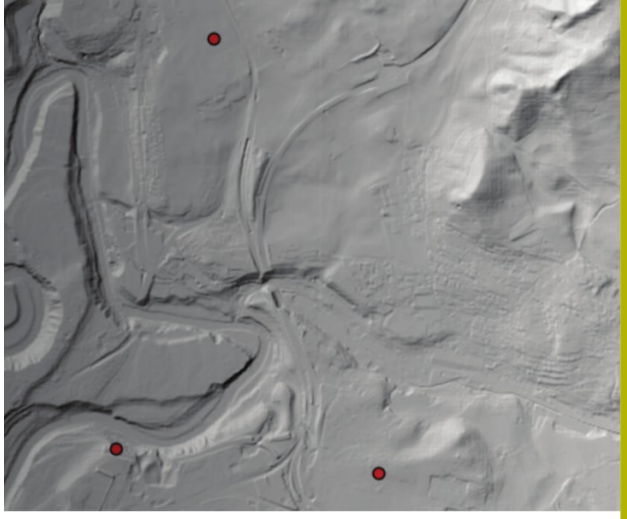

Digital Archaeology:

Quantitative approaches, spatial statistics and socioecological modelling

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CLIMATE CHANGE RESEARCH

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Abstracts

History and Perspectives of Quantitative Archaeology

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Quantitative archaeology developed a major pillar of archaeological research. Researchers have different attitudes towards quantitative archaeology as the following statements suggest: QA is still not accepted as integral part of archaeology by many scholars. Some approaches of QA are fancy stuff and magic tools. It is more than just one branch of archaeological methodology. This talk attempts to demystify QA by sketching both, the historical development of QA and the specific role of this sub-discipline among the many flavours of archaeology. A short overview of topics, developments and development phases of QA is presented. The topics include statistics, spatial analysis, modelling, simulation, classification, data mining and other aspects. QA appears to be the main methodology in archaeology for the recovering of data-inherent structures. The main part of the talk will establish QA not only as integral part of archaeology but further more as natural connection between scientific approaches of archaeology aiming on structural analysis and the traditional approach form humanities aiming on negotiating historical meaning and developing narratives. Finally, some issues of QA are addressed. Superficial application, weak connection between methodology and theory and hidden parameters and assumptions are one of the problems. Another problem is inadequate teaching of QA, missing didactic concepts and insufficient integration in archaeological curricula.

The complexity of production spaces at the Neolithic site of La Draga

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La Draga (Banyoles, Girona) is an early Neolithic pile-dwelling settlement that was occupied uninterruptedly between ca. 5300-4800 BC. This archaeological site stands out for being one of the first evidences of the Neolithisation process in the NE of the Iberian Peninsula and, for having provided an exceptional sample of organic remains thanks to its archaeological layers preserved in an anoxic environment. The research performed during last years at La Draga has been aimed at acquiring knowledge about the strategies developed, by this first farming society, on subsistence and technology. Recently, with the available information an intra-site spatial analysis has been developed with the purpose of approaching the organizational strategies of the same community.

In this paper, the results obtained from the spatial analysis of sector B of the settlement will be presented. The focus is on evidence of social space organisation and inferring socio-economic strategies and social organization.

The goal of the spatial analysis performed was to predict the nature of artefact dispersal and to account for the proper place were each particular social activity took place. From the observed degree of spatialization of subsistence and technological activities the nature of social relations can be discerned.

The approach applied relies first, on an ontological categorization of the archaeological observables in terms of social activities, and second on the nature of spatial dispersion, distinguishing the social reason for randomness or its alternative, aggregation. On this regard, a null-hypothesis of spatial random distribution is formulated to check whether there was some intentionality in the proper location of activities that generated the observed remains. The detection of concentrated patterns is interpreted in terms of the conscious selection of a particular place for a particular activity. Those hypotheses are evaluated geostatistically, measuring spatial autocorrelation and anisotropy. 2D Kernel density methods are used to test the spatial pattern of individual findings, whereas surface interpolators (IDW and Kriging) are used to test the frequency patterns at the spatial level. Results for all the archaeological categories treated are integrated using a spatially constrained Multivariable Correspondence Analysis to check whether different categories are spatially correlated.

All those analysis, at the univariate and multivariate level allows to create probability maps for the different social activities that generated the observed archaeological record.

Rising cities and long distance interactions: Modelling spatial exchanges in La Tène Europe

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Over a relatively short period between the end of the fourth and the middle of the first century BC, an unprecedented process of urbanisation developed in non-Mediterranean Europe. By focusing on trade interactions, we question the links between the observed hierarchy of grouped settlements and long-distance economic flows over the territory. The aim is to assess the extent to which long-distance trade networks and the economic flows they involve may have had an influence on the emergence, the prosperity and the hierarchy of grouped settlements. The use of a spatial interaction model developed in physics makes it possible to question the impact of the exchange networks on late Iron Age urbanisation processes.

Species range shifts in Neanderthals: a review of the available methods

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Spatial information is a major element in palaeoanthropology, as distributions of fossils or archaeological sites can reflect species, populational, or cultural extents, as well as environmental relationships. However, most applications are descriptive, based solely on the fossil or archaeological record. Neo-ecologists and conservationists have developed more formal models – generally referred to as species distribution models – that combine probabilistic parameters with the actual distributional data, to provide a more robust and biologically meaningful estimate of spatial distribution.

