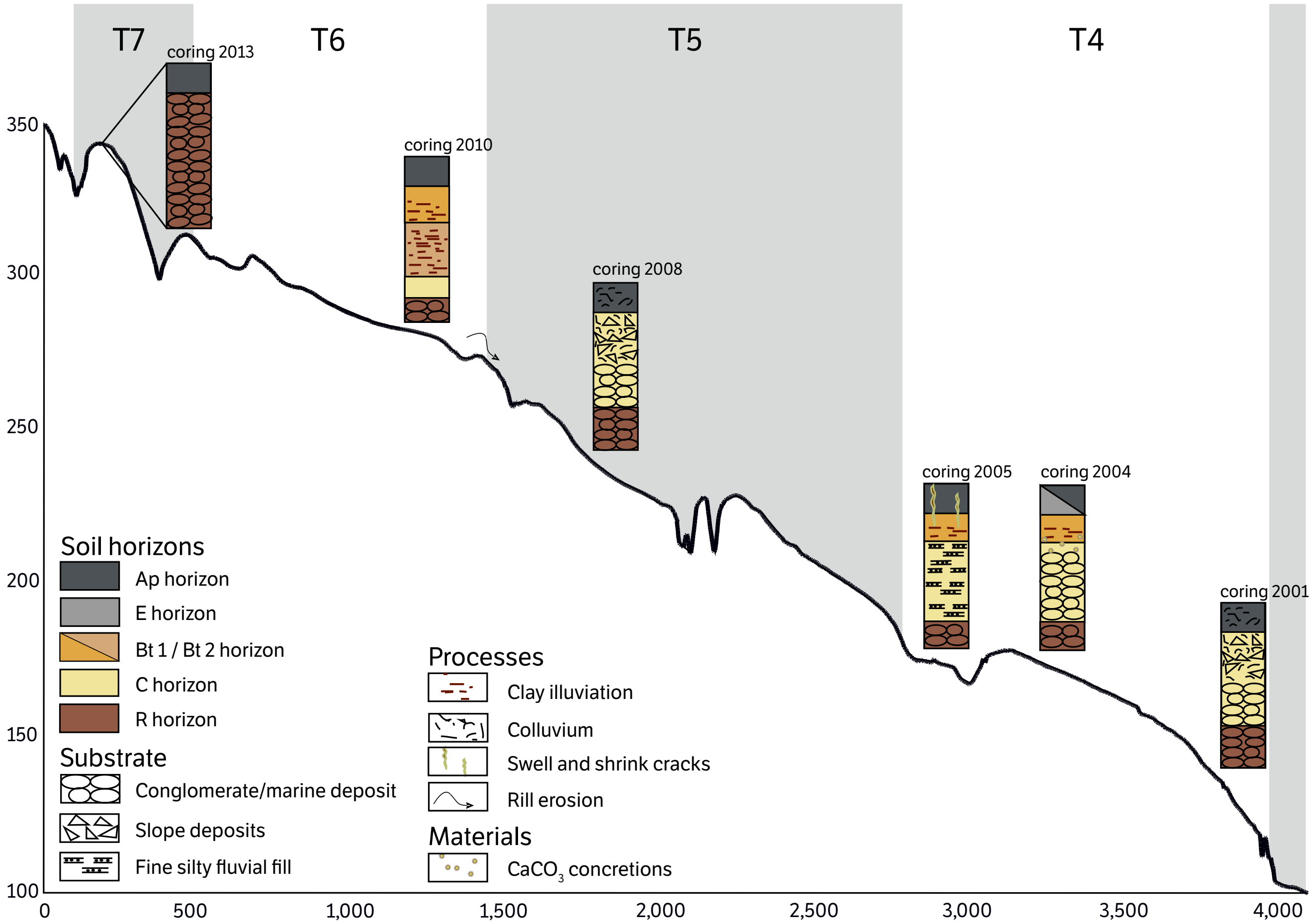

Figure 21. Transect crossing the several marine terrace stages in NW-SE direction. The terrace numbers are according to Santoro et al., 2009. For coring descriptions, see Appendix IV.

survey conducted in 2014, also lithic tools and flakes dating from the Middle Palaeolithic to the Neolithic (Van Leusen et al., in prep.). The goals of the pedological study were to establish the soil pattern in this field in the detail required for adequate interpretation of the remote sensing studies, and to better understand the provenance of the various anthropogenic materials and the potential 'subsurface reservoir' function of the soil.

In the area of interest, a thick Chromic Luvisol occurs with a clear E horizon over a fairly large area. This E horizon can easily be observed at the surface of the lower footslope (figure 22b and c), and can be described as a bleached coarse sandy horizon that is high in quartz. Figure 23 shows the cross section along the slope. Manual coring was limited to a depth of 60 to 80 centimetres due to the stoniness of all profiles. It was therefore not possible to identify the potential upslope continuation of the E-horizon and corresponding Luvisol underneath the colluvial cover towards the terrace scarp. Hence this soil is presented in figure 23 as a lenticular horizon. Evidence-supported conclusions on the distribution of the buried soil would require that deep profile pits are dug in the contact zone between the colluvium and buried Luvisol (here in fact being a palaeosol).

CONCLUSIONS

Soils in the marine terrace, if not truncated, consist of an 'impoverished' or 'bleached' topsoil that lacks the typical reddish colour of the argic horizon due to the absence of iron-clay complexes, and has a whitish to greyish colour and low clay content, over a very clayey argic Bt horizon with prominent reddish colours. A horizons in such soils are poorly developed in terms of organic matter content and thickness because of the rapid decomposition of organic matter in Mediterranean type climates (see 1.3.1), implying that the bleached colour of the impoverished topsoil is hardly masked by dark organic matter. Upon ploughing or other types of soil labour that enhance organic matter decomposition and reduce litter input, the little organic matter in the topsoil is rapidly mineralized and the A horizon is transformed into an E horizon. The absence of a dark A horizon in such soils therefore does not necessarily imply that the topsoil has been eroded. The lower part of site Rb035 exhibits such a partially intact E horizon, from whose presence it can be deduced that the soil has not been subjected to serious erosion, either because of its topographic position which prevented significant run-off and associated overland flow, or because of the balance between accumulation of colluvium originating from the overlying slope and its further downslope transport through overland flow.

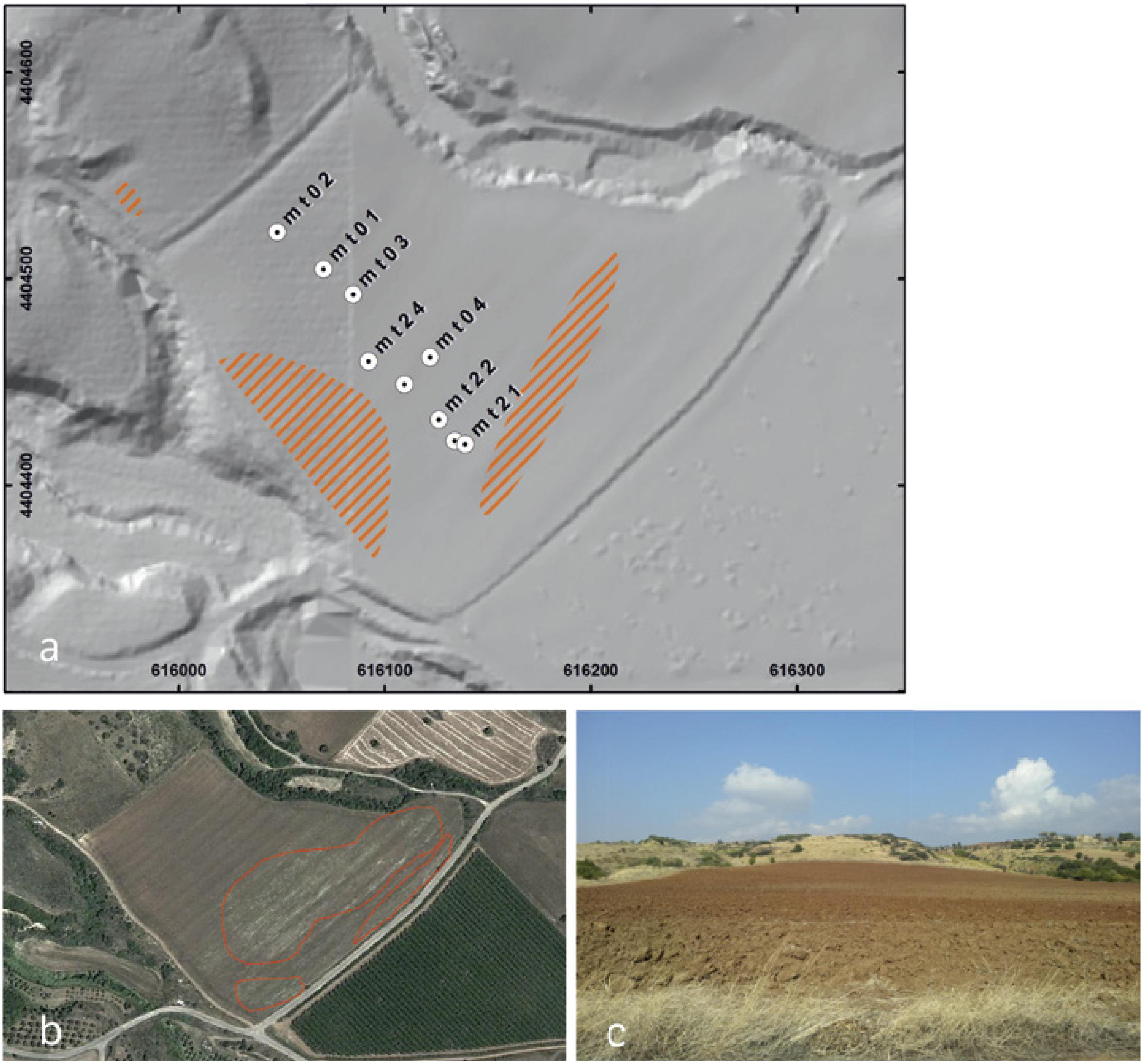

Figure 22. a: Target area of site Rb035 with the locations of the corings and RAP surface scatters. b, c: In the aerial photo (source: Google Earth) and in frontal view the presence of the E horizon in the topsoil is clearly visible. For core descriptions, see Appendix IV.

The current albic horizon (bleached E horizon) in places reaches a thickness of about 1 m, demonstrating that under continued presence of a protective natural vegetation, and with prolonged leaching, a thick E horizon developed. This E horizon testifies to the prolonged stability of the associated land surface and thus to relatively high chances for accumulation of artefacts. Evidently, stratification in such horizons will be minimal if not completely absent, because of processes such as bioturbation. With the introduction of mechanical ploughing erosion intensified, and with it colluviation. This probably resulted in the removal of the easily eroded E horizon in the upper, steeper parts of the slope, but not (yet) in the serious truncation of this E horizon on the lower, more level part. Here, its major impact seems to be the transformation of A into E material. Some erosion, however, may have occurred causing the lateral transport of fines by incidental overland flow and the residual accumulation of coarser soil fragments including artefacts, a process that characterizes such soils and has been described as 'impoverishment' (Duchaufour, 1982). The colluvium partially covered the downslope parts of the terrace, burying the original terrace soil (see also figure 23).

The results of the lithics surveys that were performed on the plot are in line with the observed pattern in soil erosion: where the E horizon is at the surface, a concentration of finds is present. Where the colluvium covers the palaeo E horizon, finds of lithic artefacts at the surface are limited,

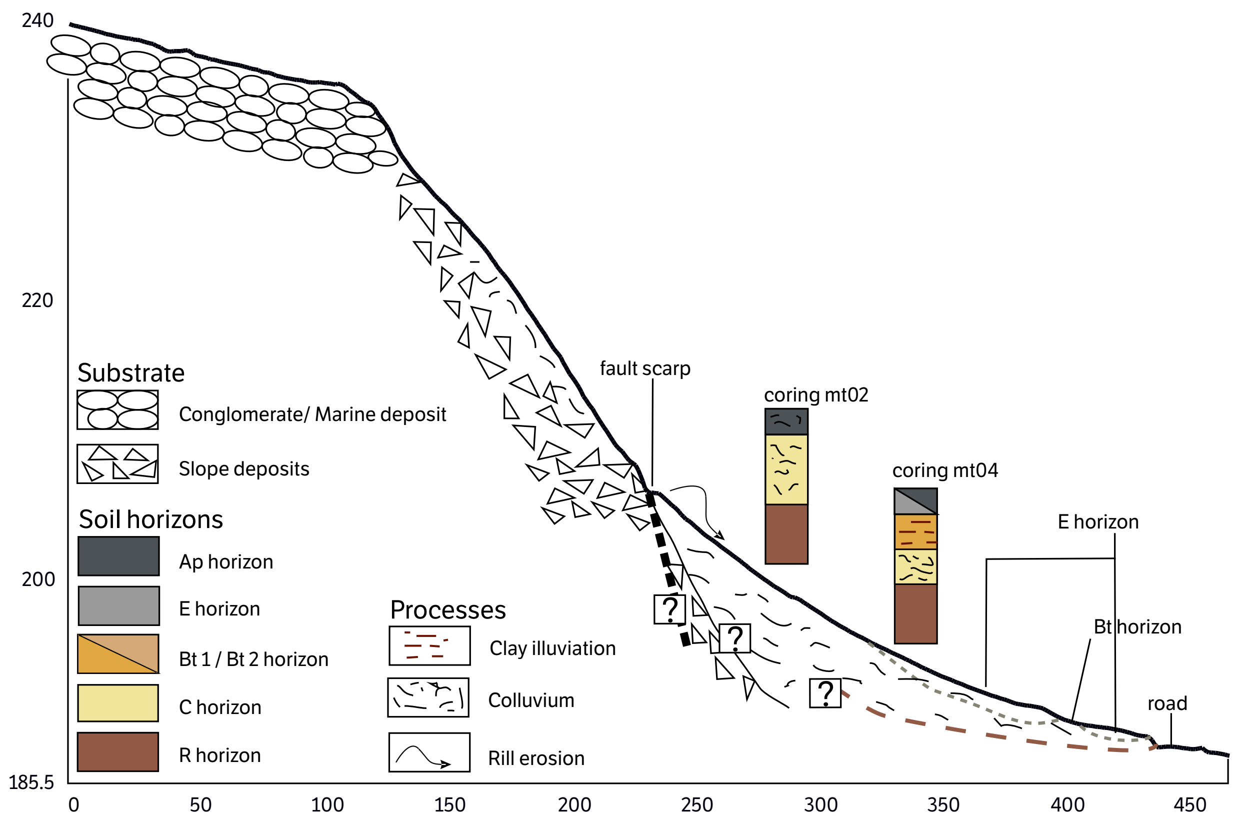

Figure 23. Longitudinal cross section of the marine terraces at site Rb035.

but nevertheless such materials might be present in the subsoil and can be brought to the surface by ploughing. The Luvisol, which locally is buried under colluvium (and in that case in fact is a palaeosol), and in particular its E horizon, thus is of great archaeological importance because of the high chance of holding archaeological remains. The results of the soil survey show that important reservoirs containing archaeological materials, which however lack stratification, are to be expected and are indeed found on the large marine terraces with (partially) intact E horizons.

3.2.3 Monte San Nicola north lobe

In earlier geophysical studies (Eastern Atlas, 2011) some circular positive magnetometer anomalies were observed on the Monte San Nicola. The north lobe of this hill was known to have been seriously eroded recently, but to still exhibit scatters of protohistoric ceramic materials. A soil survey of the north lobe was conducted to assess both the extent of erosion and the general characteristics of the soils on these earliest marine terraces. Its further aims were to support the interpretation of the results of the geophysical and archaeological surveys.

Monte San Nicola is the last remnant of one of the oldest (~600 ka) identifiable marine terraces within the Raganello catchment. It largely consists of a conglomerate caprock protecting underlying marly sediment and has a thin, discontinuous cover of marly sediment. The marl is composed of more or less silty and clayey deposits, into which palaeovalleys were cut that were refilled at a later time by similar silty deposits. These palaeovalleys have well-developed red soils and calcium carbonate concretions in the contact zone between the marly substrate and the palaeovalley fill. An example of this phenomenon is visible in a road cut (figure 24a).

Soils on the Monte San Nicola have an A horizon that has been ploughed (Ap: p = ploughing) and commonly is about 40 cm thick. Soils in the cemented conglomerate caprock are shallow (< 25 cm depth) and generally classified as Leptosols, but incidental deeper, marly soils may occur as can be seen in the cross section of figure 25. Soil profiles on the marl are deeper and underneath the Ap often have a Bt horizon. Where well developed this Bt horizon can be differentiated into subhorizons, which differ with respect to the extent of clay illuviation and associated clay content. However, there is no difference in colour between the

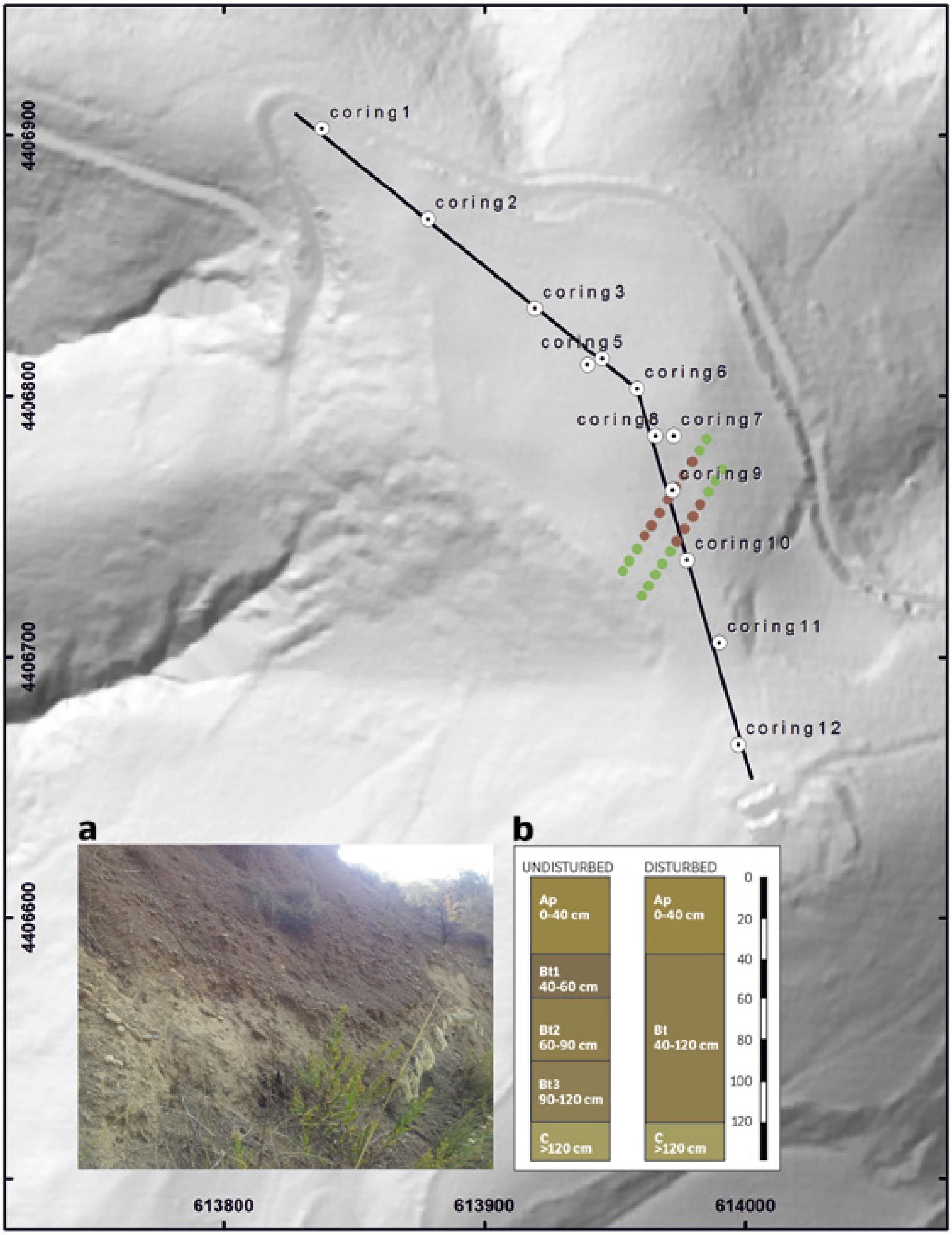

Figure 24. Target area of Monte San Nicola with the locations of the corings and transect. White arrow indicates relief transition zone caused by outcropping cemented layer. Black arrow indicates location of section shown in inset a: deeply weathered red soil with calcium carbonate concretions in the contact zone between the filled paleo-incision and the silty marl. Brown and green dots indicate the locations of, respectively, undisturbed and disturbed soil profiles as shown in inset b (colours of Bt horizons here only represent a difference in texture).

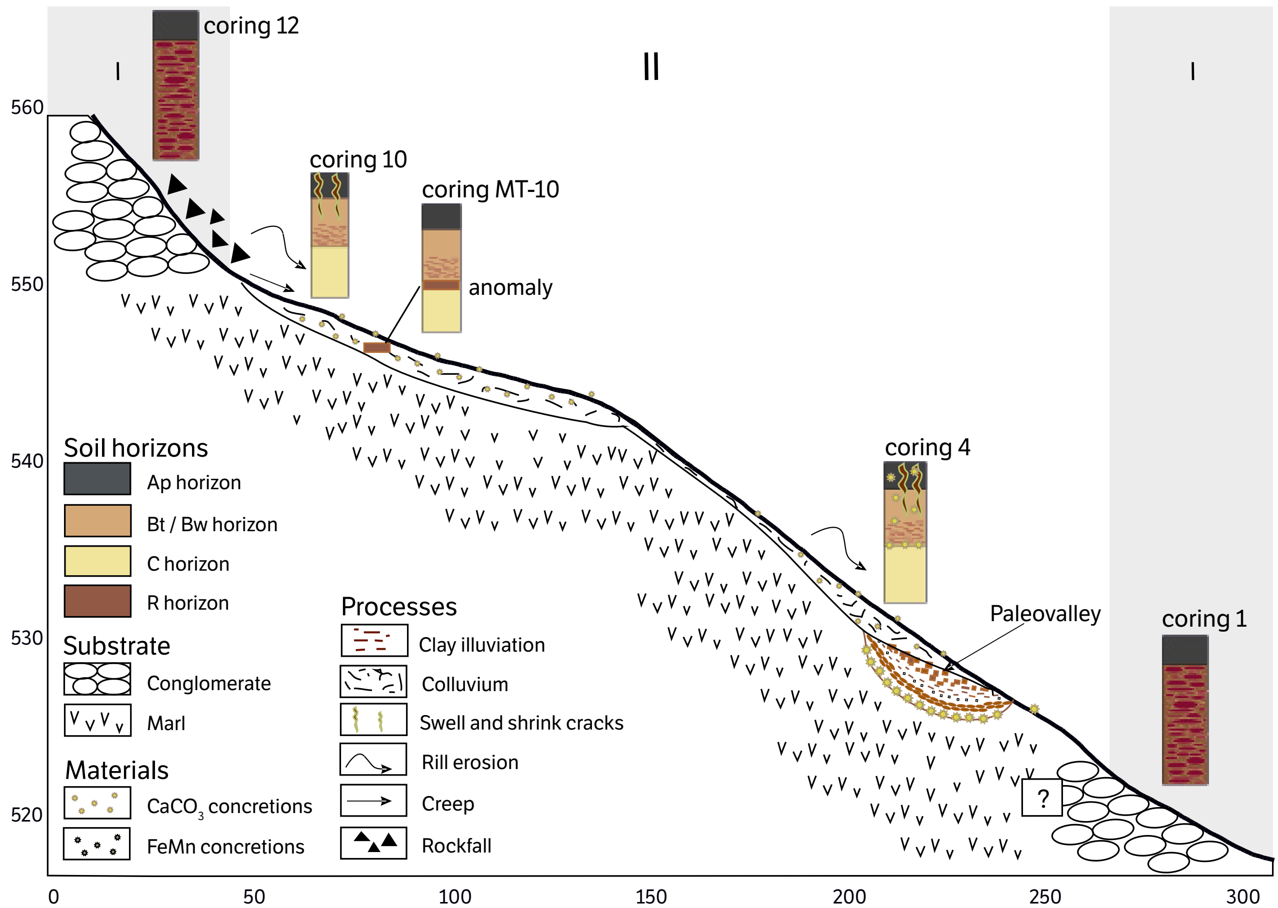

Figure 25. Longitudinal cross section of the Monte San Nicola north lobe, showing the underlying geology, morphological processes and spatial distribution of soils classified according to the IUSS-WRB (2006). For core descriptions, see Appendix IV.

different Bt horizons. Where clay illuviation is insufficient for the classification of a B horizon as a Bt horizon (e.g. no or few clay cutans) the suffix 'w' is used (Bw horizon, see appendix I). The marly soils exhibit cracks when dry, which can be ascribed to the smectitic nature of the clay in these soils, which overall have a texture of clay loam to clay, and the resulting relatively prominent swell and shrink upon wetting and drying. In other words, soils in marl, if well developed, tend to be vertic and exhibit clear cracks when dry. Calcium carbonate concretions have been found in all soil profiles on the marl. In the undisturbed soil profiles concretions occur at the contact zone between the Bt and the C horizon, where they form a nodular band preventing further coring.