These models have great potential in the past. Where a neo-ecologist would use contemporary species occurrence records and environmental variables, along with projections of future climate scenarios under global change, a palaeoecologist could use fossil sites and palaeoenvironmental records, as well as palaeoclimate models and current ecological data, to reconstruct distibutions in the past. These can also be used to address questions in palaeoanthropogy

This paper employs SDMs to explore distributional patterns among later hominins. Unlike Homo sapiens, our extinct relatives were unable to achieve a global distribution, and ultimately their ranges contracted to zero as they disappeared. Are the differences between H. sapiens and other hominins the result of different ecological contexts and tolerances, or differences in their use of these habitats. Was it particular environmental conditions that permitted Homo sapiens achieve a worldwide distribution? To what extent did environmental change contribute to the pattern of their range shifts leading towards archaic hominin extinctions?

To investigate these issues we present a complete, time-sliced record of Neanderthal fossil sites (n = 235) alongside their palaeoenvironmental context, derived from palaeoclimate modelling. The available methods in GIS are used to define environmental controls on fossil distribution. The distributional models are constructed for range sizes and boundaries during cold and warm periods, and models used to track the distance and directionality of range shifts and their environmental context.

Whom to ask the hour? The importance of filtering criteria and its implication in chronological models

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Over the years, archaeologists have been creating a lot of new radiocarbon data, but is all this data reliable? This critique has already been raised by multiple authors who have proposed the use of filtering criteria in order to avoid background noise in the modelling o the radiocarbon ages and obtain patterns that can be meaningful for multiples research questions such as the spread of pottery traditions, funerary practices or populations dynamics. In this work we want to present several chrono-spatial models using filtering criteria -based on the works of Capuzzo (2014), Manen (2014), Oms (2014) and Pardo-Gordó (2015)- and without filtering criteria at all. As a case study we will use the Mesolithic-Early Neolithic transition in the northwestern

Mediterranean territories (northern Italy, southeast France and northeast Iberian Peninsula) and Switzerland. When does the Mesolithic end and when does Early Neolithic begin in each region? Do different type of samples provide similar results? Our goal is to eventually deal with three main questions related with the use of radiocarbon data: the taphonomic aspects, the sample itself and the technical and interpretative limits. By this we mean, is what we dated a diagnostic element from the context we are interested in? Is the sample chosen adequate to date the event that we intend to date? Are we able to understand the processes involved in radiocarbon dating, and the meaning of the information obtained from it?

Lakeshores and their hinterland: A landscape archaeology approach to the alpine Attersee-Mondsee region

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The trinational Beyond Lake Villages project investigates holocene human-environment relations in the area of the northern Alpine lakes with a special focus on the 4th millenium BC. In the present talk we discuss the landscape archaeology work of the Austrian research group, which focuses on the core area of the Mondsee group, the Upper Austrian Attersee-Mondsee region. Our approach adresses different spatial scales and focuses on site location choice, visual patterns, and landscape characterization.

Firstly we investigated the lacustrine settlements on the shores of lakes Attersee and Mondsee by means of site catchment analysis on different surfaces of a high resolution terrain model. A broad variety of open source landscape data was included in the analysis. Based on this a predictive model for the shore areas of lakes Attersee and Mondsee was developped. We will discuss if and how this model could be operationalized for other alpine lakes. Secondly we aimed at enhancing our understanding of the relationship between the lakeshore areas and the dryland zones in the hinterland of the lakes through the investigation of visual patterns, cost surface analysis and various other forms of landscape characterization. One of the most remarkable results of these analysis is the distinct character of 4th millenium “visibility patterns” compared to other time periods.

Modelling Archaeological Badlands: Settlement and Landcover Dynamics in the Upper Rhine Valley

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The distribution of archaeological findings mapped upon environmental datasets rapidly leads to classification and categorization of land-use patterns and hence the distinct separation of supposed cultural and natural landscapes. However, archaeological gaps are not primarily built by the lack of evidence but rather by the lack of knowledge. Modern land-cover has a significant effect on the findability of previously occupied and culturally transformed areas, especially in areas of continuous and dense land-use activity like the Upper Rhine Valley. Current vegetation coverage and agriculturally utilized areas can be evaluated by remotely sensed satellite imagery and GIS-based analyses of the local geomorphological, geological and pedological conditions. The combination with historical, archaeological and phytosociological data leads to a better understanding of past land-use patterns to answer further questions: To what extent are recent land-use strategies transferable to past human-environmental interactions? How close can we get to the reconstruction of palaeo-environments – especially in continuously utilized and populated regions? This paper provides applications of environmental factors (e.g. flood risk, slopes, soil quality) in combination with archaeological sites and finds as well as dendroarchaeological material and phytosociological data to synthesize a model of continuous settlement dynamics and land-use strategies in the Upper Rhine Valley for the last 1500 years.