Some deeper marl soils in the area studied show signs of disturbance in the form of an 'abnormal' pattern in texture (i.e. loamy over clayey, or irregular mix of materials with variable texture), as well as the occurrence of calcium carbonate concretions throughout the soil. This disturbance can be anthropogenic (digging) or have a 'natural' origin (colluviation). In both types of disturbed soil profiles, carbonate concretions are present throughout the soil profile, since colluviation causes concretions originating from eroded upslope soils to be present throughout the colluvial soil. Secondary transport of the concretions in colluvial soils occurs when concretions from upper horizons fall into cracks formed by the swelling and shrinking of the smectitic clays, which process characterizes the marly substrate. In some corings, at or near the conglomerate substrate, iron mottling was observed in the contact zone between the Bt and the C horizon. This is related to water stagnation on the impermeable conglomerate bedrock. Both undisturbed and disturbed soil profiles in the marl soils with a Bt horizon are classified as Calcic Luvisols.

Further down the slope of the north lobe, up to where the present road marks the boundary of the research area, the cemented conglomerates are again very close to the surface, thus resulting in shallow soils classified as Leptosols. The location of this transition can be seen in figure 24 as a step change in the 1m resolution greyscale hillshaded terrain model, situated east of the previously described palaeovalley, in between the last two corings of the longitudinal transect.

In one of the corings (MT-10; see Appendix IV) a decimetre thick red coloured dense clayey layer was identified on top of the C-horizon in marl. The overlying soil horizons (Bt horizons) exhibited a change in texture with depth that conforms to the normal pedogenetic trend (more clayey in the top, less clayey below), indicating that the red clay consists of in situ soil material. The nature of the red soil material is uncertain, but it could find its origin in the red soils of the conglomerates nearby. Technical difficulties with the GPS establishment of its coordinates hampered an accurate correlation of the coring and geophysics datasets.

CONCLUSIONS

The Monte San Nicola is a very complex marine terrace exhibiting several phases of gully development and their refilling, as can be expected considering the age of the terrace. Its top level is underlain by a thick petrocalcic horizon, which protects the marly soils that cover these conglomerates against serious erosion. When still covered by vegetation, erosion of the silty soil by overland flow was very limited and soils with an argic B horizon are therefore preserved. Severe surface erosion started with the introduction of mechanical ploughing; whilst precise estimates of volumes of soil loss cannot be given, the thicknesses of soil removed will be in the range of a metre or so.

Identifiable geomagnetic anomalies on the Monte San Nicola north lobe can be divided into i) anthropogenic cut features and ii) shallow cemented conglomerate bedrock. In the lower parts of the north lobe the positioning of the anomaly corresponds with an outcrop of the cemented conglomerate bedrock, making this interpretation the most likely.

3.2.4 General remarks

Soils of the marine terraces are marked by the occurrence of a distinct Bt horizon of which the redness and thickness increases with increasing age of the terrace concerned. However, surfaces of the terraces have generally been eroded to such an extent that the original topsoil and its associated archaeological materials have disappeared. Thus archaeological materials, if found at all at the surface or in the colluvial topsoil, are either not in situ or originate from pits and trenches that were cut into these soils. This erosion is most prominent on the old, high terraces where soils are mostly completely truncated and remains of the Bt horizon are only encountered on level surfaces and residual hills.
On the large, more recent marine terraces, such as at site Rb035, soils with Bt horizon are common. In places, E horizons are encountered that represent remains of the original terrace surface, and only these may hold in situ early archaeological material. Such intact soils were encountered at site Rb035 and probably are limited to those relatively flat upper terrace sections that are more or less protected against erosion (i.e. not seriously dissected) and may also have been preserved by the accumulation of colluvial material from the slope above. Given the age of the original E horizon archaeological materials as old as Palaeolithic may be found here.

3.3 Foothill USL

From earlier observations made during the RAP surveys it was already clear that the geology and soils of the foothills are complex, and that the patterns are further complicated by anthropogenic impacts. The latter resulted in an intricate pattern of erosion and accumulation, often in the form of terrace complexes. These intricate patterns of soil and subsoil characteristics, as well as of the conservation of earlier land surfaces as dependent on erosion and burial, evidently affect the occurrence and distribution pattern of archaeological features and materials, as well as the interpretation of geophysical and spectral reflectance datasets. To improve the understanding of patterns observed and processes involved, two characteristic foothill areas were studied in detail: the Contrada Damale and the Portieri areas (figure 19). Particular attention was paid to the occurrence and distribution of colluvia and to the nature of the terraces that abound in these areas. With regard to the latter, the main research questions were whether original land surfaces (with potentially associated archaeological material) were conserved through their burial by colluvial material derived from the slope above, and what was the origin and age of these terraces (e.g. dating back to early agriculture or resulting from recent plough erosion).

The two areas studied differ with respect to their geology and drainage. In the Contrada Damale impermeable rocks (marl/shale) are common, leading to relatively poorly drained soils where in places carbonate-charged groundwater is close to the surface and caused widespread secondary carbonate accumulation. In the Portieri area steeper slopes, in combination with the presence of coarse-textured marine terrace deposits, lead to a much better external and internal drainage. Here accumulation of secondary carbonate is far less developed and petrocalcic horizons are absent. The Portieri area also includes a rare example of a morphological saddle, occupied in protohistory, with the attendant complex earth surface processes.

3.3.1 Contrada Damale

This area represents a typical foothill situation with varied geology and soils, and is marked by many terraces and abundant archaeological sites. Information on the soil pattern and lithology was gathered by a combination of survey, corings, and profile pits. The results are presented in a soil map of part of the area (figure 26) and in a longitudinal transect (figure 27) showing morphology, underlying substrate and the spatial distribution of soils along the transect.

The Contrada Damale has a varied substrate, which ranges from alternating bands of marl and shale with occasional quartzitic sandstone beds to cemented alluvial fan deposits (petrocalcic). The area is characterized by seepage of stagnating groundwater, which partly exudes in the form of springs found at several locations in the area of study. Water stagnates at the contact zone between the alternating bands of rather permeable shale and impermeable marl, and probably originates from the alluvial fan deposits that act as an aquifer. Seepage is particularly prominent after heavy rainfall and has induced local farmers to dig ditches and construct drains; it is commonly associated with accumulation of secondary carbonates in the form of soft powdery lime and locally even travertine-like beds. Marl and shale are rarely exposed, while the quartzitic sandstone is locally found in large, angular blocks and boulders, which are hard and resistant against weathering. All soils have a colluvial topsoil of varying thickness. This colluvium consists of dark, relatively humic material of very mixed composition, i.e. derived from shale and marl as well as from alluvial fan deposits, and formed by a combination of slope wash and ploughing. The alluvial fan deposits consist of more or less indurated gravels, with prominent secondary carbonates in the form of concretions and nodules.

In places where soil is continuously eroded (particularly through plough erosion) and bedrock is close to the surface, soil depth is limited (+/- 25 cm), thus classifying these soils as Leptosols. This is most evident in the north-west corner of the study area (figure 26, profile 5), where a remnant of a cemented old debris cone, consisting of limestone blocks, is overlain by a 20 cm thick ploughed A horizon (Ap). The common terraces have deep humic colluvial soils that exhibit only weak soil formation. In places, this colluvium overlies the remains of a Bt horizon that forms part of the original soil. Most other soils (profiles 1-4) have a more or less distinct and truncated Bt horizon (clay illuviation), which is least distinct in the alluvial fans where most of the soil has been eroded and only the deeper parts of the Bt horizon are retained with common calcium carbonate concretions. In the marls, the Bt horizon often has vertic properties and soft powdery lime (figure 7), but soils are mostly eroded and consist of a dark Ap horizon over weathered rock. The presence of a darker Ap horizon is characteristic for the marl and is due to the abundance of fine powdery lime (see section 1.3.1). In the alluvial fans, shale, cemented limestone debris, and quartzitic sandstone, the Ap is less darkly coloured due to the absence or lesser content of finely divided lime. Where

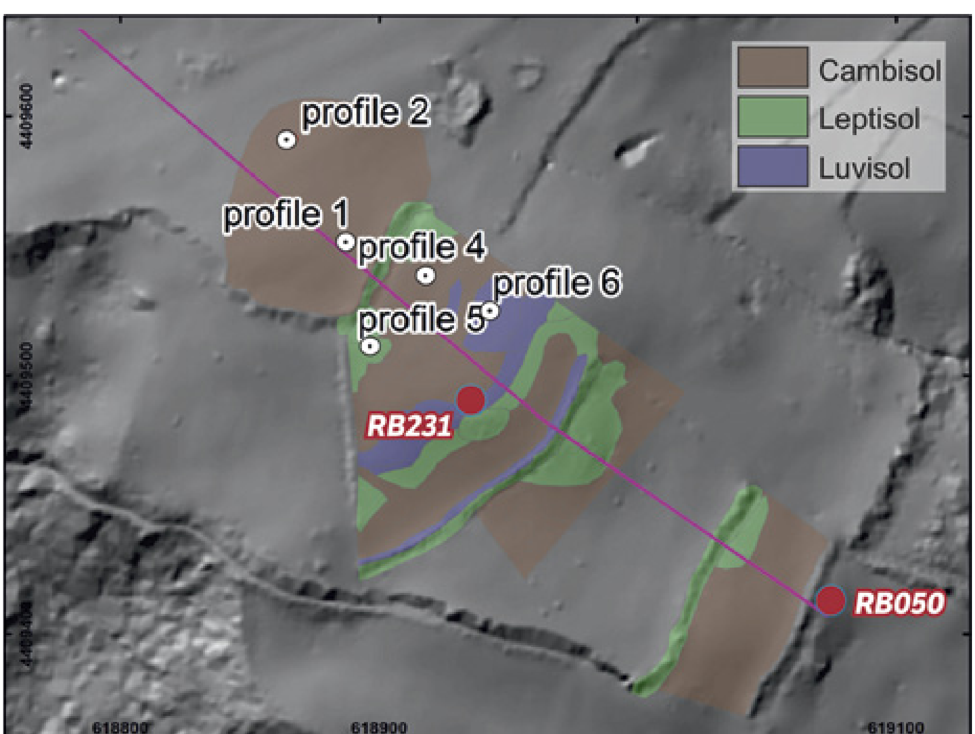

Figure 26. Soil map of the fields overlying site Rb050 in the Contrada Damale area, with line of longitudinal cross section shown in figure 27. For core descriptions, see Appendix IV.

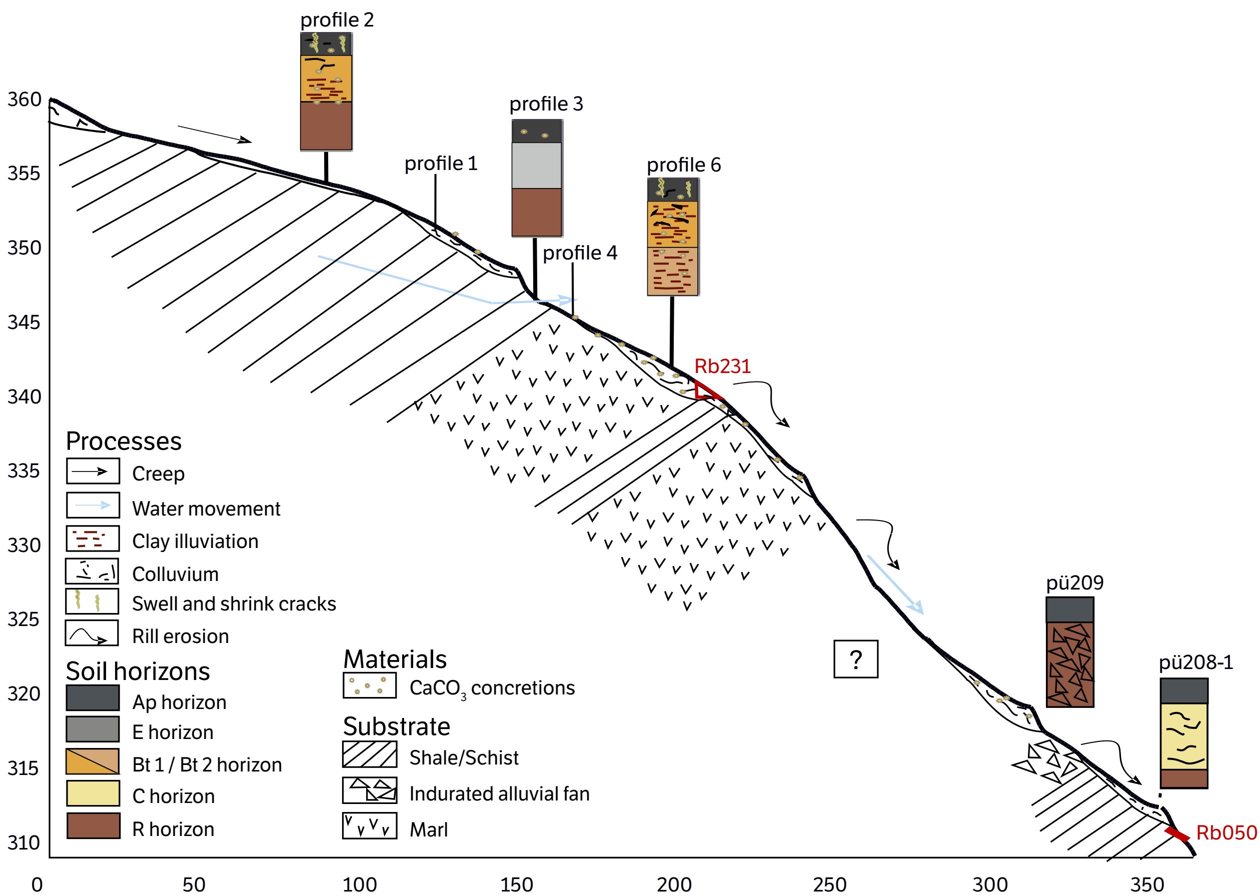

Figure 27. Longitudinal cross section of fields overlying site Rb050, showing the geology, morphological processes, and spatial distribution of soils. For core descriptions, see Appendix IV.

the Bt horizon is of sufficient thickness the soil has an argic horizon and is therefore classified as Luvisol; where the clay illuviation is less prominent (e.g. due to erosion) the soil is classified as Cambisol. Luvisols are found where the slope is protected against erosion by more resistant bedrock or by terracing, the latter resulting in deposition of slope material that covers deeply weathered soils with thick Bt horizon(s). Clay illuviation is most prominent in profile 6 (figure 27), being even strong enough for the development of a truly clayey Bt2, which exhibits slickensides starting at 60 cm. Whether in shale or fan deposits, in situ soils had a solum in the order of 1 m or more as evidenced by rare relicts of such deep soils.

All soils studied have calcic properties. On shale and marl, soft powdery lime and small concretions and nodules prevail in the contact zone with the impermeable bedrock, while the alluvial fans have large concretions. All topsoils hold smaller or larger amounts of these concretions and nodules, testifying to their colluvial origin. Within the area studied, shallow groundwater is most prominent in the north-east corner (figure 26). The humid seepage zones are marked by grey soils with a gritty structure and common soft powdery lime, in places resembling travertine-like carbonate accumulations.[20] Here, the currently well-drained soil in its lower in situ (non-colluvial) horizons shows features connected with prolonged water logging (strong secondary carbonate accumulation and prominent gley mottling) indicating the former presence of a spring. This might explain the positioning of archaeological sites nearby.

Site Rb050 within the Contrada Damale was studied in more detail. This site became of interest because in previous studies a dark, presumably anthropogenic, layer containing archaeological materials was identified directly underneath a terrace revetment wall (van Leusen and Attema, 2006; Feiken, 2014). Therefore the question arose if this dark layer might continue in the field above the terrace, though the dark layer was not present in a profile pit dug into the terrace (de Neef and van Leusen, in prep.). At the top of the field above this agricultural terrace, loosened rock fragments derived from indurated conglomerates (largely limestone gravel and stones) with secondary lime accumulation in the form of calcite crusts occur at the

20 These soil properties have also been observed around the nearby Fonte Cicciocarlo, for example at site Rb095.

surface, indicating the presence of an indurated alluvial fan right below the plough layer. Further down, along the entire length of the slope, soils occur that consist of a colluvial topsoil overlying weathered phyllite. The thickness of the colluvial layer is limited to 40-50 cm. The solum at the base of the terrace consists of several successive colluvial layers, identified by textural differences; no statements can be made concerning the age of these phases. Because of the absence of the dark non-sorted anthropogenic layer in the field above the terrace, it is likely that the archaeological materials are to be linked to a local flat surface cut into the bedrock in order to construct a habitation.

CONCLUSIONS

The Contrada Damale exhibits an intricate pattern of alluvial fan deposits (indurated gravels) overlying shales and marls, giving rise to local lime accumulation (soft powdery lime) and even travertine-like deposits, and associated local springs and wet zones. The depth of the solum of most soils in the upper part of the fields in this area is limited to several decimetres – the modern plough depth. In situ soils had a solum in the order of 1 m or more whether in shale or fan deposits (see sections 2.3 and 2.4), implying that up to 1 metre of soil material has been removed in the upper parts of the fields as a result of farming and ploughing. This is based on the assumption that, prior to the introduction of modern agriculture, in situ soils prevailed: under natural conditions, with natural vegetation, significant truncation of in situ soils can be excluded. Our observations thus indicate that soils in both the upper and central part of the fields have been severely truncated, while in the lower parts soil material has partially accumulated in the form of agricultural terraces, possibly protecting the original, in situ soil. Whilst mechanical ploughing seriously enhanced erosion, it is not yet clear to what extent pre-modern plough erosion has affected the soils and contributed to terrace formation. Historical information is needed to answer this question.

In places within the Contrada Damale the original terrace structure is well preserved, and here the 'terrace soil' itself might contain archaeological materials, although not in situ. When breached, which is an increasing phenomenon probably linked to the intention of farmers to increase the size of their fields, all soil material including possible archaeology contained in it goes in transport and is lost from the original site.

3.3.2 Portieri di Cerchiara

The Portieri area has a similarly complex geological pattern to that of the Contrada Damale, as shown by the transect studied. Additional aspects that were relevant for its further study and that distinguish it from the Contrada Damale include the occurrence of a marine terrace, its location next to the Caldana valley, and the presence of a morphological saddle. Because of the closer proximity of the limestone massive (Serra del Gufo) and the drainage of the aquifer contained in this limestone towards the east (the Caldana valley) where it surfaces at much lower altitude, the area is better drained, has a steeper morphology and more abundant limestone debris from the overlying slope, the latter partially protecting the shales against erosion.

The transect presented in figure 29 reflects the morphology, soils and underlying substrate of the area. It runs from the marl substrate intercalated with shale bands (II) west of site Rb113, to the colluvial basin (III). The colluvium

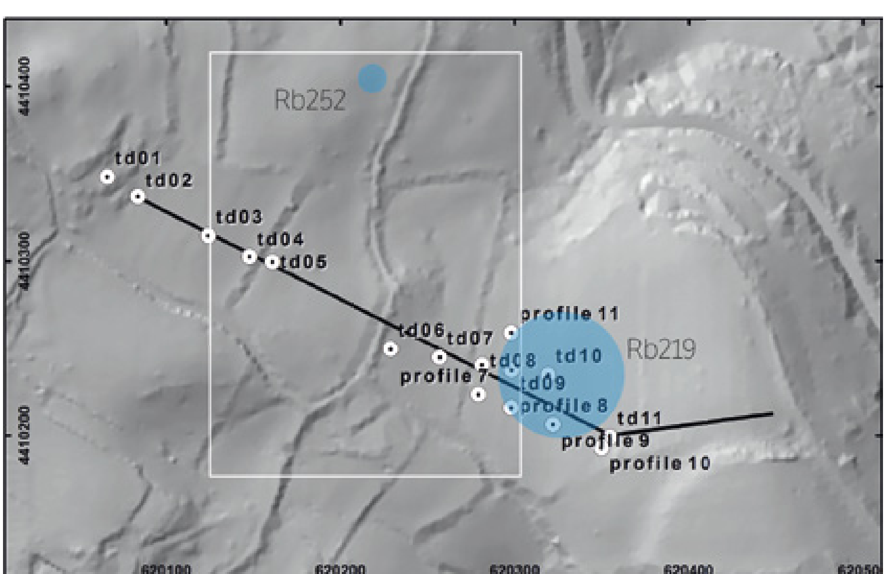

Figure 28. Target area of Portieri di Cerchiara, with the locations of corings, profile pits and transect. Area of fig. 30 outlined in white.

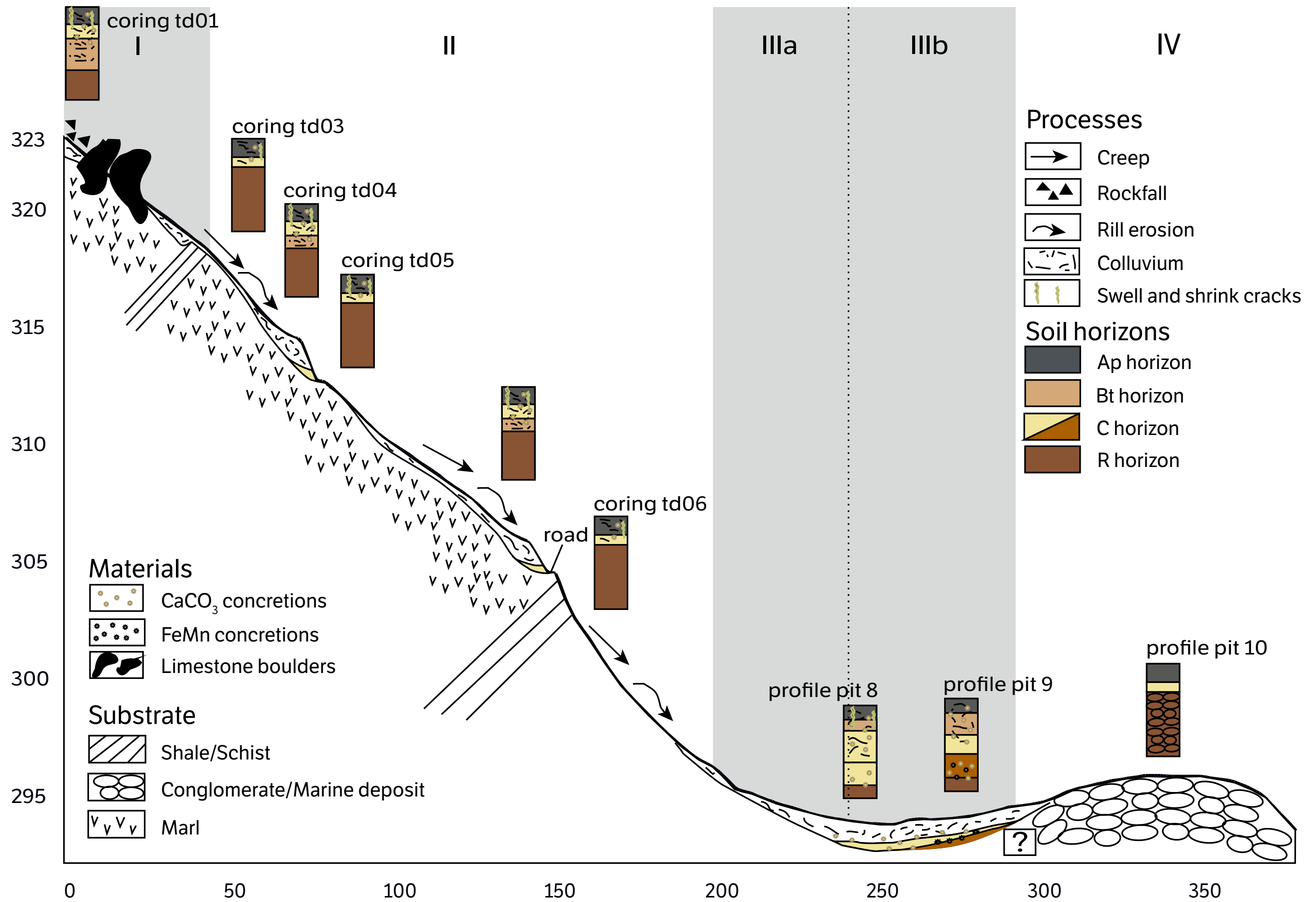

Figure 29. Longitudinal cross section of the Portieri di Cerchiara area, showing the underlying geology, morphological processes, and spatial distribution of soils. Note: the location of the shale bands is tentative - precise locations could not be identified via augering. For core descriptions, see Appendix IV.

partially covers the marine terrace (IV) at site Rb0219, where the transect ends (figure 28). Profile pits were dug at site Rb0219 to obtain detailed insight in the short-range pedo- and morphological variations across the saddle.