3D-based Digital Analysis of Tablets and Sealings

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Records of historical documents and archaeological findings extend beyond photographs and increased use of 3D digitization methods leads to large numbers of 3D models. Today’s 3D acquisition techniques is capable of reproducing finest details like

fingerprints on cuneiform tablets or remainders of heavily weathered inscriptions. Analyzing and in particular comparing human traces like marks from tools, seals or styli is a core challenge. Therefore we like to give an overview about two of our main research projects using high resolution 3D datasets:

(i) Development of computational tools for cuneiform analysis: An efficient and accurate sign spotting enables cross-referencing and statistical analyzes that are infeasible to perform manually. We extract wedges from cuneiform tablets by over-segmenting triangular shapes and solving an optimization problem of pattern-matching our keypoint representations of wedges. On the basis of our wedge descriptors we adapt part-structured models to enable segmentation-free spotting of wedge constellations, which enables word-spotting of relevant key words in cuneiform tablets.

(ii) Analyzing Aegean sealings and sigils reveals valuable insights into the Aegean socio-political organization and administration. An important question arising is the determination of authorship and origin of seals. Given two or more visually similar but not equal sealings, possibly of different provenance, do they originate from the same stamp or the same author? This work is conducted using high resolution 3D-models of the Corpus der minoischen und mykenischen Siegel (CMS) in Heidelberg. We quantify and highlight visual differences, by exposing and directly matching shared visual descriptors. Given the set of correspondences, we first estimate a rigid transform with RANSAC and proceed with fine-tuning residual alignment error with Thin-plate splines (TPS). Further, we visualize and measure the deformation of shape necessary to match sigils.

Finally a summary and an outlook for related work in analyzing Maya inscriptions will be given.

Unsupervised classification and automated shape recognition as tool for computer-assisted reproducible typology

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Since 2016, in the SNFS-project 'Mobilities, entanglements and transformations in Neolithic societies on the Swiss Plateau (3900-3500 BC)', we have been using a computer-aided classification of vessel shapes to investigate completely preserved Neolithic pottery of Swiss wetland sites and neighbouring regions from the 4th millennium BC beyond classical typologies and cultural assignments. Our strategy is essentially very simple: We follow a holistic approach in which the entire vessel body is understood as a rotational body (comparable with Mom 2005, Chapman et al., 2006, Keogh et al., 2009). One side of the rasterized, filled and equally scaled profile is extracted, and via a simple transfer of the image information into a matrix, the profile line is converted into 400 measuring points. The profile information obtained in this way, enriched with nominal values such as rim shape or decoration as well as other metric values such as absolute height, can be evaluated using various multivariate methods. We opted for a combination of t-sne as ordination and dimension-reducing method and HDBSCAN as cluster algorithm for this analysis. This computer-aided method was accompanied by a impressionistic classification by hand. In our analyses it became clear that both methods complement each other meaningfully: While computer-aided classification was able to work out more general, cross-cultural trends, which can be interpreted with regard to the function of the vessels and a consumer perspective, impressionistic classification leads to an identification of different styles, which rather open up a producer perspective. The juxtaposition of both methods on the same material can be used to overcome existing stereotypes and topoi in the ceramic classification. Furthermore the results also serve to identify yet unresolved shortcomings of the computer-based approach, which will be addressed in the future.

Automated creation of digital data, data analysis and visualisation tools from archaeological field work

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This work concerns the development of a workflow allowing for automated creation of digital data from archaeological field work, combined with data storage and management tools, integration with other data sources, data analysis software and data visualisation dashboards. The workflow allows for production of high volume of data (unfortunately rare at the moment) in

Archaeology, analysis and data visualisation updated in real time, and definitely new insight into archaeological practice and research.

Such workflow is being realized within the ArchAIDE project (www.archaide.eu), an EU Horizon 2020 RIA funded project which aims to create a system for the automatic recognition of pottery. Within the research project, an app, mainly designed for mobile devices but also having a web version, is able to recognize the type of ceramics from a photograph in seconds. Ceramic fragments are photographed, their features sent to a comparative collection activating the automatic object recognition system, based on a deep learning architecture framework.

This app represents a way to instantly turn photographs of ceramics into data concerning the type of ceramics. Moreover, once the ceramics fragment has been classified, the recognition system has immediately access to other data, such as the location of the excavation, the features and the chronology (if known) related to that ceramics type. The data are then passed to a database and instantly enriched with all other information available, coming from the database itself or coming from the integration of external sources.

Once the data is stored, it becomes immediately available to the users, through query, data analysis and data visualisation tools included in the ArchAIDE app. Features include the possibility of mapping in real time production centres and finding locations of ceramics, the construction of ceramics network, the identification of clusters, the visualization of chronologies and the identification of significant temporal breaks in the data.

We will show such workflow on data related to Terra Sigillata, a type of fine tableware with glossy surface commonly used in the Roman Empire. Tools for analysis include Network Analysis and identification of significant temporal breaks in the data. The network structure is given by linking together locations where ceramics were produced to locations where the same ceramics were retrieved, getting 3853 locations forming the vertices, throughout Europe, Middle East and North Africa.

Communities were identified within the four temporal periods distinguished, characterised by different production centres emerging and declining in the different phases (Italian, South-Gaulish, Rhine productions), and showing different production dynamics. Temporal breaks were identified by an algorithm minimising the variance within intervals while maximising the variance between intervals.