In the upper part of the transect (I) limestone blocks, originating from the overlying slope and covering the marl and shale, reduce erosion and cause slope stabilisation resulting in deeper and more developed soils in colluvium. Although a small-scale phenomenon, this soil formation is relevant at the archaeological time-scale since it testifies to the relative stability of the slope in this section. The second part of the transect consists of an erosional slope underlain by marl. Recent anthropogenic influence is evidenced by terrace walls built to limit soil erosion and retain eroded material. Erosion has been most severe right below the terrace edges and has resulted in truncated soils lacking distinct horizons below the Ap horizon, which is in colluvium and is between 10 and 30 cm thick. Bands of more erosion resistant bedrock that are present within the marl, like shale or quartzitic sandstone, induced local accumulation of slope material, hence deeper, more stabilized and stronger developed soils that in places contain a Bt horizon. In the lower parts of the cultivated fields, the terrace walls may also rest on, and thus protect, an older soil. Such older soils can easily be identified by the presence of a Bt horizon underneath the colluvial C material. The presence of more resistant bedrock can be inferred from weathered shale and quartzitic sandstone fragments that are found in soil profiles further downslope. The positions of the terrace walls are presumably related to these shale bands, of which the strike is more or less perpendicular to the slope, but distinct shale outcrops near the terrace walls could not be identified in the field.

The third section of the transect is the colluvial basin of the saddle, which was divided into two subareas. In the first (IIIa), colluvium rests on a weakly developed soil in marl; closer to the marine terrace deposits (IIIb) it rests on older and more developed soils in marl. The maturity of the soil can be deduced from its orange/red colour and the presence of iron-manganese concretions. The exact location of the transition towards the (colluvium covered) marine terrace (IV) could not be identified due to anthropogenic disturbance observed in this relatively small transitional zone. Angular stones of the colluvial material here occur in a reddish soil, so it seems that colluvium and material from soils formed in the marine terrace deposits have been mixed. This may have happened during extreme anthropogenic colluviation or natural mass movement events. From a pedological point of view it is not possible to date these events, nor is it possible to link distinct colluviation phases to increasing anthropogenic activity (e.g. mechanical ploughing).

Additional corings were made around and within anomalies identified by geomagnetic survey in zone II of the transect, and which were judged to be probably non-anthropogenic (figure 30). Soils in unaffected parts surrounding the anomalies showed a normal soil formation pattern, similar to soils on the erosional footslope described above. The slope in the northern field is rather stable, as could be deduced from the presence of a thin Bt horizon. The corings show that the anomaly at Rb252 corresponds with a bright red and orange coloured layer which, upslope, appears to be very brittle and thicker. In the downslope part of the anomaly a compact bright red/orange layer is present with a thickness of 30-40 cm. In places, the layer was too dense for manual coring. In all corings the layer contained weathered pottery fragments and was covered by slope material (colluvium) of varying thickness.

The stronger anomaly in the southwesterly field was linked with the filling of a palaeogully. This filling consisted of successive colluvial layers that varied in texture. The lower part of the solum contained fragments of land snail shells, indicating an old land surface. The weaker anomaly could be ascribed to a band of iron-containing sandstone. Rock fragments of this sandstone were found in the topsoil and were confined to the location of the anomaly.

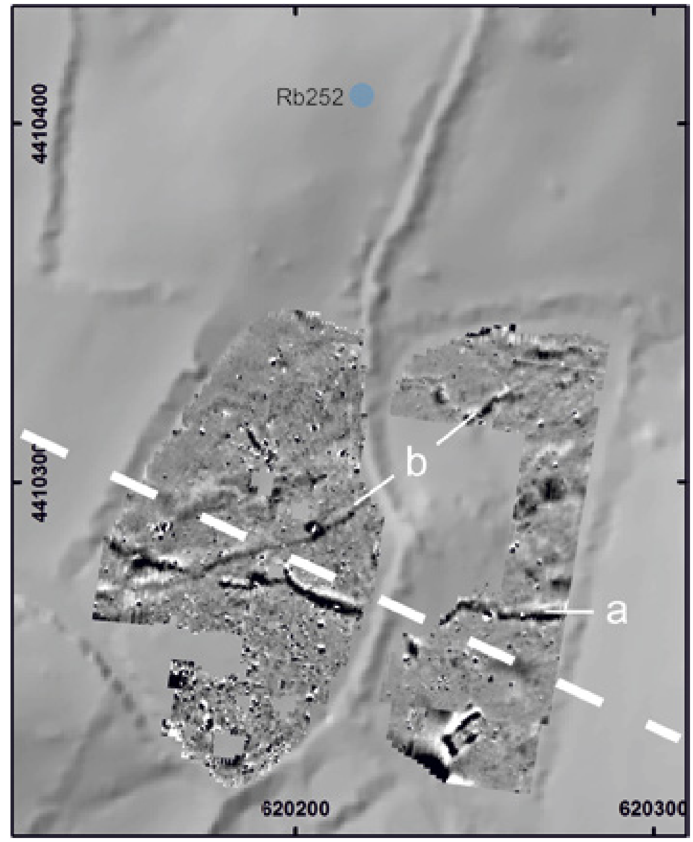

Figure 30. Geomagnetic results over zone II of the Portieri di Cerchiara transect (dashed line), showing two linear anomalies of geological origin. a appears to be an infilled gully, b an outcropping band of iron-containing sandstone.

CONCLUSIONS

Erosion of the slope from the mountain (the footslope) to the saddle is relatively limited, as shown by the good preservation of the soils (intact B horizons in marl soils). This is explained by the protection offered by the abundant large limestone blocks originating from the overlying slope through mass movements. Soils on the footslope are marked by the presence of a colluvial topsoil of up to 60 cm thick. Locally, filled palaeogullies containing an even thicker colluvial layer have been encountered. Terracing resulted in the local accumulation of eroded soil and archaeological material.

The relatively flat marine terrace surface and associated saddle are marked by relatively intact soils (i.e. at most their A horizons and upper B have eroded), due to the better internal drainage of these coarse textured terrace deposits and the associated higher stability of the slope. This explains the conservation of archaeological materials and structures on the saddle.

3.3.3 General remarks

The complex landscape pattern characterizing the topographical unit 'Foothill USL' is the result of the complex geology and geomorphology, which in turn affect the local morphology and hydrology, and result in a quite complex soil pattern. The foothills have also been intensively cultivated, and it is in particular the recent mechanized ploughing that has had a major impact, leading to widespread soil truncation and topsoil disturbance. Upper parts of the agricultural fields are mostly truncated down to the bedrock so that soil depth is limited to plough depth. Soils on slopes are generally young and shallow, and consist of a colluvial Ap horizon of variable thickness, which should be considered as a layer that is in transport. The storage of archaeological material in colluvium is confined to a small number of locations (i.e. in the agricultural terraces).

Archaeological features are only preserved in situ when soil erosion is limited so that the solum with its archaeological archive (as it existed before the modern period of heavy mechanized ploughing) is preserved, or where this archive lay deep enough to not be affected by mechanical ploughing. In consequence, interpretations of archaeological finds in the Foothill USL should take local lithology, morphology and pedological processes into account for each site individually.

3.4 Uplands

Marls dominate the geology of the Contrada Maddalena in the upland region of the Raganello catchment. These marls hold intercalated bands of shale, phyllite, and rare iron-rich quartzitic sandstone, and exhibit incidental outcrops of ophiolite. The upland is confined between two large ranges, the limestone dominated Timpa di San Lorenzo/Timpa di Cassano range and the Monte Sparviere/Monte Sellaro range, which has a more varied geology. In particular the western range is bordered by large debris slopes and fans that extend into the marl uplands and are composed of poorly sorted and very coarse limestone debris. The dramatic relief within the uplands reflects its geology, with marls being unstable and sensitive to erosion, whereas bands of the more resistant rocks (shale, phyllite and rare sandstones) stand out. Moreover, sometimes huge boulders and blocks of limestone debris also protect the marl against erosion, thus standing out as ridges and producing a very irregular relief. The eastern range is overall less steep, but southeast of the village of San Lorenzo Bellizzi limestone crops out (Timpa di Sant'Angelo), forming a nearly vertical cliff with debris cones at its foot.

The dominant landscape type in the uplands thus is an irregular marl landscape with ridges that are underlain by harder, more resistant rocks and with a fine pattern of valleys in softer marls, often with mass movements (frane) and commonly terraced. Most of the archaeological sites studied are in this landscape and their occurrence is linked to the extent of conservation of the original land surface, as shown by Feiken (2014). It is this extent of erosion and denudation, which formed the main topic of his landscape development model CALEROS. A second group of sites is linked to the debris slopes at the foot of steep limestone slopes, where rock debris produced by the slope above accumulated to form non-matrix supported deposits of angular coarse limestone debris. In several places these deposits hold important early archaeological sites of which the stratigraphy and setting is complex. To some extent the occurrence of archaeological sites in these debris slopes is surprising given the unstable nature of the overlying slope, with regular rock falls that pose a serious threat to any residents. This threat will have been most serious during seasons with more frequent rock fall, i.e. during the winter and early spring season with frost weathering and heavy rains at a maximum. During the dry season, however, risks will have been much reduced suggesting that these sites might be seasonally occupied.

General information on the geology, morphology and soils of the upland area was obtained by studying a SW-NE transect that starts near the base of the Timpa di San Lorenzo, and ends on the footslopes of the Monte Sparviere (figure 32). More detailed surveys were performed around several archaeological sites. These include the four sites Rb073 and Rb173 to Rb175, selected as typical small impasto sites of the upland USL, with nearby site Rb176 as a Hellenistic control site for the geophysics, and the two 'rich' impasto sites Rb121a and Rb130a which are both located in debris slopes. These two groups of sites – in the marl landscape and in the debris slopes at the foot of the limestone ridges - will be discussed in separate sections. For their locations, see figure 31.

3.4.1 Transect in the uplands

Soils in marl have a yellowish brown to orange yellow colour depending on the extent of soil development, and have a clay loam texture with smectitic clays. Soils generally have a cambic B horizon that is gleyic and vertic, leading to their classification as Vertic Gleyic Cambisols and Vertic Gleysols. The fine texture of the marl inhibits percolation of water. This impermeability of the marl also prevents the dissolved lime from moving down in the soil and thus results in the formation of soft calcium carbonate concretions in the lower (B and C) horizons. Groundwater exudes in the contact zone between the more permeable limestone and the marl, which because of the instability of the marls leads to an irregular topography with common landslides and mud flows. In some places limestone boulders, originating from the Timpa di San Lorenzo and sometimes reaching huge dimensions, act as a local buffer preventing the soil upslope from being eroded. Similarly, bands of more erosion resistant phyllite, shale and quartzitic sandstone locally result in relatively flat areas with similar less eroded soils and with accumulation of colluvium. Soil depth is primarily related to the amount of colluvial material deposited on top of the erosion resistant bedrocks.

Along the side of the Timpa di San Lorenzo and below the Timpa Sant'Angelo, mass wasting is prominent. Here soils consist of organic rich material filling the pores of non-matrix supported, very coarse textured deposits of limestone fragments that range from debris slopes to alluvial fans. Its young soils, lacking clear subhorizons, are classified as Cambisols with calcic properties or as calcaric Regosols.

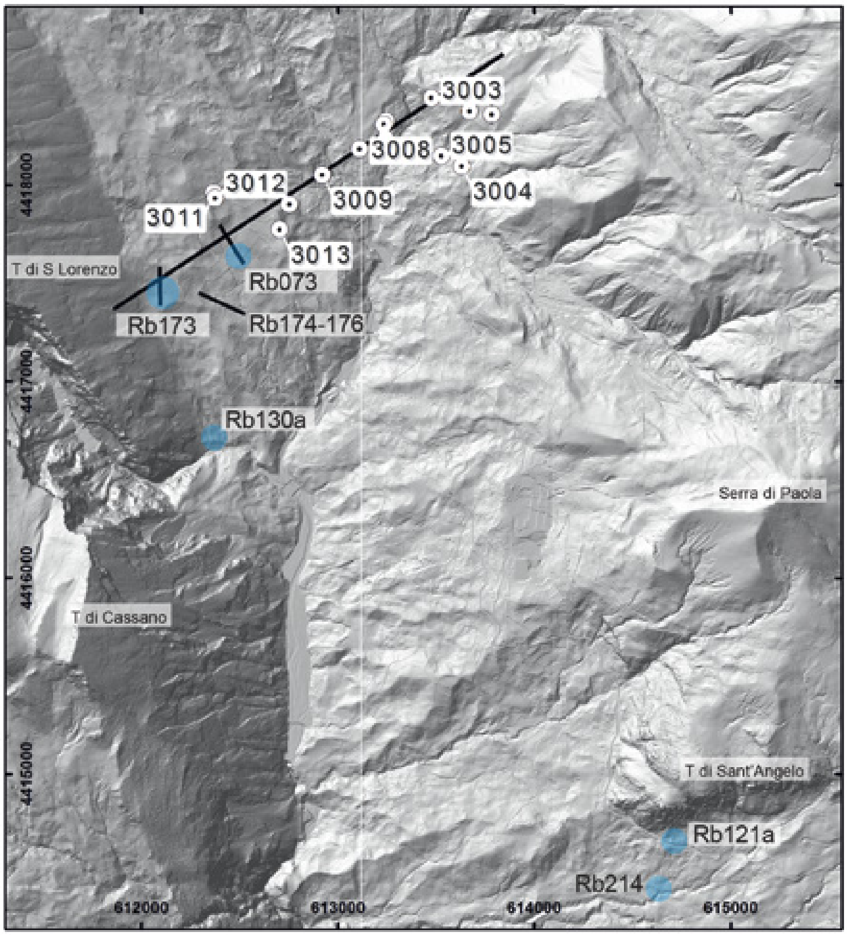

Figure 31. The locations of the corings, transects and investigated RAP sites within the uplands.

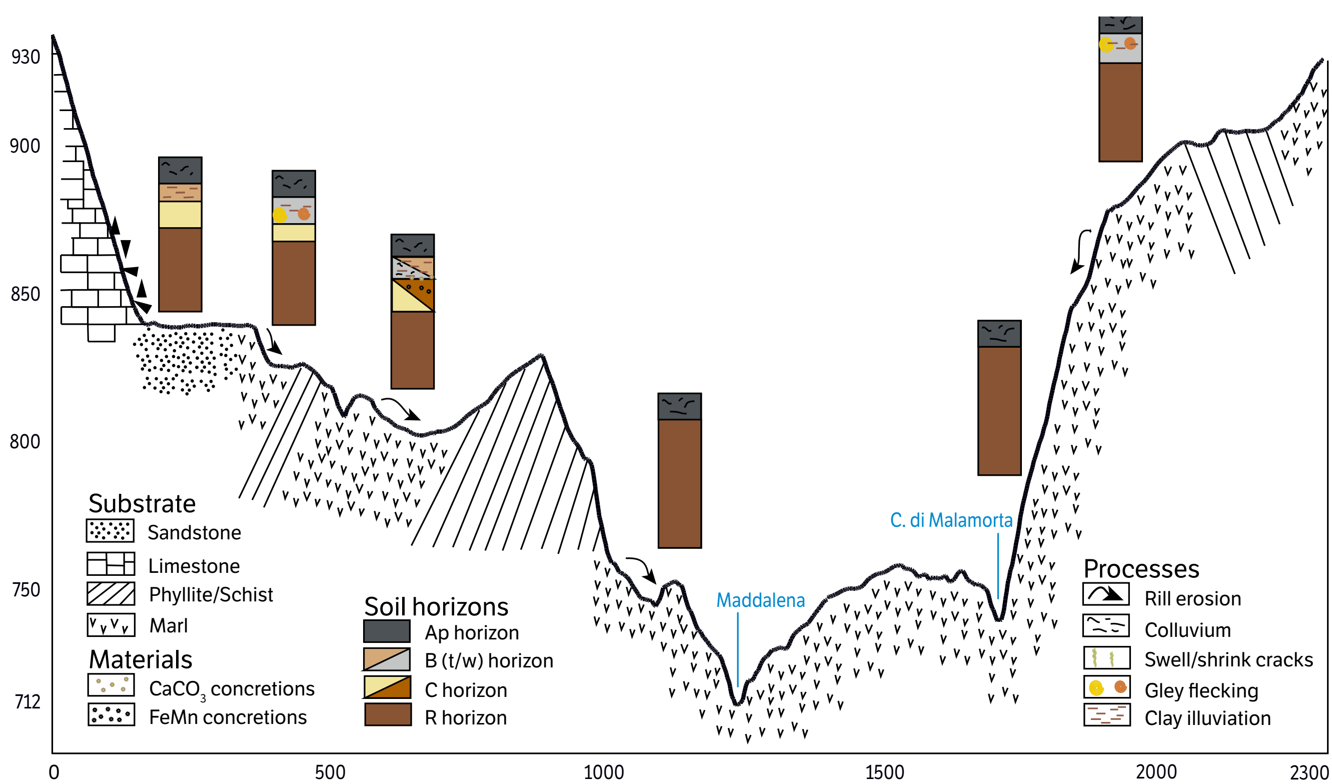

Figure 32. Schematic representation of lithology, morphology and soils in the Upland USL (Maddalena basin).

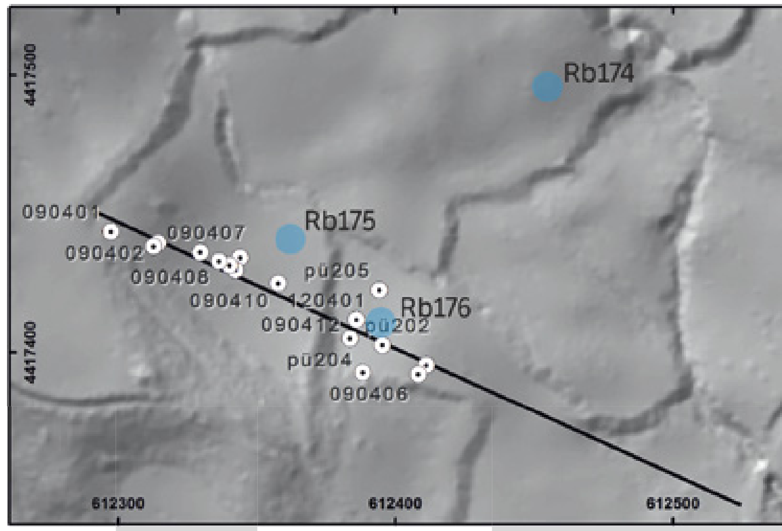

Figure 33. Locations of corings and transect around RAP sites Rb174-176. For core descriptions, see Appendix IV.

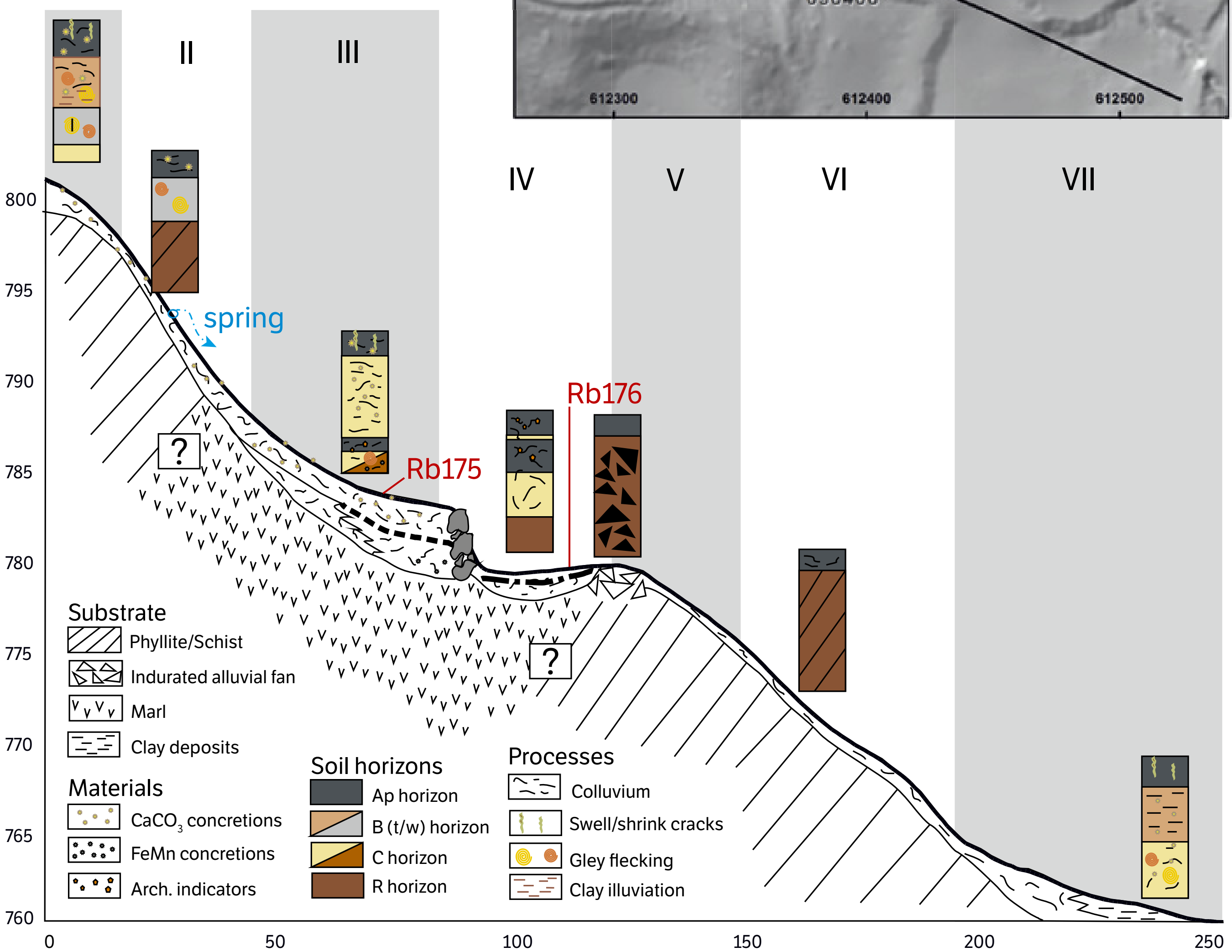

Figure 34. Schematic longitudinal cross section across sites Rb175 and Rb176, showing the underlying geology, morphological processes and spatial distribution of soils. Note: the organic rich layer underneath site 175 might continue below the terrace wall towards site 176.

3.4.2 Sites in the marl landscape: 174, 175 and 176

RAP sites Rb174 and Rb175 are classified as 'simple impasto upland sites' (figure 33). They were studied in more detail to get a better understanding of the processes acting on and around them, and their effects on the visibility of the archaeological remains and the interpretation of the geophysical signatures. The Hellenistic site Rb176 provides a potential 'control' in that it is roughly a millennium younger than the others and might help in separating plausible from implausible scenarios of post-depositional landscape history.

The bedrock at these sites includes marl, sandstone and phyllite, with a colluvial cover that contains limestone and iron-rich quartzitic sandstone blocks originating from adjacent fields (including the edge of the area around site Rb173, see section 3.4.3). Topsoils contain $CaCO_3$ concretions derived from the marl, which is sensitive to erosion. Stagnation of water on the impermeable phyllite causes groundwater to exude in the form of springs.

Figure 34 shows a longitudinal cross section of sites Rb175 and Rb176. Soils at the top of the transect (I) consist of a 70 cm thick colluvial cover over a soil in phyllite. In the colluvial cover, which is derived from the topographically overlying marl, a 40 cm thick dark Ap overlies a clay-rich C horizon. When ploughed, the upper 40-60 cm of the soil is loosened, leading to the illusion of clay enrichment with depth, which however in reality is not the case. In the C horizon, temporary reducing conditions caused by groundwater fluctuations occur, as is evidenced by yellow/orange mottles in an overall reduced matrix. The lower part of the solum, formed in phyllite substrate, also exhibits clear signs of fluctuating groundwater (greyish/white soil color), and combined with minor features of clay illuviation results in a designation as a weakly developed gleyic B (Bwg).
Soils on the slope (II) are shallow and, due to strong erosion, lack the Btg horizons with gleyic and vertic properties that were described previously as characteristic for soils at stable sites (see section 2.3). Here soils have a 40 cm thick Ap over a thin and weakly developed Bwg horizon. These soils are therefore classified as gleyic Regosols.

In the colluvial depression (III) an older occupation layer directly on top of the marl bedrock is covered by 1 metre of non-sorted light grey colluvium. The palaeosol (dashed line) has been identified by its dark color (caused by organic material) and the presence of charcoal and pottery fragments. The latter include impasto, pointing to occupation in protohistory. The underlying colluvial C horizon contains $CaCO_3$ concretions and orange-yellow reduction/oxidation mottles, which indicate that seasonal groundwater fluctuations occur within the soil. The transition from the colluviated soil horizons to the intact palaeosol, presented in figure 39 as a zigzag line, is diffuse.

Close to the terrace wall, soils are underlain by marl and are more stable and developed, as evidenced by their orange color and by the presence of Fe-Mn concretions that form upon more prolonged periods of soil formation on a marly substrate.

The transect continues underneath the terrace wall (IV) at site Rb176, where many pottery fragments from the Hellenistic period and some from protohistoric periods have been found at the surface. Here a clayey organic-rich layer containing many charcoal and ceramic fragments (dashed and dotted line) was observed in corings directly underneath the plough layer. Whether this layer should be correlated with the old occupation layer in the field above the terrace is uncertain, since the ceramics found date from different periods. Furthermore, the topographical position of the plot is inconsistent with the overall morphology. The elevation difference between the plot above and below the terrace wall points at truncation, i.e. the plot below the terrace wall lacks the colluvial layer described earlier and the adjacent stream is at an elevated position relative to the topsoil. There is no indication that the removal of this material has a natural origin (i.e. by erosion), so blockage of downslope transport of colluvium by the terrace over a long period of time (i.e. no colluvial cover since the Hellenistic period) or anthropogenic disturbance are the most likely remaining explanations. If anthropogenically disturbed, the material may well have been deposited nearby in order to elevate wet parts, but no clear pedological evidence has yet been found for this hypothesis.

The small hill downslope from site Rb176 (V) is formed by underlying resistant phyllite and is partially protected by a cemented alluvial fan consisting of limestone gravel and boulders (as indicated by the presence of limestones with a calcite crust at the surface). Soils are almost directly on top of these, so soil depth is mostly limited to the plough depth and does not exceed 40 cm (Regosols). In some places soil depth even is less than 25 cm, classifying these soils as Leptosols. The footslope (VI) is covered with a thin colluvial layer. The transect ends in a small depression that holds colluvial material. The top of the soils here (VII) consists of grey clay lacking clear signs of soil formation, which must therefore be of recent age and apparently was deposited during flooding of the adjacent stream.

Site Rb174 is situated next to the previously described sites Rb175 and Rb176, but separated from these by a small stream that acts as a morphological divide. Erosion resistant phyllite bedrock occurs as intermitting bands in the marl substrate and is responsible for exuding water. This exuding water causes fluvial and gully erosion on the slopes, resulting in the typical relief of this site, i.e. the phyllite bands stand out as residual ridges. The eroded material is transported downslope into the colluvial depressions, the topographically lower ones of which are seasonally wet, and the higher ones dry. Soil depth in the top and slope positions is limited (±70 cm) and soils consist of a 40 cm thick Ap horizon over a C horizon in colluvium. Soils in the colluvial depression are deeper (>200 cm) but lack significant soil formation, having an Ap horizon directly over a clay-rich colluvial C horizon.

CONCLUSIONS

The complexity of the lithology of the bedrock and corresponding morphological and pedological processes is again shown at sites Rb174 to Rb176, and illustrates the often very complex local relations in this marl landscape between geology, geomorphology and hydrology on the one hand, and soils on the other. Particularly important is the lithology, which exerts a strong control over the local hydrology and results in rapid alternations between zones with exuding water and springs, and dry zones with well drained soils.

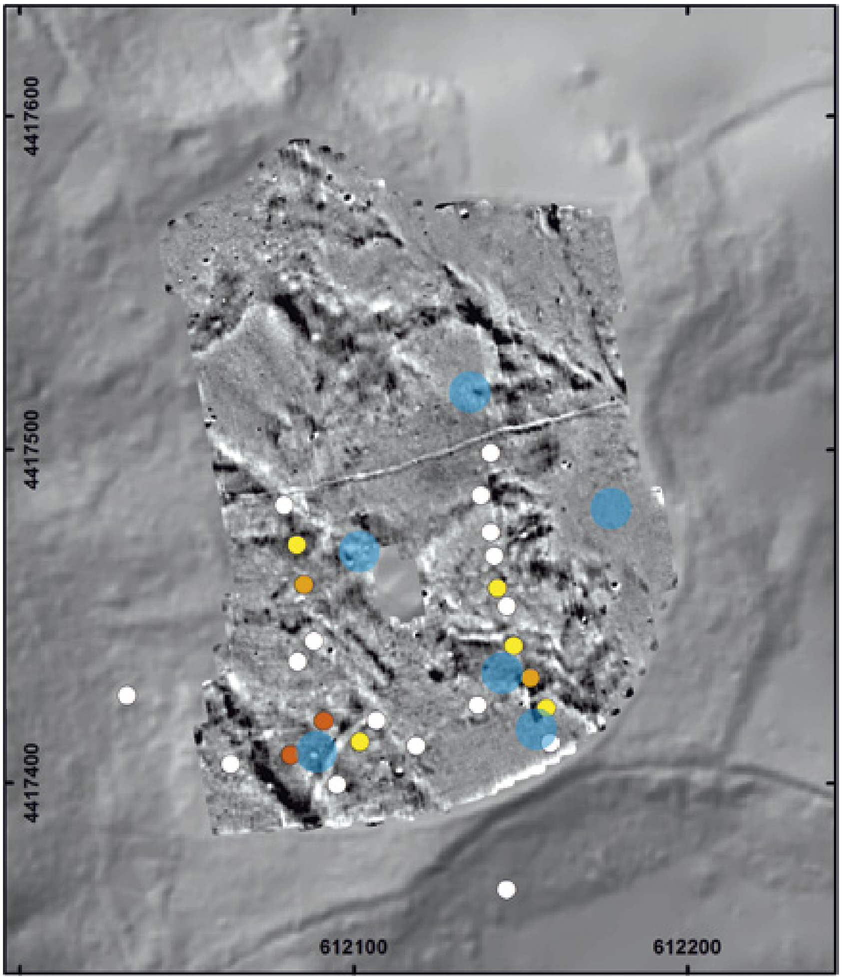

Figure 35. Investigations at site Rb173: geomagnetic readings showing the strike of the geology (Eastern Atlas 2011) with locations of RAP surface pottery scatters (blue dots) and corings by Feiken (2014).

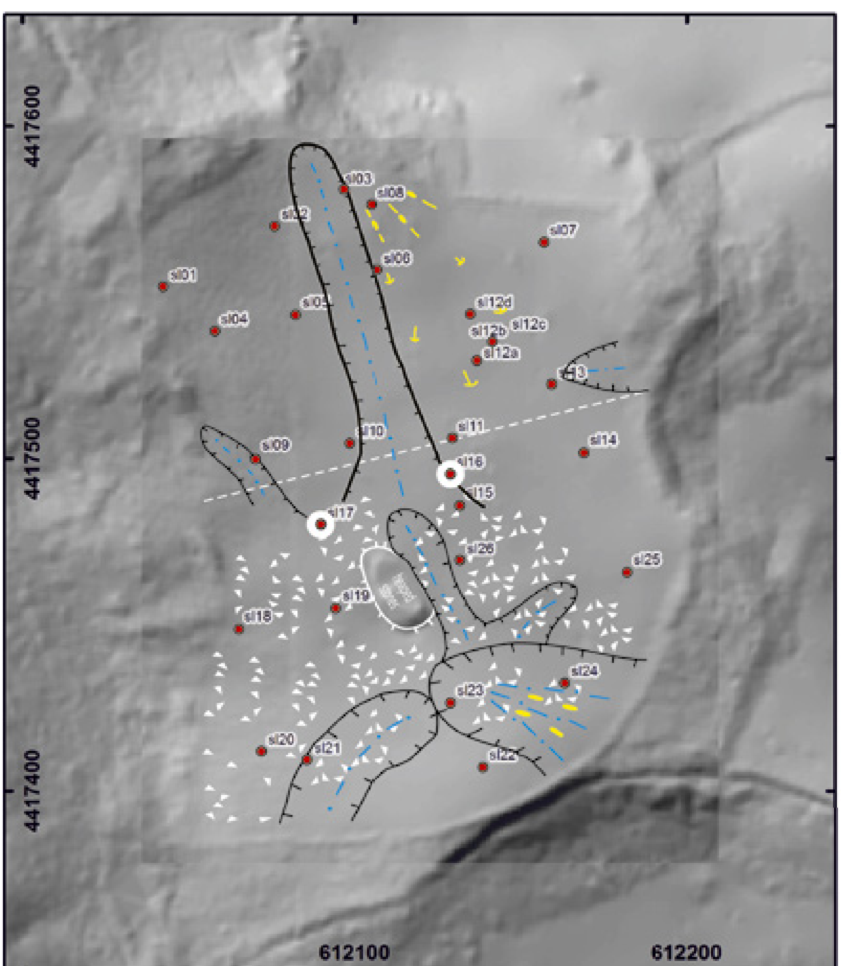

Figure 36. Investigations at site Rb173: corings and interpretation of surface processes. The white circles indicate the locations where soils with distinct argic B horizons were found; the dashed white line indicates a tillage boundary.

The archaeological materials at the surface of sites Rb175 and Rb176 seem to find their origin in an underlying reservoir in the form of old occupation surfaces and cut features that are being ploughed to the surface. For site Rb174, however, no such source could be found for the pottery fragments at the surface. It is therefore likely that they are contained in a colluvial layer that is in transport (off-site).

3.4.3 Sites in the marl landscape: 173

Site Rb173, where the RAP surveys recorded several diffuse scatters of protohistoric pottery, became of interest through studies of landscape taphonomic processes performed by Feiken (2014: 136-139), who identified a range of archaeological markers in several cores (figure 36). Our aims were to check Feiken's interpretation of continuous archaeological layers via further manual coring, to establish whether a west-east running gully is indeed present, as presumed by Feiken, and to help interpret the results of the geomagnetic survey (Eastern Atlas, 2011).

The bedrock in the plot of site Rb173 is marl with intercalated iron-rich quartzitic sandstone, overlain by more or less cemented alluvial fan deposits composed of limestone fragments originating from the adjacent Timpa di San Lorenzo. The marl is very sensitive to weathering, so the more erosion resistant quartzitic sandstone is closer to the surface, explaining some of the geophysical anomalies. The main erosional features on the marl include small alluvial fans, (intermittent) fluvial gullies, and minor slumps. Slope processes are least active where quartzitic sandstone is closer to the surface. Such a situation with rapid alternation of marl and sandstone is marked by small-scale colluviation in a local soil environment with minor erosion, as can be concluded from the presence of Bt horizons. Locations where such Bt horizons have been observed in corings are indicated in figure 36 by white circles.

Rock fragments from the Timpa di San Lorenzo, falling down by gravity, came to rest on the lower slopes, where they occur as more or less isolated blocks, often wholly or partly buried in the soft marl soils. Hard rock at shallow depth, in the form of phyllite and quartzitic sandstone, has also been encountered in several corings. No archaeological markers like charcoal, ceramics or bone fragments were found in our corings. Soil depth in these corings varied from around 50 cm in soils subjected to more intensive erosion, to 100 cm in local colluvial depressions.
Present-day anthropogenic influence is strongest south of the central plot divide, where deep ploughing causes fragmented bedrock to appear at the surface. The presence of carbonate crusts on the limestone blocks (indicated as 'boulders' in figure 36) indicates that these are derived from indurated alluvial fan deposits. The appearance of cemented bedrock at the surface indicates serious erosion, since cementation occurs deep in the soil. However, based on the current observations it is not possible to establish when and to what extent this erosion took place (e.g. recent deep ploughing or past erosion). Lastly, a large heap of stones to the south of the field divide probably is indicative for a common agricultural practice in such stony fields, being the removal of stones, and thus most likely is a clearance cairn.

CONCLUSIONS
The study showed that the morphology and soils of site Rb173 follow the typical uplands pattern. The slope is characterized by colluvium in transport and by minor slumping, and is being incised by intermittent gullies. Locally, more erosion-resistant bedrock stabilizes slopes resulting in relatively well-developed soils with a Bt horizon. In the lower part of the field a cemented alluvial fan deposit has been reached by ploughing, as is demonstrated by the presence of calcite encrusted limestone boulders at the surface.

No evidence was found for the existence of a more or less continuous archaeological layer, as described by Feiken (2014: 140-141). The current observations indicate that the archaeological markers recorded by him in several corings (figure 35) most likely derive from pits, ditches or other very local man-made depressions - a situation that was earlier encountered in the Contrada Damale (see section 3.3.1).

3.4.4 Sites in the marl landscape: 73

RAP site Rb073, a typical 'simple impasto' scatter of protohistoric pottery, was to be examined in the same manner as previous sites of this class. Additionally, results were to be checked from the previous study of an adjacent plot by Feiken (2014: 139-140), who identified archaeological markers dating to the Byzantine period at the base of the footslope. More specific interest arose when our systematic coring along transects led to the identification of an adjacent low, small hill as a presumably artificial 'mound'. In these corings we also found a volcanic ash layer of uncertain age. Subsequent 14C dating led to its identification as the 79 AD Vesuvius ash from the Pompeii eruption, and this prompted a further detailed study of the mound and its surroundings, involving systematic corings and excavation of a large test pit. Here only the generals of our initial study will be presented, including the description and discussion of the two transects and results from the radiocarbon datings on samples from one of the cores. Results from the much more extensive and detailed later studies on the genesis, stratigraphy and archaeology of the site will be presented elsewhere (de Neef in prep; Sevink et al. in prep).

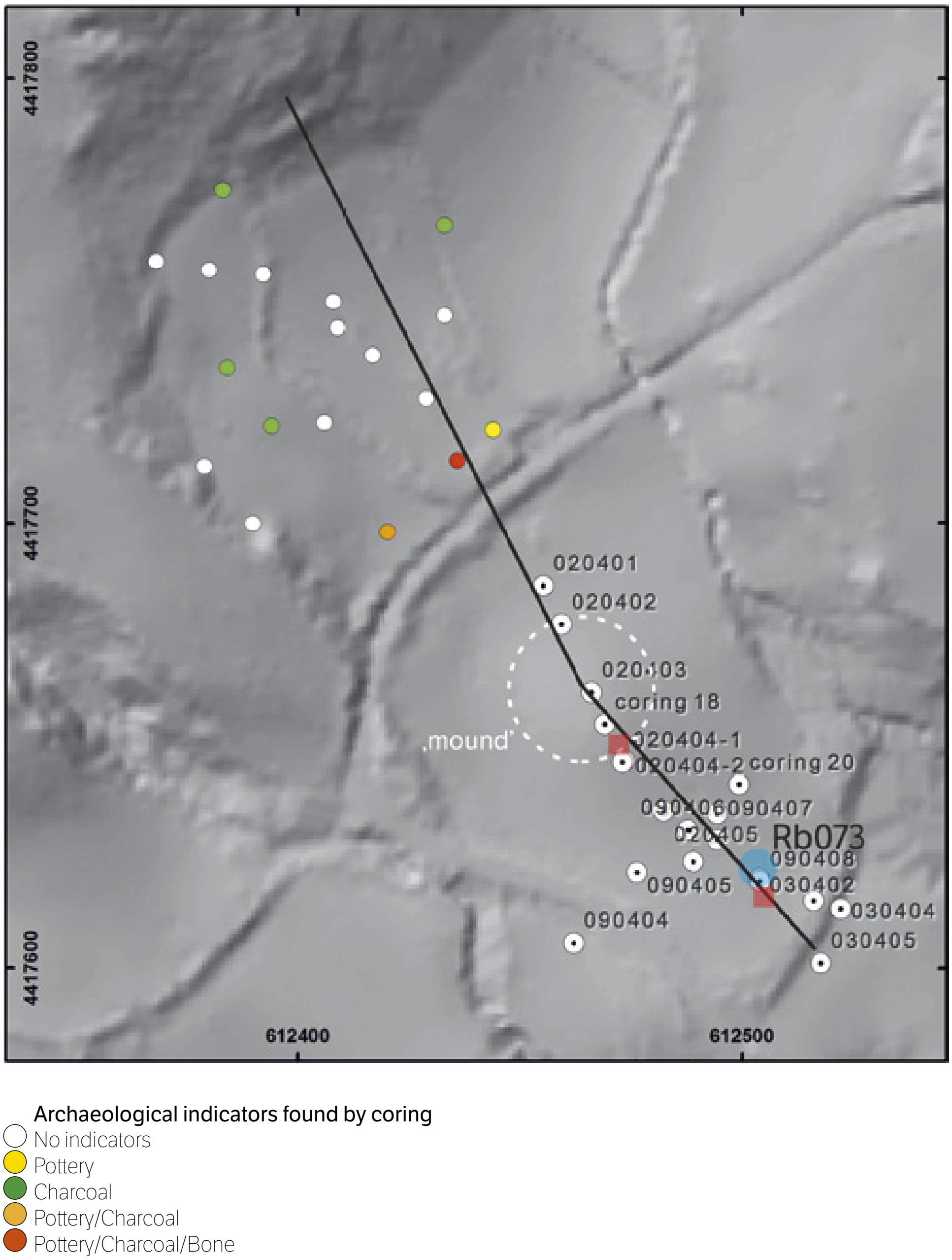

Figure 37. Corings, transect and profile pits around RAP site Rb073 (blue spot). Locations of corings by Feiken (2014) to the north of the road, and by the RLP team to the south. Two profile pits (red squares) were dug to investigate the site and the mound. For core descriptions, see Appendix IV.

The longitudinal transect (figures 37 and 38) starts north of the site, upslope of the road. In the top of this field shale/phyllite bedrock crops out. Going down towards the footslope, protohistoric pottery and lithics were identified at the surface. In several corings, the soil consists of a dense clayey organic rich old occupation surface overlain by 60 to 70 cm colluvium. The colluvium itself also contains small fragments of charcoal and ceramics (at 65 cm) that were identified as impasto, indicating that its origin should be sought in an eroded Bronze Age occupation layer. However, since near these corings bedrock was found at shallow depth, it is evident that the colluvial material occurs only very locally. Thus, our results suggest that the colluvium in reality is the infill of one or more platforms cut into the hill slope. Further down the slope, towards the road, soils consist of a 40 to 50 cm thick layer of colluvium (i.e. more or less the plough depth), lacking charcoal and ceramic fragments, and overlying weathered marl.

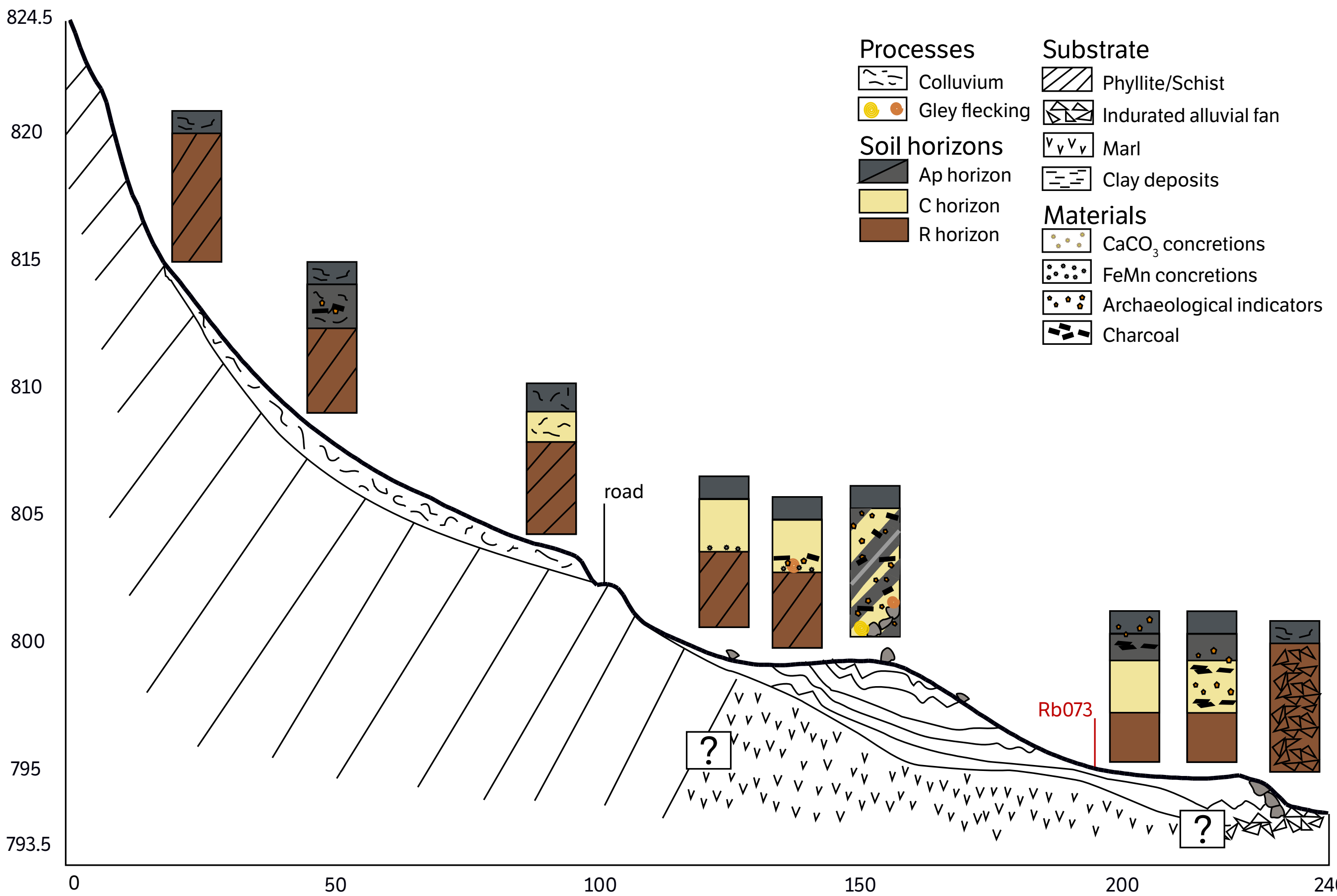

Figure 38. Schematic longitudinal cross section of fields overlying site Rb073, showing underlying geology and spatial distribution of identified paleosols.

Again these results do not conform with the observations by Feiken (2014: 139), who identified ceramics and charcoal in the lower part of the footslope and inferred the existence of a more or less continuous buried archaeological layer. Our observations strongly suggest that these archaeological materials occur only in fills of pits and/or platforms, cut into the hill slope. The occurrence of archaeological materials thus very much depends on the exact site of the coring.

Going further downslope in the same field, soils are truncated, consisting of a 50cm thick Ap horizon on top of a 50cm thick C horizon of weathered phyllite. The transition zone between the C horizon and fresh bedrock is characterized by the presence of many weathered phyllite shards and Fe-Mn mottling. Across the road, as the transect continues towards the 'mound', soils start to contain ceramics and charcoal, with increasingly complex stratification and increasing soil depth towards the centre of the mound.

Figure 39 shows the build-up of the 'mound' as based on the results from the corings, which demonstrate that the central part contains several superimposed dark layers containing abundant charcoal, bone fragments and ceramics. One of the upper layers was found to contain fine volcanic ash, identified by the abundant presence of biotite and pyroxene crystals. Remarkable is the occurrence throughout these layers, and particularly at the surface, of angular limestone boulders and stones that are very unlikely to be derived from the subsoil, which here consists largely of marl.