Data, Big Data and Machine Learning in Archaeology

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The huge quantity of data an archaeological excavation can generate cannot be processed easily. That's the reason that we have to go a step forward from classical statistics and explore some new methods that have been developed to deal with hundreds of thousands of observations. In this paper I will present the advantages of Neural networks, both in the domain of classification and image analysis (pattern recognition), but also as a powerful tool for predictive data analysis, as an advanced method for non-linear regression, that can be extremely helpful for spatial and temporal analysis in archaeology

Machine learning from geospatial data

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Machine learning (ML) is one of the most promising approach in studying complex environmental phenomena. Many real data case studies, for example, environmental pollution, natural hazards and renewable energy resources assessments, are nonlinear and multivariate, nonhomogeneous and variable at different spatial and temporal scales, they are uncertain and should be considered in high dimensional input feature spaces. Therefore, ML algorithms, which are universal, robust and computationally efficient data analysis tools became indispensable in geospatial data treatment. Nowadays, a wide variety of ML algorithms have been implemented and are available to analyze fundamental problems of clustering, classification, prediction and knowledge extraction from data.

The presentation gives an overview of the ML approach, within the framework of a generic methodology, to the main topics of data mining, in particular, how ML algorithms can be used for the intelligent exploratory analysis, modelling and data visualization.

The methodology incorporates several important phases of the ML data analysis – from data collection and preprocessing via patterns detection and recognition to understanding and communication of the results. The presentation is accompanied by the simulated, benchmark and real data case studies for better understanding of the methodology proposed and the results obtained.

Environmental natural hazards susceptibility mapping using Machine Learning

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The development of methods allowing to perform intelligent data reduction is a central issue in environmental science. Nowadays, the availability of massive digital geo-referenced databases led GISscientists to search for new tools able to make sense of such complexity. In this context, innovative techniques based on pattern recognition and data mining can be employed to find a structure in the datasets, to map susceptibility areas for a given environmental natural hazard and to address towards prevention and forecasting measures. In this presentation, we explore the ability of machine learning (ML) algorithms to model the hidden relationships between a set of observations and the environmental predictors (i.e. the occurrence of the event and the predisposing factors), with the final objective of elaborating probabilistic outputs. We present two cases studies concerning the investigation on landslides in Canton Valais (Switzerland) and wildfires in Liguria Region (Italy).

ML includes a class of algorithms for the analysis, modelling and visualization of data, and perform particularly well to model environmental and anthropogenic hazard, which naturally present a complex and non-linear behavior. After a training procedure, allowing to calibrate the parameters of the model, susceptibility maps can be displayed. In this study, we introduce Random Forest (RF), an ensemble supervised ML algorithm based on decision trees. RF, as in general ML approaches, is defined "data driven", meaning that is able to extract knowledge and insights directly from data, rather than by intuition or by personal experience. Therefore, the algorithm may successfully pinpoint a relationship among observed events and surrounding factors, identifying patterns and trends that might not be apparent to a human. Moreover, RF directly provides the measurement of the importance of each variable, allowing to rank the predisposing factors based on their relative contribution to the model. In our models the following environmental variables were considered: topography (DEM, slope, aspect, curvature) plus (1) lithology, NDVI, river proximity and road proximity for landslides; (2) climate (mean temperature and mean precipitation), land use and vegetation covers for wildfires. Observations came from a landslides inventory, consisting on the footprint of various types of observed gravitational slope deformations, and from mapped burned areas, spanning almost 20 years.

It resulted that lithology, proximity to rivers and slope / shrub vegetation, precipitation and altitude were the most important factors influencing respectively landslides / wildfires occurrences. Finally, susceptibility maps were elaborated based on the probability values resulting from RF. These maps allow to identify areas which can be affected by the investigated environmental natural hazardous events, assessed by defining a rank from low to high. The proposed approach proved to be particularly effective to deal with large, high dimensional spatial data, which reflects the great flexibility of ML methods. The investigation of other dataset consisting of observations (i.e. inventories) and predisposing variables could benefit from this same methodology.

An innovative approach for risk assessment in archaeology based on machine learning. A Swiss case study

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In a world that is more and more complex and full of artificial, we strike to master the changes which continuously affect every single domain of our reality and especially challenge human intelligence and cognitive capacities. The study of artificial intelligence (AI) is being exhibited as a core strategy to meet growing demands of science and applications, to solve complex problems in various areas such as environmental science, finance, health-sector, etc. Machine learning (ML) is as a subfield of AI, mainly concerned with the development of techniques and algorithms that allow computers to learn from data.

In an innovative way, this work intends to survey and demonstrate the effectiveness of bringing together traditional archaeological questions, such as the analysis of settlement patterns and past human behavior, with cutting edge technologies related to Machine Learning. Computations were carried out using R free software environment for statistical computing and graphics; data pre- and post-processing was performed in a GIS (Geographical Information System) environment.

We provide a data-driven basis example of archaeological predictive modeling (APM) for the Canton of Zurich, Switzerland. Namely, a dataset of known archaeological sites of the Roman period was considered. The APM represents an automated decision making and probabilistic reasoning tool, relevant for archaeological risk assessment and cultural heritage management.

We adopted Random Forest (RF) (Breiman, 2001), an ensemble ML algorithm based on decision trees. The model is capable of learning from data and make predictions starting from the acquired knowledge through the modelling of the hidden relationships between a set of input (i.e. geo-environmental features prone to influence site locations) and output variables (i.e. the archeological sites).