As observed in the corings, the maximum total thickness of the layers constituting the mound may exceed 2 m. They rest on an original land surface that can be recognized by the abundant occurrence of land snails, undisturbed character of the soil (Bg in marl), and absence of archaeological material. Samples taken from several of the charcoal containing layers and from the presumed volcanic ash were separated into fractions and microscopically studied. The radiocarbon dating of charcoal fragments surrounding the ash indicates an age of 1945 ±30 calBP (68 AD), placing it around the time of the Pompeii eruption of the Vesuvius. Based on this result the ash layer found in the mound can be attributed to this eruption, being the only major volcanic eruption in the Central Mediterranean during this era (Zanchetta et al., 2011).

Further down the transect, the separate anthropogenic layers merge into a single thinner anthropogenic layer

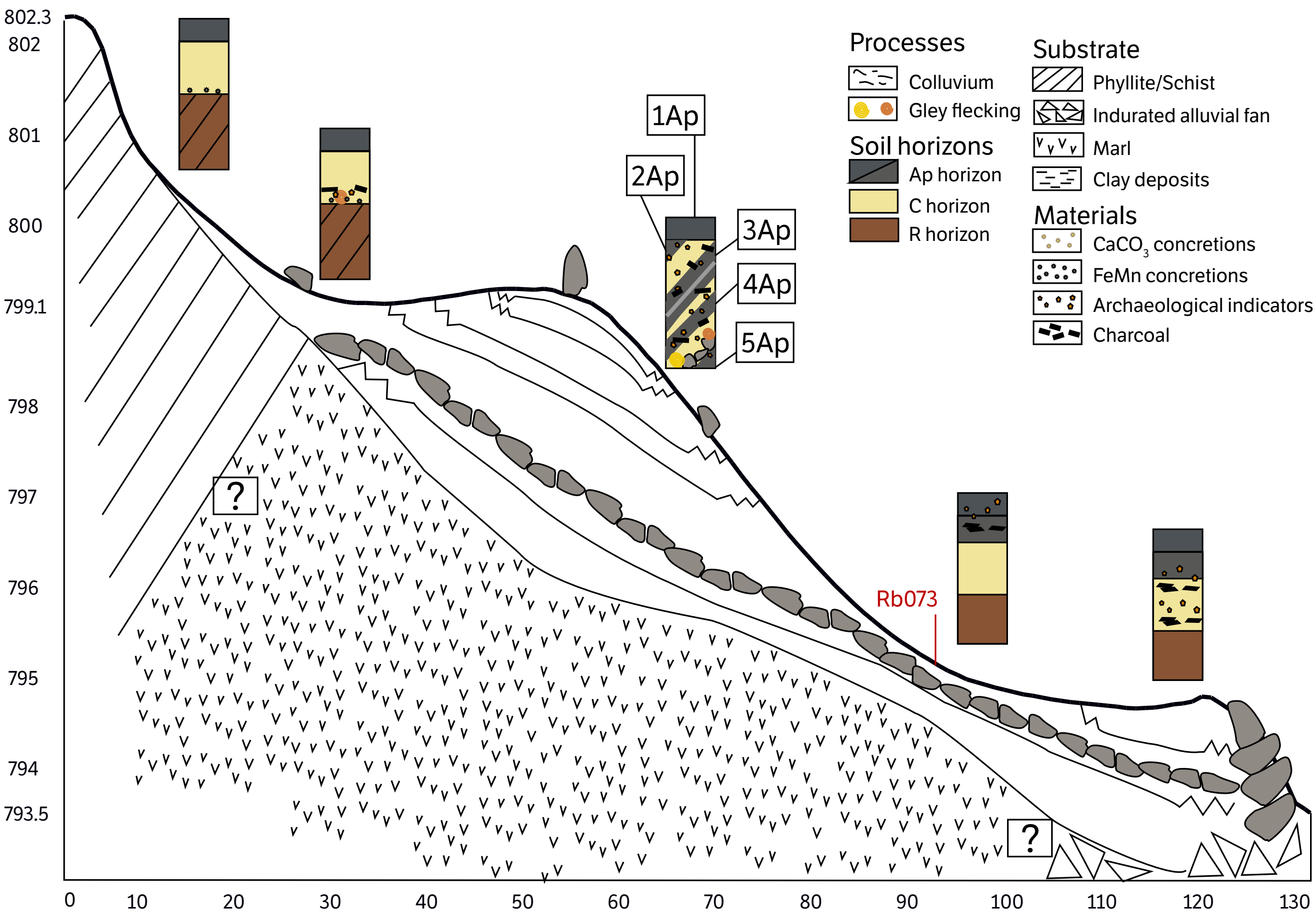

Figure 39. Detailed cross section of the 'mound' showing the underlying lithology and soil horizons.

that also contains archaeological materials (charcoal, bone and ceramic fragments) and extends all the way to the terrace that forms the lower border of the field. Here Bronze Age archaeological materials had been found at the surface (recorded as site Rb073) and again a rather complex stratigraphy was observed in a test pit, which will be described elsewhere (de Neef and van Leusen, in prep). Below this terrace wall, soils are shallow and in marl, and are clearly severely truncated because secondary carbonates, encountered in the C horizon in non-eroded soils, here occur in the Ap horizon. These soils are therefore classified as Leptosols.

CONCLUSIONS

The results of the corings performed by Feiken (2014) in the field above the road are not in accordance with the findings of this study. This discrepancy might very well be due to the nature of the archaeological features, since our observations strongly suggest that they must be cut features of limited dimensions (hut platforms and pits), with relatively deep archaeological strata and a thin superficial 'plough layer' that can be described as a layer with archaeological materials that are in transport. A much more detailed and systematic coring program thus will be needed to produce a detailed picture of the distribution of archaeological features on this slope and to fully understand their origin.

Below the road, the occurrence of a mound with a complex structure is exceptional, since it is the only mound thus far discovered in the uplands. Over a long period – at least from the Late Bronze Age up to and including the Late Roman - material has been deposited, either intentionally (raising the land surface to form a mound) or by coincidence (gradual raising through dumping of waste and/or building materials), in this way covering earlier archaeological strata and thus protecting these against erosion. This explains the pottery scatter recorded at site Rb073, which is situated in the lower perimeter of the mound. Below the terrace, in the next field down, the land surface has been lowered probably as a result of erosion and ploughing, and archaeological layers are absent. A much more extensive description and discussion of the more recent research conducted around site Rb073 is presented by De Neef (in prep) and Sevink et al. (in prep.)

3.4.5 Sites in debris slopes: 121 Pietra Sant'Angelo

Site Rb121a Pietra Sant'Angelo is located at the edge of a stone quarry on the vegetated and stony debris slopes between the Timpa Sant'Angelo limestone cliff and the provincial road at its foot, and represents the class of 'rich' impasto upland sites (figure 40). Here research was performed to understand the stratigraphy of the deposits with their intercalated soils, and their relation with the visibility of archaeological materials and old occupation layers in these debris slopes and cones.

The Timpa Sant'Angelo consists of near vertical limestone cliffs, and the instability of the area shows up along the entire length of these cliffs in the form of debris cones, and on less steep slopes as alluvial fans. A study of a section exposed in the quarry in the debris cone at the foot of the cliff (figure 41) showed that such debris in places covers older occupation surfaces. Organic rich loose soil material filled the holes between the boulders in the upper part of the profile. These boulders rest on non-matrix supported relatively fine (gravelly) limestone-derived slope deposits. The archaeological materials were found in the transition zone between the boulders and the finer slope deposits.

These older surfaces, which have a dark soil that is about 60 cm thick, are characterised by their high content of organic material and by the presence of bone fragments, pottery shards, and charcoal, and have been identified in several locations along the cliff (figure 40). Manual coring is seriously limited by the stoniness in the soil profiles, preventing any coring-based survey. Thus, in order to map the spatial distribution of older occupation surfaces, test pitting of predefined sites may provide better results.

These observations can be summarized as follows: The soil near the quarry consists of coarse debris with a highly organic fine earth filling interstitial pores (between rock fragments). In the lower section this fill contains abundant bone fragments indicating former occupation. In places, more complex soils have been identified with an upper Ah horizon containing impasto pottery sherds and a lower, intercalated organic matter containing stratum also with impasto pottery. These soils are probably largely anthropogenic in origin because of their high organic matter content and intensely black colour. Even earlier anthropogenic layers may be present underneath the debris layers, but the eventual presence of such layers cannot be checked because of the impossibility to core these materials.

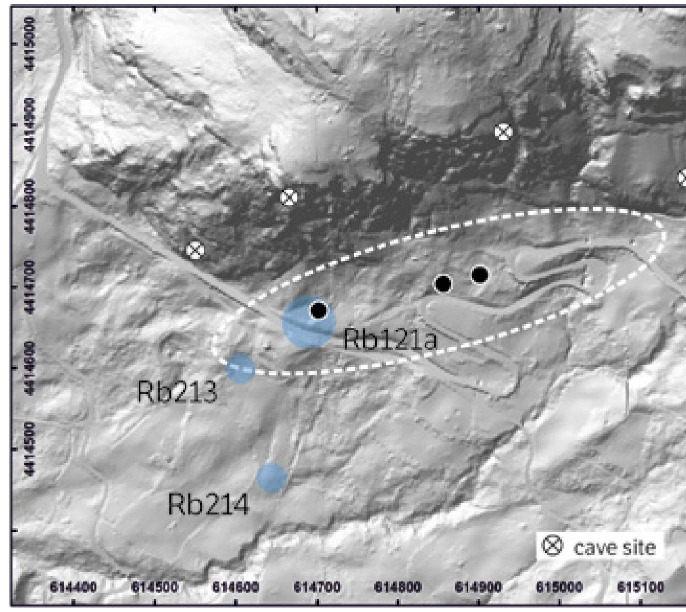

Figure 40. Overview of Timpa Sant'Angelo. Paleosols containing archaeological materials were identified in three locations (black dots) at the foot of the debris slope. RAP sites plus occasional finds indicate a large area (white outline), cut by the modern road and quarry, was inhabited in prehistory.

Figure 41. Section in the roadside quarry at Pietra Sant'Angelo. 1: Ah horizon 0-40cm, 2: matrix supported layer containing pottery and bones 40-90cm, 3: non-matrix supported layer >90cm.

Figure 42: Landscape setting of site Rb130a (Mandroni di Maddalena) on the debris slope of the Timpone di San Lorenzo, some 15m above the bed of the Raganello (not visible). The main habitation plateau has been highlighted for clarity. View from the SW (photo: W. de Neef).

3.4.6 Sites in debris slopes: 130a Mandroni di Maddalena

The steep valley slopes at the exit of the upper Raganello gorge are marked by the abundant occurrence of debris cones and slopes. In previous archaeological surveys a relatively rich and extensive concentration of protohistoric pottery fragments had been found at their surface (figure 42). The recent construction of a footpath for tourists entailed some levelling of the debris cones and damage to known occupation layers. Therefore the question arose what the extent and degree of preservation of the subsurface reservoir of archaeological material might be. To answer this question, soils and sediments in the levelled area were studied by coring for their genesis and stratification.

These corings showed that soil depth (i.e. soil material that could be cored and did not consist of stony debris without soil matrix filling interstices) was limited to about 40 cm. The presence of sherds at or near the surface has to be ascribed to transport of materials originating from the overlying slopes, but that transport may have been over a very short distance. Whether deeper layers contain archaeological materials thus could not established by coring. This site, in fact, forms a typical illustration of the inadequacy of coring as a means to assess the presence or absence of archaeology in such coarse textured debris, and of the need for observations in test pits to achieve this goal.

3.4.7 General remarks

The area of the Upland USL mainly consists of silty soils derived from a marl substrate that holds intercalated beds of more erosion resistant bedrock (i.e. phyllite and sandstone), causing this erosion sensitive area to contain more stable sites locally. Geomorphological processes like fluvial incision and mass movement (slide, slump, etc.) dominate the area and have resulted in a general prevalence of shallow soils. Local accumulation of colluvium containing archaeological material is limited, and mainly occurs behind terrace walls.

Most of the ‘simple impasto upland sites’ identified by the RAP surveys are locations where underlying reservoirs of ceramics-containing layers are being exposed by erosion or soil labour, producing a regular supply of archaeological material. These reservoirs are rarely true palaeosurfaces, since truncation is a dominant feature leading to large-scale removal of the upper soil layers. In some cases they may consist of dug-in features, which are now being exposed. True old palaeosurfaces are rare and largely owe their preservation to their protection by overlying, later deposited material. This is mostly colluvium, as in agricultural terraces, but very incidentally was found to be due to raising of the land surface (e.g. mound building). Another example is formed by the occupation layers in debris slopes underneath limestone cliffs, which owe their preservation to the continuous supply of more recent debris.

4 GENERAL DISCUSSION AND CONCLUSIONS

In the preceding chapter, observations on the geology, geomorphology, and soils around a series of characteristic archaeological sites within the Raganello river catchment have been presented and discussed. These observations can be combined into a more general theme – the link between landscape stability and archaeological record – and can be used to answer the four research questions that were posed in the preface. Additionally, the results can be used for an evaluation of the geo-archaeological approaches proposed by Feiken (2014) for the hidden landscapes of the Raganello river catchment – in particular their applicability at detailed scale. These various topics will be successively dealt with in this chapter, after which some general conclusions will be drawn.

4.1 Landscape stability and the archaeological record of the Raganello river catchment

Landscape stability can be described as soil stability or slope stability, and concerns the stability of a land surface and the extent to which this surface has been affected by 'gradational' processes. Gradational processes in this context include all erosion and accumulation processes that lead to removal of material from the land surface (degradational processes) or to deposition of material on the land surface (aggradational processes). For an extensive discussion of these concepts and their application in soil science, reference is made to Bos and Sevink (1975).

It is evident that a distinction should be made between stability and lowering (degradation) of the land surface: in the latter case archaeological materials that are present in the topsoil are removed or destroyed - unless they originate from dug-in features that are currently being exposed. Deposition (aggradation) causes a land surface to be raised. In such a case, archaeological materials may occur as buried materials, owing their preservation to anthropogenic (e.g. construction of agricultural terraces) or natural burial processes (e.g. by slope deposits underneath cliffs or by alluvial fan deposits). If buried, such archaeological materials will not show up in archaeological field surveys unless they are brought to the surface by (a combination of) later erosion, artificial cuts, tillage or levelling of agricultural terraces. Another important process is the occasional deep ploughing of fields, which may turn up previously buried archaeological materials, but which at the same time seriously disrupts the archaeological archive by deeply homogenizing the soil layer that is touched by the plough and by the devastating effect on the archaeological features and materials themselves.

Clearly, several types of landscape stability and land surfaces must be distinguished within the Raganello River catchment. Descriptions and examples of these are given below.

4.1.1 Stable land surfaces

Stable land surfaces, which have not been eroded and thus more or less truncated due to natural erosion processes or by plough erosion (anthropogenic erosion), are rare. They are limited to:

a) Older stable land surfaces with well-developed and well-drained (permeable) soils. Examples can be found in the relatively level and non-dissected older marine terraces and old alluvial fans, both with soils that have more or less retained their surface horizons. In the case of the marine terraces, these are eluvial horizons in which a complex archaeological record may be present because of their relatively high age, but stratification will be poor as a result of topsoil biological homogenisation (see section 1.3.1). Alluvial fan soils are often relatively stable because of the highly permeable subsoil, but rarely escape intensive ploughing and the concurrent truncation of their soil. In the Raganello catchment, older stable land surfaces with long archaeological records are both rare and often under intensive agriculture, so the integrity of these fragile records is likely to be rapidly destroyed, particularly by deep ploughing.[21]
b) Relatively young land surfaces that have not yet been eroded, buried under recent sediment, or intensively cultivated. Examples may be encountered in the recent coastal plain and associated fluvial deposits, but these surfaces in the plain of Sybaris are generally too young to hold pre- or protohistoric archaeological

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21 The extent to which the soil archive of stable land surfaces is preserved also depends on the soil forming processes that have been active. A typical example of this is the strong churning of Vertisols, which can destroy stratification and anthropogenic surface layers; in other soils such (bio) turbation may be inexistent and artefacts, once deposited, remain in place if not removed by geomorphological processes active on that surface.

materials (see e.g. Hofman 2002). In other words, the probability of encountering young stable land surfaces with relevant archaeological records in the overall highly unstable Raganello river catchment is very low.

4.1.2 Degradation

Most land surfaces in the Raganello catchment are unstable and have been subjected to more or less serious degradation because a combination of relatively steep slopes, unstable parent material (easily erodible or sensitive to mass movement), and intensive land use has led to large-scale soil erosion. This is reflected in the fact that more or less truncated soils are by far the dominant soil type. This truncation has been seriously aggravated by the introduction, after the Second World War, of heavy mechanized ploughing with concurrent massive plough erosion (mass transport) and enhanced erosion by surface run-off throughout the catchment.

Degradational land surfaces may still hold in situ archaeological features, if these were dug-in to such depth that later degradation (e.g. by deep ploughing) has not yet led to their complete removal. Examples of such dug-in features were encountered in all landscape types (e.g., site Rb050 in the Foothills USL and site Rb073 in the Uplands USL), and they often act as a source of archaeological materials that are spread over underlying slopes as a result of soil tillage. In many cases surface scatters of archaeological materials could be directly linked to such dug-in features. Continued mechanical ploughing and levelling of fields will lead to further degradation of these important remains.

4.1.3 Natural aggradation

Natural aggradation is defined here as aggradation ruled by the physical laws that control erosion and deposition at slope-to-landscape scale. These laws form the basis for mathematical models that predict erosion and deposition at these scales, such as the CALEROS model elaborated for the Contrada Maddalena catchment. Broadly speaking, erosion occurs on slopes above terraces, upper slope sections and in upper parts of catchments, and deposition on terraces, footslopes, and in lower parts of catchments. In the coastal plain, for example, the build-up of the huge alluvial fans of the Raganello and Crati rivers has led to the burial of the Greek town of Sybaris and its Hellenistic and Roman successors. In the uplands, local accumulation of slope debris underneath limestone cliffs has resulted in the burial of prehistoric sites.

Processes may range from more or less ‘geological’ processes to very local ‘anthropogenic soil erosion’, with corresponding differences in spatial and temporal scales. Buried land surfaces resulting from natural aggradation by geological processes are typically relatively easy to identify through appropriate studies, that is, by coring to identify and excavation to expose former land surfaces. A typical example is site Rb121a, where such layers are intercalated in a debris slope and were discovered as a result of their exposure by local quarrying. At the scale of fields, local colluviation and the concurrent development of agricultural terraces may result in the burial of land surfaces and the conservation of associated archaeological materials and features. Unfortunately it is generally very hard or even impossible to establish the genesis and age of agricultural terraces without the employment of advanced analytical methods and truly detailed studies. Thus, whether a terrace was intentionally constructed and dates back to early times (e.g. during the Bronze Age) or is of much more recent age and results from continued ploughing and associated soil transport in relatively modern times, could not be determined from our observations. Agricultural terraces are widespread in the Mediterranean, including the Raganello catchment, and since they often hold archaeological materials their characteristics and genesis merit some further discussion (see section 4.1.5).

4.1.4 Anthropogenic aggradation

Intentional or accidental raising of the land, and the attendant covering (burying) of an existing land surface, has been one of the fundamental activities of mankind during all times. Raising platforms for the construction of temples and palaces or simple houses, and construction of living mounds in inundation-prone areas, are examples of the former; decay of buildings and gradual accumulation of refuse over time, of the latter.

Whereas the types of aggradation described in section 4.1.3 are ruled by the physical laws that control erosion and deposition at slope or landscape scale, human actions raising a land surface, whether intentionally or not, do not follow such rules. Thus physically deterministic models like CALEROS cannot predict the occurrence and conservation of the associated landforms and materials. This is evident for larger, more or less monumental constructions such as the cult centre on the Timpone della Motta near Francavilla Marittima, but less so in mountainous, predominantly degradational landscapes with much more modest constructions and deposits of associated anthropogenic materials.

Small sites in such degradational landscapes that do not show up as obvious 'anthropogenic landforms' because of their morphology may easily remain unnoticed, particularly if they do not betray their presence by surface finds. The 'mound' at site Rb073 is an example of a small anthropogenic aggradational feature that remained unnoticed in the field surveys for this reason. The occupation layers identified below the ash layer represent periods of stability alternating with periods of anthropogenic aggradation. Whether the deposits in the terrace downslope of the mound are to be considered 'agricultural terrace deposits' or also are of anthropogenic origin is not clear from the corings, but the latter certainly cannot be excluded. It is also not clear whether the mound itself is unique or that more such features have remained unnoticed during the RAP field surveys.

4.1.5 Agricultural terraces and their genesis

The problems encountered in the study of Mediterranean agricultural terraces and their genesis have been extensively described in the literature (e.g. Countryman 2012). Such terraces may consist, at their base, of topsoil material which is in situ and only slightly affected by soil tillage, and which is covered by more recent colluviated soil material. In such cases more or less in situ archaeological materials and features may be encountered in and beneath that topsoil material, whereas archaeological materials in the overlying colluvial layers are reworked and derived from the overlying slope. However, an agricultural terrace may also be completely composed of relatively recently colluviated soil material, and all intermediate situations may occur, with a smaller or larger role being played by ploughing. Lastly, terraces may be completely artificial, being intentionally constructed by building retaining walls and bringing in soil material from elsewhere, a practice fairly common in modern olive culture. In the latter case, they do not result from 'natural aggradation' but from 'anthropogenic aggradation' (see section 4.1.4). Such practice has not been observed in the Raganello catchment, but it should be emphasized that this was already common practice in Roman times.

In the Raganello river catchment it has been generally impossible, on the basis of observations in corings or small pits, to discriminate between in situ but worked topsoil material and colluvial material, or between 'older' and 'younger' colluvia. Moreover, it was equally impossible to establish whether a drystone wall currently retaining an agricultural terrace was intentionally built to cause the formation of this terrace by retaining colluviated material, or was only constructed to stabilize the slope at some (possibly even late) stage in the development of a terrace formed unintentionally through colluviation induced by land use and retention of the colluvium by vegetation (e.g. rows of shrubs). In other words, drystone walls do not betray their origin and age in a straightforward way when assessed by corings or pits.

These fundamental problems in the study of agricultural terraces were particularly acute when studying terraces on alluvial fans and similar poorly sorted gravelly and stony, highly calcareous deposits, which are often very hard to core and contain too little fine earth to reliably judge the provenance of the material (A or B horizon derived). The differentiation of soil horizons in such alluvial fan materials was far too weak for the extent of post-depositional soil development to be used as a criterion for the age of specific layers in such a terrace. In other words, 'recent' colluvium from coarse textured alluvial fan deposits, 'old' (i.e. protohistoric) colluvium from such deposits, and soil material that was transported downslope as a result of intensive modern ploughing could not be distinguished from each other on the basis of macroscopic observations on soil properties. One example is the terrace at site Rb050.

Soil horizon differentiation is more rapid and pronounced in soils developed in marl, shale or phyllite derived materials, with darker and more humic topsoils (Ah horizon) over yellowish brown Bw or Bt horizons, often with some secondary lime. Nevertheless here, too, easily identifiable contrasting layers or horizons in agricultural terraces were rare. Evidently, upon gradual accumulation of colluvial material and simultaneous tillage, soil horizon differentiation, if occurring at all, is continuously being obliterated by physical homogenisation. Clear indications for the occurrence of relatively intact former topsoils buried under colluvial material, hence protected against degradation, were found only rarely. One possible example is the terrace at site Rb175.

Possibly a combination of observations in large transversal trenches, detailed microscopic studies of soil thin sections, and systematic radiocarbon dating might provide more detailed information on the age and genesis of such agricultural terraces, but this would require permissions and resources not usually available in archaeological surveys or regional studies.

4.2 Research questions

Questions posed in the preface that relate to landscape stability and gradational processes have been largely answered in the sections above. These answers can be summarized as follows:

Question 1: *How do natural and anthropogenic slope processes affect the archaeological landscape in the Mediterranean environment?*

Effects have been described in terms of the extent of 'gradation' of a land surface after a specific point in time, whether minimal (stable) or significant (either aggrading or degrading). In the Raganello river catchment, degradation is by far the dominant phenomenon, with plough erosion currently having a major impact. Furthermore, it is important to distinguish between intentional anthropogenic processes (digging and raising) and gradational processes that obey the physical laws for mass transport on slopes - including those that are triggered by humans. Whereas the former may very well escape unnoticed in field surveys, impacts of the latter can be readily identified and include the development of agricultural terraces and severe truncation of soils by ploughing.