As result, we obtained: 1) a ranking of geo-environmental features influencing the archeological site occurrence; 2) a map of probability expressing the likelihood of archaeological site presence, at different locations in a given landscape.

These outputs become important not only to verify the reliability of the data, but also to stimulate experts in different ways: they are elicited to characterize the benefits and constraints of using such techniques and ultimately to think big about archaeological data.

Earth Big Data integration for knowledge, monitoring and preservation of cultural heritage

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The use of EO technologies in Cultural Heritage is stepping in its golden age characterized by an increasing growth of both classical and emerging technologies and multidisciplinary methodologies, addressed to the study and conservation of natural and cultural heritage. The availability of the new technologies has opened new infinite possibilities, unthinkable only a few years ago especially for archaeology and cultural landscape that is an integral part of our archaeological heritage being that it preserves the main features that identity the evolutionary history of civilization over time.

Moreover, Earth Observation (EO) technologies can enable advanced performance and new operational applications specifically addressed to security and risk (see, for example Copernicus program and Sentinel missions) also including the monitoring and preservation of heritage sites. EO techniques can provide operative tools for supporting heritage protection, conservation and presentation identifying and monitoring factors that can adversely affect the property (see for example those listed in the UNESCO web site http://whc.unesco.org/en/factors/). In this context, UNESCO in partnership with some space agencies in the world (NASA, ESA, DLR, ASI, CNES, Chinese) over the years has strongly promoted the use of space technologies to assess the state of conservation of cultural and natural heritage sites. Nevertheless, even if the potential of EO technologies for assessing and monitoring natural and man-made disasters is well known, still today the applications of RS for supporting both knowledge improvements, monitoring and preservation of heritage sites require (i) the integration of different (big) Earth data and (ii) the setting up of automatic data processing for systematically support operational application.

The lecture will be focused on:

- An Overview on active and passive satellite remote sensing technologies for documentation, monitoring and preservation of natural and cultural heritage
- Remarkable case studies selected from Europe, Africa, Asia and Southern America

Modelling approaches to large-scale archaeological datasets a as a way to reveal past socio-environmental dynamics

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Archaeology asks often questions about the nature of prehistoric economies, subsistence strategies, extraction and consumption of various raw materials within a context of socio-environmental relationships. Routine use of radiocarbon dating and GIS enabled precise spatio-temporal determination of several socio-economic phenomena like spread of farming or introduction of plough. Traditionally, archaeology (also in connection with environmental archaeology) is working on the level of individual sites, analysing one or couple of settlements dated to a specific period. Nevertheless, archaeology can use its unique long-term

and geographically broad perspective in a more efficient way. In the previous project (http://longwood.cz/) archaeological evidence on human presence was collected from the eastern part of Czech Republic, and this database containing currently ca. 19,000 of archaeological components from the period between 10,000 BCE and 1,250 CE, served as a data input for a spatio-temporal modelling of the intensity of human activity. So far, our modelling approach represented an effective tool for overcoming spatial and temporal uncertainties of the archaeological dataset and for producing of the quantified human activity model, which is easily comparable with palaeoenvironmental proxies. In the upcoming research period we want to use the fact that Czech Republic is currently fully covered by archaeological databases of sites and finds and create a quantified model of land use based solely on the archaeological evidence. This would help us to calibrate land cover models based on pollen profiles. Use of large-scale archaeological datasets and quantified modelling will thus allow us gaining new insight into the past human-environment interactions.

Human demography changes in Morocco and environmental imprint during the Holocene

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The aim of this work is to reconstruct the periods of growth and decline of human populations in Morocco and their potential impacts on the landscape over the last 10,000 years. For estimating the trends of human population size between 10,000 and 3000 years ago we used a Summed Probability Distribution (SPD) of radiocarbon dates from a wide range of archaeological sites available throughout Morocco. The landscape changes were identified and quantified from a data set of fossil pollen records. Different anthropogenic pollen markers as well as natural vegetation groups and taxonomic richness were used to analyze the relationship between the long-term trends of human expansion or regression and the type of impact on the landscape.

Morocco has different topographies and climates which have either favored or prevented the installation and/or spread of human populations. In order to identify the most impacted areas and the timing of the impact we have reconstructed and compared the same past anthropogenic and landscape proxies with the population trends within the lowlands and the mountain areas. The lowlands were more strongly impacted earlier during the Holocene than the mountain areas. Anthropogenic markers indicate that farming expanded in the lowlands during the first major expansion of human populations between ca. 7200 and 6700 calibrated years BP at the start of the Neolithic period. In the Atlas and Rif Mountains the anthropogenic impact is not clearly detectable in any of these areas before 4000 cal. BP. There has been no detectable human impact on the taxonomic richness of ecosystems during the Holocene.

The use of mega pollen dataset to reveal early fruit-tree cultivation across the Mediterranean

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[1] Tel Aviv University

Recent studies have demonstrated the great potential that paleoenvironmental big datasets have in addressing archaeological questions related to vast geographical regions and throughout relatively long periods of time. In a new study I use a Holocene Mediterranean pollen dataset in order to reveal early fruit-tree cultivation. Within the lecture, the olive tree (Olea europaea L.) will be presented as a case study. Olive was one of the most important fruit trees in the ancient Mediterranean region and a founder species of horticulture in the Mediterranean Basin. Olive oil and table olives have been a staple food in ancient and traditional Mediterranean societies for several millennia. Different views have been expressed regarding the geographical origins and timing of olive cultivation and large-scale management. Since genetic studies and macro-botanical remains present various opinions, I turn to another proxy – the palynological evidence. The fossil pollen dataset is composed of high-resolution pollen records obtained across the Mediterranean Basin covering the entire Holocene. Human activity is depicted when olive pollen percentages rise fairly suddenly, are not accompanied by an increase in other Mediterranean sclerophyllous trees and when the rise occurs in combination with consistent archaeological and archaeobotanical evidence. Based on these criteria, the results show that the southern Levant served as the locus of primary olive cultivation as early as ~6,500 years BP, and that a later, early/mid 6th millennium BP cultivation process occurred in the Aegean (Crete) – whether as an independent large-scale management event or as a result of knowledge and/or seedling transfer from the southern Levant. Thus, the early management of olive trees corresponds to the establishment of the Mediterranean village economy and the completion of the ‘secondary

products revolution', rather than to urbanization or state formation. From these two areas of origin, the southern Levant and the Aegean, olive cultivation spread across other regions in the Mediterranean.

Crops, Cows, Calories – A digital model for the carrying capacity of Bronze Age settlements in the inner Alps

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Between 2007 and 2016 a project explored the Alpine pastoral economy in the Lower Engadine (Grisons, Switzerland). Late Bronze Age structures discovered at >2000 m asl are interpreted as evidence of an actual Alpine pastoral economy in prehistoric times. To gain a better understanding of this agricultural system and the overall economic significance of livestock farming, a GIS-based scenario evaluation of prehistoric land use was carried out. Since the data available on the settlement's size and structure is not sufficiently large, the aim was to achieve a theoretical calculation of the maximum number of people and livestock. This calculation was based on a complex subsistence model which was developed from archaeological, physiological and agricultural specialist literature and took into account the area required for crop cultivation and animal husbandry. Based on separately modelled areas of farmland within each site catchment, this allowed us to calculate the carrying capacity or population sizes. The Alpine topography was seen as a severely limiting factor with regard to agricultural output, which would mean that an expanding settlement would be forced to move their livestock to higher pastures further afield during the summer months. Our models, however, have not allowed us to state that economic or ecological pressure was the primary reason for the Alpine pastoral economy. It would have been possible to sustain a population of up to 200 people living in or around each valley settlement all year round. Seasonal vertical mobility must therefore have been established for other reasons, possibly in order to increase the output of agricultural produce for exchange within and beyond the Alpine region. Our paper will present the model's methodological approach and its relevant results, which form an innovative basis for future discussion of prehistoric spatiotemporal organisation, land use and economy in the inner Alpine region.

How many, how far? Quantitative models of Neolithic land use in six wetland sites of the northern alpine forelands between 4300 and 3700 BC

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A general quantitative model of economy and land use in Neolithic wetland sites in the northern Alpine forelands (ca. 4300-3700 BC) is presented. To this aim, archaeological data and information from an agronomic crop yield model (MONICA) is used in an agent-based simulation model of Neolithic land use (WELASSIMO). In a second step, the general model is fitted to specific conditions in six archaeological sites and their surrounding environment using local data from the trinational research project BELAVI. In the simulations, crop yields fluctuate markedly around a long term mean and decrease with ongoing crop production. Sources of readily available non-crop calories are needed to fill the gap. We argue that hazel (Corylus avellana) plays an important role in this context and interpret evidence of frequent human-induced fires in the landscape surrounding the wetland sites as signs of this strategy. The extent of the different land use methods is quantified and visualized in tiles of 8 km2 around the six study sites. The importance of hunting and the number of livestock animals have a large effect on the total area required. The composition of the landscape around the sites determines the resource availability and so has influence on the spatial demand, too. Only small adjustments were necessary to fit the general model to local conditions; no data was found that contradicts the use of the general model. The described overall features seem to be valid for all six sites, spanning nearly 500 km.

Land use dynamics in Neolithic Western Switzerland

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Neolithic communities of the Northern Alpine Foreland show a distinct settlement behavior which prefers locations at the shores of water bodies and short-lived phases of occupation, implicating a high residential mobility. The reciprocal social and environ-

mental conditions and choices to create and maintain such a settlement system are highly debated and belong to the sphere of the investigation of socioecological systems.

The interdisciplinary tri-national research project "*Beyond lake villages: Studying Neolithic environmental changes and human impact at small lakes in Switzerland, Germany and Austria*" explores old and new archaeological as well as paleoecological data to widen the view on the phenomena of the Neolithic wetland sites at different spatial scales. For Western Switzerland a computer-based simulation model on the meso-regional scale is built to simulate land use (LU), anthropogenic land cover change (ALCC) and the demographic and socio-technological development of Neolithic communities.

Based on the gradient adaptive dynamics between population density and sociocultural traits under environmental constrains a regional scaled down version of he "**G**lobal **L**and **U**se and technological **E**volution **S**imulator" (*GLUES*) simulates growth and decline of prehistoric communities. The LU module of our simulation model, based on the agent-based **We**t**la**nd Settlement **Sim**ulat**o**r" (*WELASSIMO*), translates the population size and assumptions about the subsistence economy into spatially explicit LU. During the simulation the alteration of important resources affected by the communities' induced LU is tracked. Legacy effects from former inhabitation of a landscape have influence on the attractiveness of specific places that can be chosen as settlement location.