Question 2: *How has the specific post-depositional history of each landscape unit contributed to its current archaeological surface record? What are the diachronic effects of erosion and sedimentation on the preservation and detectability of archaeological remains in each landscape unit?*

It is the gradational history of the unit that largely determines the resulting archaeological surface record, keeping in mind that this record is the combination of archaeological materials deposited over time, as well as their in- and output by post-depositional processes. The current surface record for a given field may in many instances be largely controlled by downslope transport, through ploughing, of archaeological materials that stem from dug-in features on the overlying slope. Such materials could originally have been absent in the field concerned, or could have been exported from that field when agricultural terraces are being destroyed by levelling or field boundaries were changed.

The recent intensive plough erosion is gradually transforming the archaeological surface record from one in which the fragments encountered in the topsoil could be described as more or less in situ, to one where they are part of a transient soil layer that is moving downslope while at the same time being homogenized (see section 3.3.1). At the same time, the more fragile materials are increasingly fragmented and decayed. Exceptions are formed by land surfaces that were buried under sediment to such a depth that they are not affected by modern tillage (plough erosion), and dug-in features that are still intact. In most of the Raganello river catchment, only archaeological materials in dug-in features still reflect the in situ archaeological archive.

Question 3: *What is the current state of preservation of archaeological remains as recorded in surveys, and what is the character of the main current threats to this heritage?*

Evidently, the major current threat to the archaeological heritage is intensive agriculture, with its mechanized ploughing, tendency to increase field sizes by removal of terrace retaining walls and other field boundaries, and levelling of slope discontinuities. Retaining walls are in many cases no longer being maintained, leading to their gradual decay and concomitant further erosion of the materials contained in the terrace fills. Concentrations of archaeological remains in topsoils may *temporarily* increase because of their release from the reservoirs (e.g. dug-in features, former occupation layers and colluvium-protected former land surfaces) below, but over time such remains will be dispersed and degraded - a process that is clearly ongoing.

The fourth question raised in the preface was '*Which are the prevalent archaeologically exploited soils in the different landscape zones, and what soil characteristics are likely to have determined the type of exploitation?*'

These questions were extensively dealt with by Feiken (2014), who focused on the evaluation of the land units and their soils for various types of early land use. Our own observations provide little additional systematic information on soils and their suitability over time at larger spatial scales (i.e. beyond the site scale). At the local scale, our soil key (Appendix II) and the information on soil formation in the Raganello river catchment provided in chapter 2 can be used to identify the general characteristics of the soils in the types of parent material that are present in the specific area of study. This was the major aim in developing the soil key.

Using the soil key, and interpreting the gradational history in terms of the depth and nature of the soil profile that existed in the period for which the specific area is being evaluated for suitability and crop production, values for relevant soil parameters can be estimated and used as inputs for CALEROS-type models. However, this will require an adaptation of the model, replacing the current approach of a start of soil formation in the Early Holocene by one which starts with a specified soil pattern, including related soil characteristics and properties, at a specified point in time.

4.3 Evaluation of the mapping approaches developed by Feiken (2014)

Feiken (2014) developed two geoarchaeological approaches for mapping aspects of the landscape relevant to understanding its archaeological record: the LC landscape classification approach, and the CALEROS-computer simulation approach. These approaches allow for results to be applied in regional archaeological surveys, predicting the likelihood that archaeological materials, if they ever were deposited, will have continued to be present (and therefore detectable) at the surface or in the topsoil. In terms of landscape stability and related concepts, the detectability of preserved finds is based on the overall gradational history of the unit, being stable, aggradational or degradational, with degradational units having the least chance of preservation of archaeological materials. In these approaches, the likelihood that the unit was used depends on substrate characteristics and other, unit specific environmental characteristics (e.g. altitude, insolation, etc.).

In his LC approach Feiken used geological and geomorphological criteria to classify the landscape and its composing units, assuming that individual land units, particularly at the LC10 scale, are sufficiently uniform regarding their geology and the geomorphological processes involved. The approach has been extensively described by van Leusen and Feiken (2007) and by Feiken (2014). At scale 1:10 000, mapping units such as the marine terraces and large alluvial fans may indeed be quite homogeneous regarding the parameters that were used in the classification. However, particularly for landscapes that exhibit a fine pattern of erosive and accumulative slope sections, such as the uplands and foothills USL with complexes of agricultural terraces, LC10 units are often not sufficiently homogeneous as was already noted by the above mentioned authors. Yet another example of this is provided by the stable surfaces of the older marine terraces, where an intricate pattern occurs of intact (with E horizon) and slightly truncated soils (without E horizon).

In such complex landscapes, the LC approach provides an indication for the overall structure of the landscape in terms of stable, aggradational and degradational parts of that landscape, and can be used as such for the design of regional surveys and for the selection of terrains with a high likelihood of preserved and detectable archaeological remains. However, actual distribution patterns of artefacts at the field scale are far more complex and 'fine-grained', and cannot be predicted or readily explained in this manner. This holds particularly for archaeological materials that originate from dug-in features and have 'surfaced' as a result of plough erosion and other forms of degradation. The LC approach also does not take into account the possibility of anthropogenic aggradation (see section 4.1.3), nor does it account for differences in age and related extent of soil formation between mapping units that are identical in terms of the geomorphological processes involved, or for soil variation directly linked to subsoil variability (e.g. an alternation between marls and sandstones). A typical example of these latter objections is provided by the landscape of marine terraces, which is classified as a single unit in the LC10 system but ranges from relatively recent terraces with weakly developed Orthic Luvisols to old marine terraces with very strongly developed Albic Chromic Luvisols (section 2.5.1).

It might be thought that these limitations can be overcome by further detailing the scale of the survey, for example to 1:5 000. However, this would not fundamentally solve the problem that the differentiating criteria do not include the nature and extent of soil development. These can only be assessed through detailed soil surveys. Moreover, early land utilization (e.g. Bronze Age) may be landscape controlled at even finer scales, with fields at decametre-scale. The gap between the parameter scale and criteria applied in the theoretical assessment of suitability for early agriculture, and those that were in fact applied for past land use, might be considerable. Nor would a more detailed LC5 survey perform better in predictions of artefact distributions, since the archaeological archive appears to be mostly contained in dug-in features and agricultural terraces.

Feiken (2014) used the deterministic model CALEROS to quantitatively predict degradation and aggradation of the land surface. CALEROS has several stated limitations: apart from being hard to parametrize and validate, it assumes a full control of gradation by natural physical transport processes and neglects intentional anthropogenic transport (digging in or raising of the land surface). Furthermore, it considers the landscape at a relatively coarse resolution (25m cells), averaging out smaller-scale differences. Thus, for example, slopes that have a series of small agricultural terraces holding a significant archaeological archive not yet destroyed by ploughing cannot be distinguished from slopes with similar general characteristics, but without such terraces and associated archives.

A further limitation of the CALEROS approach was that land use is assumed to start with soils that were optimally developed over a prolonged period of stability. Feiken solved the problem of changes in soil properties upon land use by coupling an erosion and soil development model with a land evaluation model, linking crop production to soil erosion and changes in soil properties. He also, unrealistically, assumed that actual land use equals potential land use for given land use types and associated crops, whereas in reality it is much more likely that land use (being dependent on such factors as cultural preferences, political and demographic developments, et cetera, besides local economic factors) was not maximal in either time or space. The exploratory character of CALEROS required such simplifying assumptions to be made, but it also means that its current predictive value is low.

4.4 Final remarks and conclusions

It is evident that our research was at a detailed scale and oriented towards the identification and impacts of processes that act at such scale. Moreover, our results are based on intensive coring of representative sites and interpretations in terms of the succession of gradational processes at that scale, instead of the delineation of landscape units on the basis of the current geomorphology and major geological units at far less detailed scales as was done in essence for the Landscape Classification (LC) method by Feiken (2014). Feiken understood and described the shortcomings of his terrain classification system and CALEROS-model for the evaluation of the results of archaeological field surveys, including the fact that these are due to the discrepancy between the scale of his system and that of the archaeological survey, and to the assumption of *natural* gradation being the only relevant type of process.

Our observations indicate that further detailing of the scale of LC-like classification systems for landscapes such as that of the Raganello river catchment will do little to improve its results, and that another approach is needed, founded on a systematic coring program to assess the history of the land surface (‘gradational history’) and the properties of the soils and sediments, taking into account such phenomena as anthropogenic gradation. Nevertheless, the LC10 approach can be adequately used for strategic planning of archaeological surveys in such complex areas, delineating zones which differ with respect to type and likelihood of occurrence of surface or near surface sites other than those connected with dug-in or buried archives.

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APPENDICES

Appendix I: Terminology used for the description and classification of soils

In the description of soils according to the internationally used FAO Guidelines for soil description (FAO, Rome, 2006), use is made of master horizons and layers. These were formed as a result of specific soil forming processes (or their absence) and are grouped into master horizons, adding suffixes to indicate the specific process or processes involved. Master horizons or layers may meet the criteria set for diagnostic horizons or layers, or those that are defined for diagnostic properties. These diagnostic horizons, layers, and properties are used for classifying soils in the 'World Reference Base for Soil Resources 2006' (IUSS, WGWRB, 2006). The criteria are based on the quantified extent to which a certain process or group of soil forming processes has resulted in specific soil properties. For extensive descriptions of horizons, layers, and properties reference is made to the Guidelines for Soil Description and the World Reference Base for Soil Resources; here, the descriptions are limited to those that are characteristic for the soils in the Raganello catchment and in similar Mediterranean-type areas.

MASTER HORIZONS AND LAYERS

A horizons

These are mineral horizons that formed at the surface or below an O horizon (humus), in which all or much of the original rock structure has been obliterated and which are characterized by one or more of the following:

- an accumulation of humified organic matter intimately mixed with the mineral fraction and not displaying properties characteristic of E or B horizons (see below);
- properties resulting from cultivation, pasturing, or similar kinds of disturbance;
- a morphology that is different from the underlying B or C horizon, resulting from processes related to the surface.

If a surface horizon (or epipedon) has properties of both A and E horizons but the dominant feature is an accumulation of humified organic matter, it is designated an A horizon.

E horizons

These are mineral horizons in which the main feature is loss of silicate clay, iron, aluminium, or some combination of these, leaving a concentration of sand and silt particles, and in which all or much of the original rock structure has been obliterated.

An E horizon is lighter in colour than an underlying B horizon. In some soils, the colour is that of the sand and silt particles, but in many soils coatings of iron oxides or other compounds mask the colour of the primary particles. An E horizon is most commonly differentiated from an underlying B horizon in the same soil profile: by colour of higher value or lower chroma, or both; by coarser texture; or by a combination of these properties. An E horizon is commonly near the surface, below an O or A horizon and above a B horizon.

B horizons

These are horizons that formed below an A, E, H or O horizon, and in which the dominant features are the obliteration of all or much of the original rock structure, together with one or a combination of the following:

- illuvial concentration, alone or in combination, of silicate clay, iron, aluminium, humus, carbonates, gypsum or silica;
- evidence of removal of carbonates;
- residual concentration of sesquioxides;
- coatings of sesquioxides that make the horizon conspicuously lower in value, higher in chroma, or redder in hue than overlying and underlying horizons without apparent illuviation of iron;
- alteration that forms silicate clay or liberates oxides or both and that forms a granular, blocky or prismatic structure if volume changes accompany changes in moisture content;

All kinds of B horizons are, or were originally, subsurface horizons. Included as B horizons are layers of illuvial concentration of carbonates, gypsum or silica that are the results of pedogenetic processes (these layers may or may not be cemented).

Examples of layers that are not B horizons are: layers in which clay films either coat rock fragments or are on finely stratified unconsolidated sediments, whether the films were formed in place or by illuviation; layers into which carbonates have been illuviated but that are not contiguous to an overlying genetic horizon; and layers with gleying but no other pedogenetic changes.

In the Raganello area only a few types of the various B horizons are truly relevant:

- Bt horizon. Based on the illuvial accumulation of clay and sesquioxides, i.e. with abundant clay-iron cutans (leading to argic B horizon as diagnostic horizon)

- Bw horizon. (cambic B horizon as diagnostic horizon). A horizon is classified as Bw when the B horizon has vertic properties or only exhibits soil structure in combination with stronger chroma or redder hue than the parent material and does not fulfil the requirements of a Bt horizon. Based on the weathering and associated formation of structure and clay. If clayey, often with more or less pronounced vertic properties (because of swell and shrink) and/or secondary calcium carbonate accumulation (leading to cambic horizon as diagnostic horizon).

Suffixes: subordinate characteristics within master horizons and layers

h. Accumulation of organic matter: Designates the accumulation of organic matter in mineral horizons. The accumulation may occur in surface horizons, or in subsurface horizons through illuviation.

p. Ploughing or other human disturbance: Indicates disturbance of the surface layer by ploughing or other tillage practices. A disturbed organic horizon is designated Op or Hp. A disturbed mineral horizon, even though clearly once an E, B or C, is designated Ap.

t. Accumulation of silicate clay: Used with B to indicate an accumulation of silicate clay that either has formed in the horizon or has been moved into it by illuviation, or both. At least some part should show evidence of clay accumulation in the form of coatings on ped surfaces or in pores, as lamellae, or as bridges between mineral grains.

DIAGNOSTIC HORIZONS, PROPERTIES, AND MATERIALS

Argic horizon

The argic horizon (from Latin argilla, white clay) is a subsurface horizon with distinct higher clay content than the overlying horizon. The textural differentiation may be caused by:

- an illuvial accumulation of clay;
- predominant pedogenetic formation of clay in the subsoil;
- destruction of clay in the surface horizon;
- selective surface erosion of clay;
- upward movement of coarser particles due to swelling and shrinking;
- biological activity;
- a combination of two or more of these different processes.

Sedimentation of surface materials that are coarser than the subsurface horizon may enhance a pedogenetic textural differentiation. However, a mere lithological discontinuity, such as may occur in alluvial deposits, does not qualify as an argic horizon. Soils with argic horizons often have a specific set of morphological, physico-chemical and mineralogical properties other than a mere clay increase. These properties allow various types of argic horizons to be distinguished and their pathways of development to be traced.

Field identification

Textural differentiation is the main feature for recognition of argic horizons. The illuvial nature may be established using a ×10 hand-lens if clay skins occur on ped surfaces, in fissures, in pores and in channels – an illuvial argic horizon should show clay skins on at least 5 percent of both horizontal and vertical ped faces and in the pores. Clay skins are often difficult to detect in shrink–swell soils. The presence of clay skins in protected positions, e.g. in pores, meets the requirements for an illuvial argic horizon.

Calcic horizon

The calcic horizon (from Latin calx, lime) is a horizon in which secondary calcium carbonate ($CaCO_3$) has accumulated in a diffuse form (calcium carbonate present only in the form of fine particles of less than 1 mm, dispersed in the matrix) or as discontinuous concentrations (pseudomycelia, cutans, soft and hard nodules, or veins). The accumulation may be in the parent material or in subsurface horizons, but it can also occur in surface horizons. If the accumulation of soft carbonates becomes such that all or most of the pedological and/or lithological structures disappear and continuous concentrations of calcium carbonate prevail, a hypercalcic qualifier is used.

Diagnostic criteria

A calcic horizon has:

1. a calcium carbonate equivalent in the fine earth fraction of 15 percent or more; and
2. 5 percent or more (by volume) secondary carbonates or a calcium carbonate equivalent of 5 percent or more higher (absolute, by mass) than that of an underlying layer; and
3. a thickness of 15 cm or more.

Field identification

Calcium carbonate can be identified in the field using a 10-percent hydrochloric acid (HCl) solution. The degree of effervescence (audible only, visible as individual bubbles, or foam-like) is an indication of the amount of lime present. This test is important if only diffuse distributions are present. When foam develops after adding 1 M HCl, it indicates a calcium carbonate equivalent near or more than 15 percent.

Other indications for the presence of a calcic horizon are:

- white, pinkish to reddish, or grey colours (if not overlapping horizons rich in organic carbon);

- a low porosity (interaggregate porosity is usually less than that in the horizon immediately above and, possibly, also less than in the horizon directly underneath).

Calcium carbonate content may decrease with depth, but this is difficult to establish in some places, particularly where the calcic horizon occurs in the deeper subsoil. Therefore, accumulation of secondary lime is sufficient to diagnose a calcic horizon.

Relationships with some other diagnostic horizons
When calcic horizons become indurated, transition takes place to the petrocalcic horizon, the expression of which may be massive or platy. In dry regions and in the presence of sulphate-bearing soil or groundwater solutions, calcic horizons occur associated with gypsic horizons. Calcic and gypsic horizons typically (but not everywhere) occupy different positions in the soil profile because of the difference in solubility of calcium carbonate and gypsum, and they can normally be distinguished clearly from each other by the difference in morphology. Gypsum crystals tend to be needle-shaped, often visible to the naked eye, whereas pedogenetic calcium carbonate crystals are much finer in size.

Cambic horizon
The cambic horizon (from Italian cambiare, to change) is a subsurface horizon showing evidence of alteration relative to the underlying horizons, but the alteration is not sufficient enough for the classification of other horizons.

Diagnostic criteria
A cambic horizon:
1. has a texture in the fine earth fraction of very fine sand, loamy very fine sand, or finer; and
2. has soil structure or absence of rock structure in half or more of the volume of the fine earth; and
3. shows evidence of alteration in one or more of the following:
   a. higher Munsell chroma (moist), higher value (moist), redder hue, or higher clay content than the underlying or an overlying layer; or
   b. evidence of removal of carbonates or gypsum; or
   c. presence of soil structure and absence of rock structure in the entire fine earth, if carbonates and gypsum are absent in the parent material and in the dust that falls on the soil; and
4. does not form part of a plough layer, does not consist of organic material and does not form part of an another diagnostic horizon (e.g. argic, calcic, petrocalcic or vertic horizon); and
5. has a thickness of 15 cm or more

Carbonates
Carbonates in soils are either residues of the parent material or the result of neo-formation (secondary carbonates). The latter are concentrated mainly in the form of soft powdery lime, coatings on peds, concretions, surface or subsoil crusts, or hard banks. The presence of calcium carbonate ($CaCO_3$) is established by adding some drops of 10-percent HCl to the soil. The degree of effervescence of carbon dioxide gas is indicative for the amount of calcium carbonate present. In many soils, it is difficult to distinguish in the field between primary and secondary carbonates. The reaction to acid depends upon soil texture and is usually more vigorous in sandy material than in fine-textured material with the same carbonate content. Other materials, such as roots, may also give an audible reaction. Dolomite commonly reacts more slowly and less vigorously than calcite. Secondary carbonates should be tested separately; they normally react much more intensely with HCl.

Note for classification purposes
Important carbonate contents for classification are:
- ≥ 2 percent calcium carbonate equivalent → calcaric material.
- ≥ 15 percent calcium carbonate equivalent in the fine earth, at least partly secondary → calcic horizon.

Indurated layer with calcium carbonate, at least partly secondary → petrocalcic horizon.

Petrocalcic horizon
A petrocalcic horizon (from Greek petros, rock, and Latin calx, lime) is an indurated calcic horizon that is cemented by calcium carbonate and, in places, by calcium and some magnesium carbonate. It is either massive or platy in nature, and extremely hard.

Diagnostic criteria
A petrocalcic horizon has:
1. very strong effervescence after adding a 10-percent HCl solution; and
2. induration or cementation, at least partially by secondary carbonates, to the extent that air-dry fragments do not slake in water and roots cannot enter except along vertical fractures (which have an average horizontal spacing of 10 cm or more and which occupy less than 20 percent [by volume] of the layer); and
3. extremely hard consistence when dry, so that it cannot be penetrated by spade or auger; and
4. a thickness of 10 cm or more, or 1 cm or more if it is laminar and rests directly on continuous rock.

Field identification

Petrocalcic horizons occur as non-platy calcrete (either massive or nodular) or as platy calcrete, of which the following types are the most common:

- Lamellar calcrete: superimposed, separate, petrified layers varying in thickness from a few millimetres to several centimetres. The colour is generally white or pink.
- Petrified lamellar calcrete: one or several extremely hard layers, grey or pink in colour. They are generally more cemented than the lamellar calcrete and very massive (no fine lamellar structures, but coarse lamellar structures may be present).

Non-capillary pores in petrocalcic horizons are filled, and the hydraulic conductivity is moderately slow to very slow.

Relationships with some other diagnostic horizons

In arid regions, petrocalcic horizons may occur in association with (petro-) duric horizons, into which they may grade laterally. The cementing agent differentiates petrocalcic and duric horizons. In petrocalcic horizons, calcium and some magnesium carbonate constitute the main cementing agent while some accessory silica may be present. In duric horizons, silica is the main cementing agent, with or without calcium carbonate. Petrocalcic horizons also occur in association with gypsic or petrogypsic horizon.

Vertic horizon

The vertic horizon (from Latin vertere, to turn) is a clayey subsurface horizon that, as a result of shrinking and swelling, has slickensides and wedge-shaped structural aggregates.

Field identification

Vertic horizons are clayey, with a hard to very hard consistency. When dry, vertic horizons show cracks of 1 cm wide or more. Polished, shiny ped surfaces (slickensides), often at sharp angles, are distinctive.

Appendix II: Soil Key for the Raganello Basin

Criteria used for soil classification for archaeological purposes in the Raganello catchment

For the classification of the soils various criteria are used that are listed below and conform to the criteria and parameters that are generally used in the FAO soil classification (IUSS Working Group WRB, 2006). Additional criteria used are meant to aid archaeologists in a meaningful classification of soils for archaeological purposes, i.e. paying particular attention to anthropogenic impacts on soils, such as the presence of colluvial material over in situ soil horizons, the origin and genesis of this colluvial material, etc. This classification is meant for the soils of the Raganello catchment in Calabria, but can also be used for classification of soils for archaeological purposes in similar Mediterranean areas, i.e. having similar geology and climate.

The classification below starts with the distinction between soils having in situ soil material below the Ah or Ap horizon, and soils which hold intermediate soil horizon(s) which are either composed of colluvium[22] (material that by its composition deviates from the underlying soil and/or weathered rock) or contain materials that are of anthropogenic origin such as ceramics, bone and charcoal. That Ap or Ah horizons are excluded is due to the fact that the provenance of their soil material cannot be established with certainty on the basis of its intrinsic properties. Evidently, in case that they rest on colluvium or material that clearly is of anthropogenic origin, the provenance of the Ap or Ah material is beyond doubt, but such evidence is circumstantial.

If layers/horizons that occur between the Ah or Ap horizon and in situ soil horizons are characterized as anthropogenic (A), their thickness is indicated in decimetre accuracy (measured from the land surface). Criteria by which these layers/horizons are identified as non-original soil horizons include:

- dark organic layer because of the presence of finely divided organic matter as contained in Ah material that has been colluviated: suffix 'om'
- containing charcoal or other materials that indicate its anthropogenic origin: charcoal: suffix ch; ceramics: ca; bones: b; burnt bones: bb; lithics: l

The soil classification pertains to the in situ soil materials that occur below these anthropogenic materials/ horizon(s) or colluvium. It is given below. Depths used for the classification pertain to the depth below the in situ soil surface. Where anthropogenic layers/colluvium occur, this classification thus concerns the soil horizons and their depth below that soil surface. Codes are given as follows: M1/Ach-b-ca70 (Soil classification/anthropogenic horizons).

Descriptions are preferentially based on soil profile pits, but can also be made from corings, though such observations are less precise (e.g. on the occurrence of clay illuviation and slickensides). Tools needed include the Munsell Soil Colour Charts, diluted hydrochloric acid (to test for the presence of $CaCO_3$) and the Guidelines for Soil Description (FAO, 1990: ftp://ftp.fao.org/agl/agll/docs/guidel_soil_descr.pdf).

Criteria and properties used in soil classification include:

1 Hard rock – soft rock: can you auger into it (see FAO) and rock type.
2 Limestone, calcareous / other: see FAO, based on hydrochloric acid test
3 Texture: boulder, gravel, stones, sand, silt, clay (see FAO)
4 Colour: Munsell scale
5 Mollic: Colour Munsell scale and thickness criteria (see FAO)
6 Occurrence of E and B horizons (see FAO)

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22 Instead of the term 'anthropogenic colluvium', in the key the term 'colluvium' is used. This might lead to confusion resulting from the differences in definition of the term 'colluvium' between various schools of earth scientists. Anglosaxons use the term in a much broader sense (including natural deposits) than most Europeans, who restrict its use to anthropogenic deposits only (see also section 1.3.3). Anthropogenic colluvium and colluvium s.s. pertain to material that is composed of a mixture of soil materials and rocks of varied origin, as a result of processes such as man-induced erosion/ deposition, ploughing and intentional anthropogenic deposition. Characteristics include:
- composed of a mixture of materials from different sources, e.g. alluvial fan/terrace gravels and stones, angular marl/schist/sandstone fragments, brick and other anthropogenic materials (charcoal/bone/ceramics).
- generally mixed texture, i.e. clay loam to loamy clay, due to prevalence of loamy to clayey textures in the intact soils. However, if derived from gravelly terrace/alluvial fan deposits, it may also be gravelly and stony.
- generally relatively high in organic matter resulting in a dark colour
- lacking distinct horizon differentiation, e.g. B horizon characteristics
- often calcareous throughout, if parent material upslope is calcareous.