Under different scenarios concerning communities' resilience, economic choices and environmental changes we investigate probable reasons and mechanism of LU dynamics and its influence Neolithic settlement behaviour at a long-term scale.

Computational socioecological science: quantitative approaches to long-term dynamics and feedbacks in coupled human and natural systems

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Most archaeological research involves making sense of (i.e., interpreting or explaining) empirical data we collect–in spite of decades of calls in the theoretical literature to test hypotheses. This interpretive approach is consistent with a goal of reconstructing the past that is pervasive across all archaeology– including pre-processual, processual, post-processual, and other archaeologies of today. However, the program of reconstruction is an impossible goal for our field. Our human informants are long dead and mute. Nearly all of their material culture is irretrievably gone or inaccessible. What remains is mixed into palimpsests that often span generations to centuries. And we only have resources to recover and analyze a tiny fraction of it.

Yet archaeology controls unique and valuable knowledge about long-term dynamics of human society and its interactions with the natural world–knowledge we desperately need if we are to make informed decisions about our future. How can we embrace the importance of archaeological knowledge and also face the mission impossible of reconstruction? We can do this by reframing archaeology as seeking to understand long-term dynamics (i.e., spatial/temporal change) in human cultural and social systems by proposing explicit models of how and why this takes place, and evaluating them against our unique empirical record. Quantitative and digital methods can make our models more transparent and explicit, and their evaluation more replicable and convincing. We need not abandon our compelling, but often speculative, narratives of reconstruction, but make them a consequence of robust testing of explicit models rather than our discipline's primary goal.

Drawing on recent research, I present a few short case studies of digital and quantitative approaches can be used to devise and test models of past human systems and their interactions with the environment.

Poster: Quantifying functions in urban contexts: Reconstructing the functions of spaces in Roman Ostia based on spatial characteristics

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The spatial characteristics of buildings can relate strongly to different types of use (Al-Sayed et al. 2014, 7-8). In order to uncover these characteristics, the buildings are converted into graphs and their properties are measured using space syntax methods. By linking spatial characteristics to certain functions, the presence of a combination of features could be used to reconstruct the function of a building or space.

Archaeologists are often dependent on assigning labels (e.g. tablinum or triclinium) to spaces based on their location in a plan, even though it is generally difficult to establish a 1:1 relationship between label and function (DeLaine 2004, 148). However, this poster argues that, through the use of space syntax methods, we could ignore the need for labels and focus only on functions. Categorizing the typical features that are related to the different ways in which spaces are used, would allow for the reconstruction of the functions of spaces based on their spatial characteristics. A similar approach has been applied by Hanson (1999), but she used it to study and understand modern houses.

This poster presents the results of a case study in Ostia, Italy. The spatial characteristics of the buildings and spaces in insula V ii, a city block, were analysed using four space syntax methods: access analysis, isovist analysis, visibility graph analysis, and agent analysis. For the purpose of reconstructing functions, the results acquired through access analysis proved to be the most suitable. The interpretations are primarily based on this data, and are combined and compared with previous interpretations of this insula by Boersma (1985).

In order to compare the interpretation based on space syntax methods with Boersma's interpretations, this poster uses the same five categories for functions: domestic, commercial, industrial, social, and utilitarian. One additional category, named 'other', is included to represent staircases. These functioned primarily to provide access to other floors, but were not included separately by Boersma.

The space syntax data is displayed in graphs in order to study how the spatial characteristics correlate to the functions proposed by Boersma. His publication provides the extensive documentation of multiple construction phases, but he reconstructed the functions of spaces only for the final phase (c. 400-500 AD). This provides an opportunity to reconstruct the functions during the previous phase of the insula, based on the space syntax analysis. The correlations are thus used to reconstruct the functions of spaces during the Severan phase, around c. 200 AD. Additionally, several minor changes are suggested to Boersma's interpretation of the final phase.

This approach would be particularly useful to interpret architectural remains in cases where no archaeological finds are present that could be used to assist with the reconstruction of the functions of spaces. For example, in areas where such finds have been lost or destroyed, remain undocumented, or simply never existed. Even if this approach were less accurate or reliable, it would still provide us with an indication of how such spaces could have been used.

Poster: Digital Iron Age: data analysis with MySQL and GQIS

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The interdisciplinary e-learning project "EisenzeitDigital" (EZD; see presentations of July 2017 and May 2018) or "Digital Iron Age" pursues two aims. In the first place, its goal is to record as many Iron Age sites in Bavaria as possible in a MySQL database and to analyse their distribution, for example in relation to topography, geology, soil quality, and hydrology using both the program QGIS for a visual approach and (My)SQL for an analysis based on algorithms. Secondly, students learn how to create a relational database, how to use a GIS and how to bring these two different tools to interact in a fruitful way. In addition to that, students are shown how (archaeological) data are to be organized or structured in a relational format in order to draw conclusions from analytical approaches. Teaching includes the use of a WordPress-Environment, where teachers and students alike present and share their work and have the possibility to comment and interact.

The University of Munich (LMU) currently funds the project as an e-learning class. The MySQL database and the program QGIS both are accessible on a virtual platform called "Digital Humanities Virtual Laboratory" (DHVLab), which has been developed as a teaching platform as part of the initiative Digital Campus of Bavaria that is funded by the Bavarian Ministry of Education and Culture.