Key for soils in the Raganello basin

1 Hard rock within 30 cm from the soil surface
- 1.1 Limestone: L1
- 1.2 Sandstone: S1
- 1.3 Conglomerate (petrocalcic): P1
- 1.4 Ophiolite: O1

Other soils: go to 2

2 Soils with hard rock deeper than 30 cm or with soft rock:
- 2.1 With Ah horizon (not ploughed, under natural vegetation): go to 3
- 2.2 With Ap horizon: go to 4

3 Ah horizon meeting colour and thickness requirements of mollic A horizon (dark colour due to organic matter):
- 3.1 On limestone: with Ah over reddish/reddish brown clayey B horizon of at least 10 cm: L2
- 3.2 On marl (calcareous clayey to loamy material) or shale
  - Ah over marl/shale: M1
  - Ah over calcareous yellowish / yellowish brown clayey to loamy B horizon of at least 10 cm (formed by weathering of marl/shale), over marl/shale: M2

4 Ap horizon meeting colour requirements of a mollic A horizon (dark Ap horizon), over:
- 4.1 Calcareous yellowish / yellowish brown clayey to loamy B horizon of at least 10 cm (formed by weathering of marl/shale), over marl/shale: M1m
- 4.2 Marl/shale: M2m
- 4.3 Schist (with common angular schist fragments): SCm
- 4.4 Sandstone: S1m
- 4.5 Loamy marine terrace and alluvial fan deposits, lacking petrocalcic horizon or gravels with less than 20% fine earth within 50 cm from the surface: T1m
- 4.6 Loamy marine terrace and alluvial fan deposits, with petrocalcic horizon or gravels with less than 20% fine earth within 50 cm from the surface: T2m
- 4.7 Gravelly marine terrace and alluvial fan deposits (with less than 20% fine earth: T3m
- 4.8 Colluvial deposits: Cm

Other soils: go to 5

5 Ap horizon not meeting colour and / or thickness requirements of mollic A horizon (dark colour due to organic matter):

Soils in colluvium:
- 5.1 Soils in colluvium (>100 cm): Cp.

Soils on Pleistocene marine terrace and alluvial fan deposits:
- 5.2 Light coloured E horizon with sandy to sandy loamy texture of at least 10 cm thickness, over reddish / reddish brown clayey B horizon in marine terrace and alluvial fan deposits: T1p
- 5.3 On marine terrace and alluvial fan deposits with yellowish to reddish loamy to clayey B horizon, lacking petrocalcic horizon or gravels with less than 20% fine earth within 50 cm from the surface: T2p
- 5.4 On marine terrace and alluvial fan deposits with yellowish to reddish loamy to clayey B horizon, with petrocalcic horizon or gravels with less than 20% fine earth within 50 cm from the surface: T3p
- 5.5 Gravelly marine terrace and alluvial fan deposits (gravels with less than 20% fine earth) with secondary lime in the form of concretions, nodules or soft powdery lime: G1p
- 5.6 Gravelly marine terrace and alluvial fan deposits (gravels with less than 20% fine earth) lacking secondary lime in the form of concretions, nodules or soft powdery lime: G2p

Soils of the recent (Holocene) alluvial fans and terraces:
- 5.7 Yellowish grey to grey loamy to clayey recent marine terrace, fluvial and alluvial fan deposits, with secondary lime in the form of concretions, nodules or soft powdery lime: T4p
- 5.8 Yellowish grey to grey loamy to clayey recent marine terrace, fluvial and alluvial fan deposits, lacking secondary lime in the form of concretions, nodules or soft powdery lime: T5p
- 5.9 Gravelly marine terrace and alluvial fan deposits (gravels with less than 20% fine earth) lacking secondary lime in the form of concretions, nodules or soft powdery lime: G3p

Soils on marl/shale:
- 5.10 Calcareous yellowish / yellowish brown clayey to loamy B horizon of at least 10 cm (formed by weathering of marl/shale), over marl/shale: M1p
- 5.11 Calcareous marl/shale: M2p

Soils on schist:

5.12 Yellowish brown to brown clayey to loamy B horizon of at least 10 cm (formed by weathering of schist), over schist (angular schist fragments): SC1p

5.13 Schist (angular schist fragments): SC2p

Soils on sandstone:

5.14 Yellowish brown to brown clayey to loamy B horizon of at least 10 cm (formed by weathering of sandstone), over sandstone: S1p

5.15 Sandstone: S2p

Appendix III: Chemical composition and archaeological relevance of clays

CLAY MINERALS, CHEMICAL COMPOSITION

Clays are secondary minerals that are formed through the alteration of a primary mineral or through the precipitation of solutes. The secondary silicates of interest in soils are the phyllosilicate[1] or aluminosilicate minerals.

Clay minerals are hydrous phyllosilicates with variable amounts of silicon (Si), aluminium (Al), iron (Fe), magnesium (Mg), potassium (K) and other elements[2]

In Dana's system phyllosilicates are separated into a hierarchal system of Types, Groups and Species. In the Raganello catchment two main types are present, namely:

- 1:1 phyllosilicates (1 Si tetrahedral sheet and 1 Al (and/or Mg and Fe) octahedral sheet)
- 2:1 phyllosilicates (1 Al/Mg/Fe octahedral sheet bound between 2 Si tetrahedral sheets)

The Kandite Group, which includes a.o. the mineral kaolinite, is one of the 1:1 Type phyllosilicate minerals. The Mica Group, with biotite, illite, vermiculite, and smectite (with montmorillonite and nontronite) is of the 2:1 Type phyllosilicate minerals.

The 1:1 phyllosilicate minerals have very little isomorphic substitution[3], the 1:1 layers are held to adjacent 1:1 layers by very strong hydrogen bonds, hence the stability of these clay minerals.

Smectitic clays have a high isomorphic substitution (Si by Al and Al by Mg/Fe) and associated layer charge, but the internal surfaces (the region between the 2:1 layers) are accessible to water molecules, ions and molecules present in the aqueous phase, hence the swelling and shrinking of these clay minerals. Illite and other clay minerals in the Mica Group have isomorphic substitution of Al^{3+} for Si^{4+} and are non-swelling.

CLAY MINERALS, DETERMINATION

Clay minerals can be identified with special analytical techniques such as X-ray diffraction, electron diffraction or various spectroscopic methods.

Clay minerals can also be differentiated by their CEC (Cation Exchange Capacity); the stable 1:1 phyllosilicates, Mica and Illite Groups have a CEC that is respectively between 1 – 10 and 10 – 40 cmol kg^{-1}, whereas for the Smectite and Vermiculite Groups the CEC is respectively between 60 – 150 and 100 – 200 cmol kg^{-1}. CEC determination cannot be performed in the field, but has to be done in the laboratory.

CLAY MINERALS, ARCHAEOLOGICAL IMPLICATIONS

The non-swelling character of the (inherent stable) 1:1 phyllosilicates and the permanent physical changes after firing, make that these clay minerals are very suited for ceramics. Smectitic clays, on the contrary, are not suited for pottery, due to their swell and shrink properties.

[1] Phyllosilicates are sheet (or layer) silicate (Si) minerals, formed by parallel sheets of silica tetrahedrons and of octahedrons, filled by Al, Mg or Fe.

[2] A cation is a metal ion with fewer electrons than protons, giving it a positive charge.

[3] Isomorphic substitution is the process by which one element fills a position (within a crystalline structure of a mineral) usually filled by another element of a similar size. However, its charge is often less, causing a charge deficit and thus a permanent negative charge (e.g. Al^{3+} by Mg^{2+})

Appendix IV: Core descriptions

The following core descriptions are organized by landscape zone - Upland Undulating Sloping Land, Marine Terraces, and Foothill Undulating Sloping Land - and within that by numbered site or named transect. Coring identifiers as assigned in the field are given in parentheses.

UPLAND UNDULATING SLOPING LAND

CORINGS SITE Rb173		
UUSL-001 (core SL01)		
Alluvial fan with some stones (quartzitic sandstone) at the surface, yellowish brown topsoil, containing some ceramics		
0-40	Ap	Clay, slightly gritty, small FeMn nodules throughout
40-80	Btk	Less dark soil colour, more yellow. Slightly gritty clay. Carbonate concretions start to occur at 50 cm depth. Weathered rock fragments starting at 60 cm, increasing with depth
80+	C/R	Grittier, orange mottles, clay loam to loam
UUSL-002 (core SL02)		
Soil colour similar to previous, limestone fragments at surface and some pottery shards		
0-40	Ap	Yellowish brown to grey. Very clayey even at the surface
40-70	Bt1	Slightly yellower soil colour. Presumably charcoal sample taken at 60cm. Very thin layer (<5cm) of red soil (burned clay??) at 60 cm and dark aggregate at 70cm (charcoal?)
70-100	Bt2	More yellow with depth, apparent slickensides at 80cm. At 90 cm heavily weathered limestone (might easily be wrongly interpreted as tool). Dark soil aggregates at 100cm
100	C/R	-
UUSL-003 (core SL03)		
Similar to previous two corings, slightly more gritty at surface compared to SL02		
0-40	Ap	-
40-50	C	Transition zone, soil becomes more gritty and yellow
50+	C	-
UUSL-004 (core SL04)		
0-40	Ap	Yellowish brown clayey topsoil
40-80/90	Bt	Darker soil compared to overlying horizon and slightly more clayey. Weathered phyllite present. Starting at 60 cm soil turns more yellow, to turn truly yellow at 70 cm (no more organic material). Slickensides marking the transition between the Bt and C horizon. Again dark aggregates and red soil layer found at 90cm
80/90-100	C	Very gritty, many stones at 100cm, sandstone present
100+	R	Sandstone

UUSL-005 (core SL05)		
Surface similar to SL02		
0-40	Ap	Very wet topsoil
40-70	Bt	Darker and clayey soil, with many angular stones
70+	?	Unable to continue coring due to rock in core
UUSL-006 (core SL06)		
More limestone gravel and stones at surface, slightly yellower soil. Carbonate nodules at surface. Truncated soil covered with colluvium		
0-40	Apk	Large carbonate concretions (>1cm) within the first 20cm, very clayey
40-50	Btk	Yellower soil colour, grittier texture and more stones (unsorted)
50+	C	-
UUSL-007 (core SL07)		
Topsoil is less stony and no calcium carbonate concretions at the surface		
0-40/45	Ap	Brown/yellowish soil colour
40/45-80	Btgk	Top of horizon has a greyish soil colour (reduction), further down the profile soil colour turns yellow, very clayey (clay illuviation) and carbonate nodules present
80+	?	Unable to continue (rock)
UUSL-008 (core SL08)		
Colluvium covered, truncated soil		
0-40	Ap	Clayey with weathered unsorted rock fragments
40-70	Cb	Very slight increase in clay content down the profile (vertic properties), yellowish brown, very stony with unsorted rocks throughout profile
70+	R	-
UUSL-009 (core SL09)		
Medium rocky brown soil with colluvial top and well developed argillic horizon		
0-40	Apk	Very clayey, brown soil with some minor yellow mottles (carbonate)
40-60	Bt1	More stones (colluvium), brownish yellow
60-100	Bt2	Yellower soil (less organic material), more stones
100-110	Cg	Gritty structure, greyish soil colour with red mottles (water stagnation)
110+	R	Abundant rock fragments (<5cm)

UUSL-010 (core SL10)		
Similar to SL09, but outlier of fluvial incision, brown topsoil		
0-50	Ap	Very clayey, brown soil with some small yellow mottles
50-80	Btk	Yellower soil colour, at contact zone with overlying Ap horizon layer of rocks (<10cm), indicating erosional contact at top of Bt
80+	Ck	Gritty structure, yellower soil colour, rock fragments (<5cm)
UUSL-011 (core SL11)		
More stones on surface when compared with previous locations		
0-35	Ap	-
35+	R	-
UUSL-012 (core SL12)		
Medium stony surface, yellowish topsoil, calciumcarbonate concretions at surface (similar to SL09)		
0-40	Apk	-
40-60	Btk1	Brownish/yellow soil with carbonate concretions,
60-90	Btk2	Yellow soil colour, very clayey (more clayey than overlying horizon), wet soil
90-100	C	Concretions are absent, yellow soil, less clayey
100+	R	-
UUSL-013 (core SL12c/d)		
Reference coring 1m west and east respectively of core SL12		
0-40	Ap	-
40+	R	-
UUSL-014 (core SL13)		
Similar to SL09		
0-40	Ap	Brown soil with yellow mottles, stones in profile (colluvium), deeper soils might occur but only in local pockets
40+	R	-
UUSL-015 (core SL14)		
Freshly ploughed soil, yellowish brown topsoil, medium stony (quartzitic sandstones, marl and limestone)		
0-30	Ap	-
30-70	Bt	Brownish yellow soil, rounded and angular rock fragments (<5cm) pointing to mixed origin (fluvial sediment and bedrock), very clayey, common gravel and stone size phyllite fragments, slickensides
70+	R	-
UUSL-016 (core SL15)		
Alluvial fan, extremely stony, angular stones, yellowish brown topsoil		
0-30	Ap	-
30-50	Bt	Brownish yellow clay to clay loam with common weathered stones. Brown colour changes to yellowish with depth
50+	R	-

UUSL-017 (core SL16)		
Similar to SL15		
0-30	Ap	-
30-50	Bt	Similar to SL15, soil colour turns more yellow with depth but does not become truly yellow at contact zone between Bt and R
50+	R	-
UUSL-018 (core SL17)		
Brown topsoil, mainly quartzitic sandstone and minor limestone		
0-40	Ap	-
40-100	Bt	Brownish yellow clay, turning more yellow with depth
100+	C	-
UUSL-019 (core SL18)		
Alluvial fan, extremely stony and yellowish brown topsoil		
0-40	Ap	Soil might be deeper but due to extreme amount of stones in the profile, further coring was impossible
UUSL-020 (core SL19)		
Similar to SL17, brown topsoil		
0-40	Ap	-
40-90	Bt	No colour difference between Ap and Bt
UUSL-021 (core SL20)		
Gully incision, moderately stony surface (quartzitic sandstone, limestone)		
0-40	Ap	Very clayey (estimated at +-80%)
40-50	Bt	Too stony to continue coring
50+	?	-
UUSL-022 (core SL21)		
Similar to SL20		
0-40	Ap	-
40-110	Bt	Very clayey, very weathered iron rich quartzitic sandstone, starting at 80 cm iron oxidation (red mottles)
110+		Large rock limited further coring
UUSL-023 (core SL22)		
On top of quartzitic sandstone remnant, topsoil yellowish brown colour		
0-30	Ap	-
30-40	C	Brownish yellow, very stony clay loam
40+	R	-
UUSL-024 (core SL23)		
Moderately stony, brown topsoil		
0-30	Ap	-
30-35	C	Soil colour more yellow with depth
35+	R	-
UUSL-025 (core SL24)		
Gully incision, medium stony surface		
0-30	Ap	-
30+	Bt?	Further coring limited by rocks in profile

UUSL-026 (core SL25)		
Medium stony surface (marl, quartzitic sandstone), yellow topsoil		
0-20	Ap	-
20-70	Btk	Yellow clay with clear swell and shrink, calcium carbonate concretions. Starting at 60 cm red mottles (iron oxidation) and more stones
70-80	Ck	Less clayey, yellow soil colour
80+	R	-
UUSL-027 (core SL26)		
Alluvial fan with medium stony surface and calcium carbonate concretions (limestone, quartzitic sandstone)		
0-40	Ap	-
40-60	Btk	Slightly stony yellowish brown clay, becoming more yellow, clayey, and stony with depth
60+	R	-

CORINGS SITE Rb175

UUSL-028 (2013_1 core 1)		
Water stagnates on phyllite, resulting in gleyic properties		
0-30	Ap	$CaCO_3$ concretions at the surface
30-70	Btgk	Clay with orange brown mottles
70-160	Bgk	Gritty clay with greyish white / orange mottling
160-200+	Bg/C	-
UUSL-029 (2013_1 core 2)		
0-15	Apk	Yellow clay loam with calcium carbonate concretions
15-50	CR	Grey gritty clay loam to loam with many stones
50+	R	Phyllite
UUSL-030 (2013_1 core 3)		
0-40	Ap	Dark grey
40-100	C	Greyish unsorted material
100-150	2Ap	Dark yellowish brown loam containing charcoal and pottery, lighter coloured with depth
150-200	2Ck	Yellow loam, orange mottles and $CaCO_3$ concretions
UUSL-031 (2013_1 core 7)		
0-40	Ap	-
40-200	C	Dark grey colluvium
UUSL-032 (2013_1 core 8)		
0-40	Ap	-
40-120	C	Dark grey
120-140	2Ap	Slightly darker than previous horizon and contains charcoal
140-200	2Bt/C	More clayey with depth
UUSL-033 (2013_1 core 9)		
0-40	Ap	-
40-100	C	Colluvium
100-130	2Ap	Dark loam, containing charcoal
130-200	2C	Dark humic loam, containing charcoal. Probably colluvium
200+	3C	Yellow loam

CORINGS SITE Rb176

UUSL-034 (2013_1 core 12)		
Secondary weathering pocket within cemented alluvial fan/debris cone		
0-50	Ap	-
50-90	Ck	Yellow heavy clay, slight mottling
UUSL-035 (2013_1 core 4a)		
Calcium carbonate concretions at surface		
0-30	Apk	-
30-50	Bwk	Reddish brown clay, many stones
UUSL-036 (2013_1 core 4b)		
Calcium carbonate concretions at surface		
0-30	Apk	-
30-60	Bgk	Greyish white with yellow orange mottling, many stones
UUSL-037 (2013_1 core 5)		
Phyllite colluvium; no colour change through profile		
0-40	Ap	Grey to dark grey gritty clay loam
40-100	C	Weathered phyllite
100-130	C/R	More stony
130+	R	-
UUSL-038 (2013_1 core 6)		
0-40	Apk	Light grey, very clayey. Concretions throughout profile
40-70	C	Orange yellow mottles, alluvial sediment
UUSL-039 (2013_1 core 10)		
0-40	Ap	Dark grey
40-80	C	Colluvium, charcoal
80-100	2Ap	Dark grey, pottery and charcoal
100-130	2C	Colluvium, minor white/grey and orange mottling, charcoal
130-180	3Cg	Yellow colluvium with white/grey and orange mottling
UUSL-040 (2013_1 core 11)		
Successive colluvia with Ap/Aan horizons (charcoal)		
0-40	Ap	-
40-50	C	-
50-70	2Ap	-
70-90	2C	-
90-110	3Ap	-
110-130	3C	-

CORINGS SITE RB174

UUSL-041 (2013_1 core 13)		
0-30	Ap	Grey
30-70	Cg	Light grey orange mottling
70+	R	Phyllite
UUSL-042 (2013_1 core 14)		
Colluvial soil on top of marl		
0-40	Ap	-
40-140	C	Yellow with grey mottles

UUSL-043 (2013_1 core 15)		
Humid colluvial depression on marl		
0-40	Ap	-
40-200	C	More yellow, with depth iron-rich sandstone
UUSL-044 (2013_1 core 16)		
0-40	Ap	-
40-70	C	Yellow clay loam
70-100	CR	Increasing stones (iron rich quartz sandstone) grey soil colour
100+	R	-
UUSL-044 (2013_1 core 16)		
0-25	Ap	Light grey
25-40	Bw	Yellow
40-70	C	Light grey/yellow
70+	R	-

CORINGS SITE Rb073

UUSL-045 (2013_1 core 18)		
0-40	Ap	Dark grey, charcoal, pottery
40-70	C	Yellowish grey, charcoal, pottery. Layer of stones at contact between C and 2Ap
70-90	2Ap	Large amounts of charcoal and pottery. Dark grey, darker when compared with Ap
90-100	2C	Dark grey/yellow, charcoal and pottery fragments, compact layer
100-130	3Ap	Dark grey/yellow, darker than previous layer, charcoal and pottery fragments, clay
130-170	3Bt	Progressively less dark with depth, clay illuviation
170-200	3C	Grey/yellow
UUSL-046 (2013_1 core 19)		
0-40	Ap	-
40-70	C	Charcoal and pottery fragments
70+	R	wet
UUSL-047 (2013_1 core 20)		
Colluvium with many stones		
0-40	Ap	-
40-120	C	Grey
120+	R	-
UUSL-048 (2013_1 core 20401)		
0-50	Ap	-
50-100	C	Yellow, FeMn mottling, Weathered phyllite stones
UUSL-049 (2013_1 core 20402)		
0-50	Ap	-
50-100	Cg	Charcoal and pottery fragments, gley mottling
100+	R	Phyllite
UUSL-050 (2013_1 core 20403)		
0-40	Ap	-
40-60	2Ap	Dark layer
60-70	2C	Yellow layer
70-90	3Ap	Dark layer
90-	3Cg	Charcoal and pottery fragments, yellowish brown layer, minor gley mottles

UUSL-051 (2013_1 core 20404)		
Profile originally sampled for radiocarbon dating (samples lost)		
0-40	Ap	-
40-60	C	-
60-100	2Ap	Charcoal and pottery fragments
100-120	2C	Less chaotic soil material, charcoal
120-140	3Ap	Darker layer, charcoal and pottery fragments
140-145	3Ap	Volcanic ash layer, fine sand
145-160	3Ap	Dark loam with common charcoal
160-190	3Ck	Many charcoal fragments, $CaCO_3$ nodules, some pottery
190-200	4C	Charcoal, pottery, bone fragment, snail shells
200+	5C/R	FeMn mottling and many fragments of weathered phyllite bedrock
UUSL-052 (2013_1 core 20405)		
0-70	Ap/C	-
70-90	2Ap	-
90-100	2C	Yellowish, charcoal fragments
100-130	3Ap	-
130+	3Cg	Weathered phyllite, FeMn mottling
UUSL-053 (2013_1 core 30401)		
No volcanic ash layer		
0-40	Ap	-
40-60	C	-
60-100	2Ap	-
100-120	2C	-
120-160	3Ap	-
160-200	3C	-
200+	3CR/R	-
UUSL-054 (2013_1 core 30402)		
0-40	Ap	-
40-70	2Ap	Very chaotic soil structure, many charcoal and pottery fragments, minor bone fragments
70-110	2C	Very chaotic soil structure, many charcoal and pottery fragments, minor bone fragments
110-130	2Cg	Cumulated material, seems more natural because of FeMn mottling
130+	R	-
UUSL-055 (2013_1 core 30403)		
0-40	Ap	-
40-105	2Ap/ 2C	Many large pieces of charcoal and pottery fragments; at 70 cm burned bone
105-120	2Cg	Cumulated material, seems more natural because of FeMn mottling
120+	R	-
UUSL-056 (2013_1 core 30404)		
Colluvium directly on marl; Leptosol		
0-25	Ap	-
25+	R	Marl
UUSL-057 (2013_1 core 30405)		
0-40	Ap	At 40 cm charcoal
40-100	C	At 70 cm charcoal, FeMn mottling at 90 cm, many phyllite fragments in profile

UUSL-058 (2013_1 core 90404)		
0-80	-	Light brown anthropogenic layer, abundant charcoal, bone
80-140	-	Dark brown anthropogenic layer, charcoal
UUSL-059 (2013_1 core 90405)		
0-30	Ap	Dark clay loam
30-70	-	Light brown clay loam
70-170	-	Light brown; groundwater at 130cm, charcoal
UUSL-060 (2013_1 core 90406)		
0-30	Ap	Dark clay loam
30-70	C	Dark grey clay loam
70-75	C	Gravelly, yellowish brown clay loam
75-100	2Ap	Dark brown, charcoal
100-105	2C	Gravelly, yellowish brown
105-140	3Ap	Dark brown, protohistoric pottery, charcoal
140-145	3C1	Gravelly, yellow-brown layer
145-175	4C2	Yellow layer of weathered stones, Fe-reduction, FeMn stains, charcoal
175	(R)	Phyllite
UUSL-061 (2013_1 core 90407)		
0-30	Ap	Protohistoric pottery at 30cm
30-70	C	Gravelly clay, FeMn mottles, weathered stone ("rotten rock")
70	R	Phyllite
UUSL-062 (2013_1 core 90408)		
0-30	Ap	-
30-170	C1	Dark grey, protohistoric pottery at 80-90, 90-100, 120-130cm
170-	C2	Gravelly layer
UUSL-063 (2013_2 Pü 210)		
0-40	Ap	-
40-100	CR	Weathered marl
UUSL-064 (2013_2 Pü 211)		
0-40	Ap	-
40-55	C	Young colluvium, no charcoal and pottery
55-75	2C	Weathered marl
75+	2R	Marl
UUSL-065 (2013_2 Pü 212)		
Flint arrow head on surface		
0-40	Ap	-
40-75	C	Darker soil colour than pü 211, pottery at 65 cm
75-90	2Ap	Very dark clay, charcoal and pottery
UUSL-066 (2013_2 Pü 213)		
5 cm next to pü 212		
0-40	Ap	-
40-75	C	Dark clay loam, protohistoric pottery at 60 cm
70-90	2Ap	Very dark clay, charcoal and pottery (lower part of the coring is characterized by a crumbly white substance with black spots)
UUSL-067 (2013_2 Pü 214)		
30 cm next to pü 212		
0-40	Ap	-
30-70	C	Charcoal and pottery
70-100	2Ap	Very dark clay, charcoal and pottery

UUSL-068 (2013_2 Pü 215)		
500 cm next to pü 212		
0-30	Ap	-
30-60	C	Charcoal and pottery
60-100	2Ap	Very dark clay, charcoal and pottery, weathered phyllite rock fragments

CORING TRANSECT 'CONTRADA MADDALENA'

UUSL-069 (core 3001)		
Phyllite		
0-50	Ap	Clay
50+	C	Dark greyish brown gravelly clay
UUSL-070 (core 3002)		
Phyllite bedrock covered with marly colluvium		
0-30	Ap	Clay
30+	Cg	Gley mottles
UUSL-071 (core 3003)		
Similar to previous		
0-30	Ap	Clay
30+	Cg	Gley mottles
UUSL-072 (core 3004)		
Marl colluvium		
0-40	Ap	Sample 3004
40-80	Bt	-
80+	C	Dark brown colluvium
UUSL-073 (core 3005)		
Phyllite		
0-50	Ap	-
50+	Cg	Gley mottles
UUSL-074 (core 3006)		
Phyllite covered with colluvial marl material		
0-50	Ap	-
50+	C	-
UUSL-075 (core 3007)		
Green/grey schist covered with colluvial marl material		
0-20	Ap	-
20+	C	-
UUSL-076 (core 3008)		
Green/grey schist covered with colluvial marl material		
0-50	Ap	-
50+	C	-
UUSL-077 (core 3009)		
Phyllite		
0-50	Ap	-
50-110	Bt	Increasing clay content with depth
110+	C	Marl at contact zone
UUSL-078 (core 3010)		
Marl		
0-50	Ap	-
50-100	Bt	Clay
100-150	Bt/C	Clay loam
150+	C	Dark yellowish brown

UUSL-079 (core 3011)		
Marl with colluvial phyllite material		
0-50	Ap	-
50-90	Bt	-
90+	C	-
UUSL-080 (core 3012)		
Marl with colluvial phyllite material		
0-50	Ap	-
50-90	Bt	-
90+	C	-
UUSL-081 (core 3013)		
0-50	Ap	-
50-90	Bt	Yellow colluvial clay loam
90-150	2Bt	Brown strongly weathered marl
150+	2C	-

MARINE TERRACES

CORING TRANSECT 'MONTE SAN NICOLA' (TWO PARALLEL LINES ACROSS THE TOP OF THE MONTE SAN NICOLA, 10 APR 2012)		
MT-001 (core 1)		
0-50	Ap	Dark olive brown
50-80	Bt	Olive brown clay loam. No increase in clay content with depth
80	C	-
MT-002 (core 2)		
0-40	Ap	Dark olive brown
40-80	Bt	Olive brown clay loam. No increase in clay content with depth
80	C	-
MT-003 (core 3)		
0-50	Ap	Dark olive brown
50-90	Bt	Olive brown clay loam. No increase in clay content with depth
90	C	-
MT-004 (core 4)		
0-45	Ap	Dark olive brown
45-120	Bt	Olive brown clay loam. No increase in clay content with depth
120	C	-
MT-005 (core 5)		
0-40	Ap	Dark olive brown
40-120	Bt	Olive brown clay loam. No increase in clay content with depth; slight gley at base, indicates water stagnation
?	Cg	-
MT-006 (core 6)		
0-50	Ap	Dark olive brown
50-90	Bt1	Olive brown silty clay
90-110	Bt2	Textural difference with previous layer, silt loam
110	C	-
MT-007 (core 7)		
0-40	Ap	Dark olive brown
40-100	Btg	Olive brown silty clay; iron(hydr)oxide mottles around root pores
100-120	Btk	Silt loam (gritty), texture difference could be related to increase of calcium carbonate concretions
?	Ck	Presumably very close due to high amount of (broken) calcium carbonate concretions in auger
MT-008 (core 8)		
0-40	Ap	Dark olive brown
40-100	Bt	Olive brown silty clay
100-120	Btk	Yellow and gritty further down the profile
?	C	-

MT-009 (core 9)		
0-40	Ap	Dark olive brown
40-60	Bt	Olive brown silty clay
60-120	Btk	Yellow and gritty further down the profile
120	C	-
MT-010 (core 10)		
0-40	Ap	Dark olive brown
40-60	Bt	Olive brown silty clay
60-70	red layer	Sticky red clay; sharp boundary with previous horizon
70	C	-
MT-011 (core 11)		
0-30	Ap	Dark olive brown
30-70	Bt	Olive brown silty clay no textural difference along the profile; no increase in clay content with depth
70	C	-
MT-012 (core 12)		
0-30	Ap	Dark olive brown
30-100	Bt	Olive brown silty clay. No textural difference along the profile; no increase in clay content with depth
100	C	-
MT-013 (core 13)		
0-40	Ap	Dark olive brown
40	C	-
MT-014 (core 14)		
0-40	Ap	Dark olive brown
40-90	Bt	Olive brown clay loam. No textural difference along the profile; no increase in clay content with depth
90	C	-
MT-015 (core 15)		
0-40	Ap	Dark olive brown
40-120	Btk	Olive brown clay loam. At 40 cm first signs of yellow mottles due to calcium carbonate, no textural difference, no increase in clay content
?	C	-
MT-016 (core 16)		
0-40	Ap	Dark olive brown
40-80	Bt	Olive brown silty clay
80-120	Btk	More yellow mottles, gritty
?	C	-
MT-017 (core 17)		
0-40	Ap	Dark olive brown
40-70	Bt1	Olive brown colluvium with minor stones, no colour difference with other horizons
70-100	2Btk1	Olive brown silty clay
100-120	2Btk2	Increase in calcium carbonate down the profile
?	C	-

MT-018 (core 18)		
0-40	Ap	Dark olive brown
40-70	Bt1	Olive brown silty clay
70-120	Bt2	more yellow flecking, gritty
?	C	-
MT-019 (core 19)		
0-40	Ap	Dark olive brown. Charcoal at 30 cm
40-60	Bt1	Olive brown silt loam
60-90	Bt2	Olive brown clay
90-120	Btk	Silt loam with yellow mottles (calcic)
?	C	-
MT-020 (core 20)		
0-40	Ap	Dark olive brown
40-70	Bt1	Olive brown silt loam
70-100	Bt2	Olive brown clay loam
100-120	Btk	Olive brown clay with yellow mottles
120	C	-
MT-021 (core 21)		
0-40	Ap	Dark olive brown
40-100	Bt	Olive brown silt loam
100-120	Btk	Olive brown, increase in clay content and carbonate concretions
?	C	-
MT-022 (core 22)		
0-40	Ap	Dark olive brown
40-120	Bt	Olive brown; some yellow mottles at the bottom of the profile, but not distinctive
?	C	-
MT-023 (core 23)		
carbonate concretions at the surface		
0-40	Apk	Dark olive brown
40-70	Btk	Olive brown clay loam
70	C	-
MT-024 (core 24)		
0-40	Ap	Dark olive brown
40-60	Btk	Olive brown
60	C	-

CORING TRANSECT 'MARINE TERRACES' (FROM TOP OF CONGLOMERATES DOWN TO THE MARL SUBSTRATE TO END AT CONGLOMERATES, 31 OCT 2012)

MT-025 (core 1)		
0-40	Apk	Reddish brown clay loam; Yellow mottles around 25 cm ($CaCO_3$ concretions)
40	R	Cemented conglomerate
MT-026 (core 2)		
0-40	Ap	Reddish brown clay with pottery fragments. At 25 cm more stones and black orange/grey mottles at 30 cm (stagnation)
40	R	Cemented conglomerate
MT-027 (core 3)		
0-30	Apk	Yellowish brown loam, gritty (rock fragments)
30-45	Bt	Colluvium, clay
45	R	Calcite band ($CaCO_3$ concretions)
MT-028 (core 4)		
0-40	Ap	Brownish yellow clay loam
40-60	Bt	Yellowish grey clay loam, minor stones
60-65	C	calcite band starts appearing, sandy, weathered marl
70	R	-
MT-029 (core 5)		
Calcite concretions at surface, all horizons have concretions		
0-40	Apk	Yellowish brown, colluvial clay loam
40-50	Bt	Clay rich colluvium
50-60	2Bt1	Silt loam, more yellow downwards (original profile)
60-70	2Bt2	Loam
70-80	2Bt3	Clay loam, very dry
80	R	-
MT-030 (core 6)		
Anomaly 1		
0-30	Ap	Brownish yellow sandy loam
30-80	C	Similar to 2Bt2 in core MT-029
MT-031 (core 7)		
0-30	Apk	Brownish yellow, calcite concretions
30-65	Btk	$CaCO_3$ throughout horizon
65	C	-
MT-032 (core 8)		
0-40	Apk	Concretions, weathered black stones
40-60	Btk	Loam
60	C	Clear concretionary band of $CaCO_3$
MT-033 (core 9)		
In small erosional, gully concretions throughout the profile		
0-40	Apk	More clayey than other cores, due to morphological position
40-100	Btk	Disturbed from 100 cm more concretions
MT-034 (core 10)		
0-40	Apk	Reddish brownish yellow clay loam
40-70	Ck	Gritty parts red, silty parts yellowish greenish. At 50 cm band of coarser material and calcites
70	2Ck	Yellow, coarser
MT-035 (core 11)		
Fluvial rocks and calcium carbonate concretions at surface		
0-30	Ap	Red (conglomerate)
30	R	-
MT-036 (core 12)		
Fluvial rocks and calcium carbonate concretions at surface		
0-20	Apk	Red (conglomerate)
20	R	-

CORINGS ALONG TRANSECT 'MARINE TERRACES' (12 APR 2012)		
MT-046 (core 2001)		
0-40	Ap	Dark reddish brown
40-80	Bt	Dark reddish brown
80	C	-
MT-047 (core 2002)		
0-40	Ap	Dark reddish brown
40-100	Bt	Dark reddish brown, charcoal between 50-60cm
100	C	-
MT-048 (core 2003)		
0-30	Ap	Dark reddish brown
30-40	Bt	Dark reddish brown
40-50	Btk	Dark reddish brown, carbonate concretions
50+	C	-
MT-049 (core 2004)		
0-40	Ap	-
40-120	Bt	Reddish brown
120	C	-
MT-050 (core 2005)		
0-40	Ap	-
40-80	Bt	Very dark brown, charcoal at 50 cm
80+	C	-
MT-051 (core 2006)		
0-50	Ap	Dark reddish brown clay loam
50+	C	-
MT-052 (core 2007)		
0-40	Ap	-
40+	?	Stony, further coring impossible
MT-053 (core 2008)		
0-40	Ap	Brown
40-80	Bt1	Brown, clay loam
80-100	Bt2	Strong brown, clay
100+	C	-
MT-055 (core 2010)		
0-20	Ap	-
20+	?	Stony, further coring impossible
MT-056 (core 2011)		
0-40	Ap	-
40-90	Bt	Dark reddish brown. No increase in clay content down the profile
90+	C	-
MT-057 (core 2012)		
Leptosol		
0-20	Ap	Dark reddish brown
20+	R	-
MT-058 (core 2013)		
0-40	Ap	Reddish brown
40+	C	-
MT-059 (core 2014)		
Leptosol		
0-25	Ap	Dark reddish brown
25+	R	-

FOOTHILL UNDULATING SLOPING LAND

CORINGS TRANSECT 'PORTIERI DI CERCHIARA'

FUSL-001 (TD01)		
Marl with limestone boulders, local colluvial basin		
0-30	Ap	-
30-50	C	-
FUSL-002 (TD02)		
Marl, concretions at surface, topsoil reddish brown		
0-30	Ap	Reddish brown clay
30-40	C	Colluvium, mottled yellow/grey
40-50	2Btk	Dark brown clay
50-60	2Ck	Colluvium, shale, grey/red
60-70	3Ck	Weathered yellow marl
FUSL-003 (TD03)		
Local colluvial basin in marl, dark topsoil		
0-30	Ap	Dark brown
30-60	Btk	Dark brown clay
60-80	BCk	Transition zone, rich in carbonate concretions, yellow mottles, gritty texture
FUSL-004 (TD04)		
Above terrace, olive green topsoil, concretions at surface		
0-40	Apk	-
40-70	Ck	Olive clay loam with non-sorted stones, common carbonate nodules, slightly mottled
70-100	2Btk	Clay with darker soil colour when compared with overlying horizon. Increase in nodules down the profile
100+	2Ck	Yellow mottled
FUSL-005 (TD05)		
Below terrace, concretions at surface, yellowish brown topsoil		
0-40	Ap	-
40-60	Ck	Yellowish, white smears (weathered nodules?), shale weathering residue
FUSL-006 (TD06)		
Same location as previous, only one terrace lower on hill slope		
0-30	Ap	Brownish yellow clay loam
30-40	Ck	Mottled, weathered marl and shale
40+	R	-
FUSL-007 (TD07)		
Minor rocks at surface		
0-20	Ap	Brown
20-50	Btk	Yellow clay, further down the horizon more nodules
50-60	Ck	Less clayey, mottled and weathered bedrock
FUSL-008 (TD08)		
0-30	Ap	-
30-60	Ck	Increasingly clayey with depth (vertic properties) but not sufficient for Bt
FUSL-009 (TD09)		
Disturbed profile		
0-30	Ap	Brown
30-70	C	Reddish sandstone fragments. Parent material seems a mixture of colluvium, marl and marine terrace deposits
FUSL-010 (TD10)		
Near transition colluvium/marine terrace		
0-30	Ap	Brown
30-60	Bt	Brown clay, minor stones
60-100	C	Yellow, more stony
FUSL-011 (TD11)		
Marine terrace with reddish brown topsoil, clayey soil		
0-30	Ap	-
30-50	C	Many stones, less dark, more reddish
50+		Coring limited by stones

CORINGS SITE 113 ANOMALY

FUSL-012 (above anomaly)		
0-30	Ap	-
30-50	C	At 30/35cm slightly more yellow and clayey, not sufficient soil development for Bt; after 35 cm slightly redder
FUSL-013 (below anomaly)		
0-30	Ap	Brownish yellow
30-40	C	Slightly redder than overlying horizon
FUSL-014 (anomaly)		
0-20	Ap	Yellowish brown colluvium
20-30	Bt	Yellow clay, colluvium
30-40	C	Reddish colluvium
40-60	unknown 1	Brown, charcoal and yellow mottles, brittle structure
60-70	unknown 2	Reddish brown, yellow flecks, brittle structure
70-80	unknown 3	Yellowish brown, yellow mottles decreasing with depth, brittle structure
80-90	2Ck	Yellowish brown, weathered marl

RB094 PROFILE PITS

FUSL-015 (site 94 profile 1)		
Near the top of the hill on shale, highly eroded soil (most likely truncated) with rather immature soil		
0-40	Ap	Dark unsorted rocks and medium sized (<5cm) calcite nodules. The nodules have a different origin, presumably transported into the upper horizon as a result of colluviation. The boundary to the next horizon is sharp
40-50/60	Ck	Horizon with vertic properties, clearly not well developed enough to be classified as a Bt-horizon. More clayey compared to the overlying horizon and with small (<1cm) calcium carbonate concretions
50/60-60/100	2Ck	This horizon is only present in local tongues and consists of weathered rocks of the parent substrate (shale). The rock fragments easily fall apart The soil in between the weathered bedrock is clayey and contains carbonate concretions. The soil colour is yellow with orange mottles
FUSL-016 (site 94 profile 2)		
Truncated soil: possibly an Ap horizon overlying a truncated paleo Bt		
0-40	Ap	Dark colour with unsorted rocks, calcium carbonate concretions are present but originate from elsewhere
40-45	Ck	Horizon with vertic properties, not classified as Bt because of insufficient thickness. Colour is slightly darker and more clayey compared to the overlying horizon. Carbonate concretions with varying sizes and weathered rock with varying sizes
45-80/90	2Ck	More weathered rocks lower in the profile. Soil colour is yellowish brown and the sol has a high calcium carbonate content (mottles and nodules)
FUSL-017 (site 94 profile 3)		
Highly weathered soil in shale with severe seepage		
0-40	Apk	Dark grey clay with unsorted rocks and carbonate concretions and minor pottery shards
40-60	Crk	Light grey, reduced clay with high amounts of calcium carbonate concretions and mottles. Very clayey but locally gritty texture. The soil is eroded and truncated resulting in a shallow Ap overlying a thin layer of weathered bedrock
FUSL-018 (site 94 profile 4)		
Shallow, highly weathered soil on shale, with a thin colluvial top layer (Apk)		
0-40	Apk	Dark coloured clay loam with concretions and unsorted rocks
40-45	Btkb	Reddish brown layer with weathered parent material and varying sizes of carbonate nodules. Slightly higher clay content when compared with the overlying horizon. Presumably a remnant of an older soil (Bt)
45-60	Ck	Brownish red clay with minor rock fragments. Contains small carbonate nodules
FUSL-019 (site 94 profile 5)		
Shallow highly eroded soil directly on cemented limestone colluvium		
0-30	Apk	Dark coloured with cemented rocks brought to the surface by ploughing. Carbonate nodules and darker veins with minor clay illuviation primarily around (former) root canals
30-35/40	Ck	Brownish red colour with many rocks and carbonate nodules
FUSL-020 (site 94 profile 6)		
Deep, well developed soil on marl with intensive clay illuviation		
0-40	Apk	Dark clay with carbonate concretions and rock fragments from slope deposits
40-90/110	Btk1	Yellowish brown clay. Organic material diminishes with depth and is not found below 70cm
90/110-150+	Btk2	Yellow clay with prominent slickensides. Carbonate concretions throughout the profile. Lower boundary of this horizon was not reached

PORTIERI DI CERCHIARA PROFILE PITS

FUSL-021 (site 113-115 profile 1)		
Severely truncated shallow soil right under terrace edge on marl substrate. Minor colluvial cover (+- 50cm) with increased erosion as a result of ploughing		
0-40	Ap	Dark soil with carbonate concretions originating from slope deposits
40-50	Ck1	Weathered marl, darker than the underlying horizon. Small carbonate nodules which presumably find their origin in this horizon
50-70	Ck2	Yellowish brown soil with large rock fragments and carbonate nodules. Augering in this horizon was limited by clay content and stoniness
FUSL-022 (site 113-115 profile 2)		
Colluvial soil on marl with swell and shrink Calcium carbonate concentrations around stones, clay has been translocated but not sufficient enough for a Bt-horizon		
0-40	Ap	Dark, crumb structure as a result of ploughing. Unsorted stones of varying sizes originating from colluvium, as are the carbonate nodules found in this horizon
40-60	Ck1	More clayey when compared to overlying horizon. Both $CaCO_3$ and FeMn nodules are found in this horizon
60-90	Ck2	Brownish/yellowish colour and high clay content of the soil originating from the weathered marl bedrock. Calcium carbonate concentrations highest around the stones. Common small FeMn nodules
90	R	Marl

FUSL-023 (site 113-115 profile 3)		
Colluvial material and iron-rich quartzitic sandstone boulders on top of highly weathered bedrock		
0-40	Ap	Dark topsoil consisting of unsorted material and carbonate nodules
40-60	Btk1	Yellowish brown clay. $CaCO_3$ and FeMn nodules throughout the horizon
60-80	Ck1	Reddish brown clay loam. FeMn and $CaCO_3$ nodules are found throughout the horizon
80-90	Ck2	Reddish brown clay with common FeMn nodules than overlying horizon
90+	?	Not able to go any deeper, not even with bucket excavator
FUSL-024 (site 113-115 profile 4)		
Similar to profile 3, but shallower		
0-40	Ap	Angular stones (colluvial), carbonate nodules and dark topsoil
40-60	Btgk	Mottled clay with angular colluvial stones, carbonate and iron-manganese nodules
60-75	Ck	Mottled clay loam with angular colluvial stones, carbonate and iron-manganese nodules
FUSL-025 (site 113-115 profile 5)		
Archaeological excavation		
0-40	Apk	Dark topsoil with carbonate concretions and unsorted angular rocks originating from colluvium
40-60	Ck	Brown colluvial clay with unsorted angular rocks and carbonate nodules. Yellowish brown soil colour
60-90	unknown	Gritty texture, red colour with black band marking the beginning of the layer
90-110	2Ck	Presumably a yellowish brown truncated paleo-soil. Soil material originating from weathered marl and colluvium, with carbonate nodules
FUSL-026 (site 113-115 profile 6)		
Disturbed profile with archaeological finds. Too irregular to describe. Presumably truncated and excavated (debris pit?)		
0-40	Ap	Dark topsoil
40-60	Ck	Archaeological material at several depths. Darker soil colour compared to overlying horizon. $CaCO_3$ and FeMg nodules throughout profile

CORINGS SITE RB050 (1 NOV 2013)

FUSL-027 (site T50 Pü 206)		
0-30	Ap	-
30-50	Bwg	Red weathered phyllite/schist with clay loam texture
50-70	CRk	Weathered phyllite/schist with some secondary lime

FUSL-028 (site T50 Pü 207)		
5 meter distance to terrace edge		
0-40	Ap	-
40-80	CR	Weathered phyllite
FUSL-029 (site T50 Pü 208)		
1,5 meter distance to terrace. No colour difference between C1 and C2		
0-30	Ap	Recent colluvium, lighter colour and more crumbly than underlying
30-50	C1	Older colluvium, crumbly structure stony
50-75	C2	Older colluvium, clayey dense structure, stony
75-90	2CR	Weathered phyllite
FUSL-030 (site T50 Pü 208)		
Dug-in feature: anthropogenic disturbance in bedrock, granite artefacts (millstone etc.)		
0-40	Ap	-
40-80	2Ap	Charcoal and pottery
80-90	CR	-
FUSL-031 (site T50 Pü 209)		
Next to anthropogenic disturbance. Natural soil contains calcite cemented rocks at surface		
0-30	Ap	-
30+	CRk	Weathered phyllite with secondary lime

CORINGS FOR THE IDENTIFICATION AND EXPLANATION OF GEOLOGICAL ANOMALIES AT TX/TZ (2 NOV 2013)

FUSL-032 (site Tx/Tz Pü 217)		
Inside strong anomaly, not identified at surface		
0-40	Ap	-
40-60	C1	Colluvium, dark unsorted many minor stones
60-80	C2	Older colluvium, more clayey, unsorted, shell fragments (land snails)
FUSL-033 (site Tx/Tz Pü 218)		
Outside anomaly, natural soil		
0-40	Ap	-
40-55	1C	Colluvium
55-80	2CRk	Weathered marl, yellow silt loam
FUSL-034 (site Tx/Tz Pü 219)		
Inside weak anomaly		
0-40	Ap	-
40-50	C	Colluvium
50-80	2CRk	Weathered marl, yellowish brown with minor whitish specks, silty to clayey

Understanding how past and current physical landscape processes, both natural and anthropogenic, affect the archaeological record has become one of the main aims of the burgeoning field of Geoarchaeology. But the ideal of effective multidisciplinary research collaboration is hard to achieve. This second volume of the Raganello Basin Studies series demonstrates how intensive collaboration between earth scientists and archaeologists has resulted in a systematic approach to the description and assessment of archaeologically relevant soils and landscape processes in a typical Mediterranean landscape - the basin of the Raganello River in southern Italy. It is both a detailed report on the extensive field studies conducted by the authors in 2012-2014, and a much needed 'how to' guide to the study of landscapes and soils within the framework of landscape archaeological projects in the Mediterranean. The work described here builds on the expertise in Mediterranean soils and landscapes gained by the first author over decades of research, and avoids or explains jargon that would otherwise deter those with a purely humanities background.

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