The datasets in the database are drawn from the atlas of prehistoric monuments (Bayerischer Denkmal-Atlas) and the information system ("Fachinformationssystem", FIS) compiled by the Bavarian State Office of Heritage (Bayerisches Landesamt für Denkmalpflege), and are systematically complemented by data from publications. The project "Digital Iron Age" thus allows to study the development of settlement patterns and the relationships of different site types in the long term, and to recognize different land use strategies in different parts of Bavaria.

Poster: A new Approach for Structure from Motion Underwater Pile-Field Documentation

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For a pilot study carried out by the University of Bern together with local partners in Summer 2018 at the pile-dwelling site Bay of Bones (Rep. of Macedonia), a new workflow for underwater pile-field documentation was developed.

The site lies in shallow water of 3–5 meters depth and the most obvious constructive remains of the prehistoric settlement are thousands of wooden piles. The piles, mainly of oak and juniper, are excellently preserved in the lake sediments. The aim of the project was to document and sample 40 m^2 surface area of the pile-field and the dendrochronological analysis of the samples.

Dendrochronological sampling requires cutting the top-ends of the piles and thus changes the preserved situation. Therefore beforehand documentation must ensure the localization of each pile on a map.

This calls for a method that ensures a) that every pile is distinctly labeled and b) the location of each pile is accurately captured. While on land, this can easily be achieved, underwater working conditions complicate common procedures. E.g. by measuring with a folding ruler from a local grid, there is later no way to evaluate measuring mistakes or the internal error of the local grid. In addition, for unpracticed divers measuring by hand underwater is not only time-consuming but also tends a lot more to erroneous results than on land.

The goal was therefore to find a time-saving, accurate and easy to carry out way to locate the positions of several hundred piles in shallow water. The best solution for us to achieve these goals was a new standardized and reproducible workflow with Structure from Motion (SfM). The applied approach for underwater SfM-documentation includes on-site workflow and post-processing.

The on-site workflow covers all steps from the preparation of the archaeological structures to the photographic data acquisition, the calculation of a preliminary 3D-model and its on-site verification. The crucial step was to ensure the suitability for modeling of the data before the situation underwater was irreversibly changed through sampling.

Post-processing was carried out in Adobe Photoshop, Agisoft PhotoScan and QGIS where the data was optimized in quality and standardized from digital image processing to the construction of a georeferenced orthomosaic. Applying these results, we can later visualize patterns in the spatial distribution of the piles concerning e.g. their age, their size or their wood species. This will lead to answers regarding architecture, internal chronology and in-site settlement dynamics.

With this newly standardized two-step-workflow for underwater pile-field documentation, we are able to asses and compare the quality of each orthomosaic in a reproducible way. The presented method is highly promising for underwater-documentation of prehistoric pile-fields, yielding accurate digital plans in an efficient and cost-saving way.

Poster: Material interactions and regional groupings in the Iron Age North-eastern Adriatic (7th–1st centuries B.C.)

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The aim of my thesis is to detect the existence of regional groupings in the Iron Age North-eastern Adriatic (700-1 B.C) through an analysis of the distribution of specific material categories among archaeological sites. The material categories include various types of bronze, iron, ceramic and amber objects that circulated on a wide geographical scale during the last Millennium B.C., with well established typologies and up-to-date distribution maps. The methodology I am using was partly inspired by Emilia Blake's book Social Network Analysis and Regional Identity in Bronze Age Italy (2014); that is using non-local object's circulation at the local level to infer (potential) interactions between neighboring sites. However, my methodology is quite different and was developed after a workshop on the use of SNA in R held at Bibracte (France) in october 2018 and organized by Kiel University, Paris 1 and ENS Paris. After having plotted the occurence of the material categories in the study region, I used a set of functions provided by the Moin package (MOdelling INteraction) in R which allow to create a distance matrix, calculating the distance between sites according to the material categories they contain as well as taking into account their geographical distance. From this distance matrix, a network is created with archaeological sites as nodes, and the distance between each others as edge's weight.

The resulting networks ideally aim at detecting the existence of distinct site's clusters defined after their material similarity as well as their close geographical distance; these material networks are an attempt to model regional groupings through the homogeneous consumption of imported objects.

The main research goals of such model are: 1) Providing a method that can overcome the sole reliance on Graeco-Roman literary sources for the detection of Iron Age groups in the region; as well as providing comparative date with that of the archaeological culture established by previous scholarship. 2) The analysis of the organizational properties of the detected material networks. 3) Taking a longue durée perspective on formation of regional groups in the Iron Age North-eastern Adriatic through a diachronic comparison between the Early Iron Age (700-400 B.C.) and the Late Iron Age (400-1 B.C). The two periods are characterized by major historic phenomena that affected the region (such as the Greek colonisation, the migration of groups of the La Tène cultural milieu, and the progressive military involvement and finally occupation of the region by Rome). A central question is the potential visibility of these phenomena in the results, as well as the degree of continuity and difference between the EIA and LIA networks.

The poster will describe the methodology applied and especially discuss the benefits and limits of such models in archaeology, as well as present the preliminary results gathered so far.

Poster: The spatial structure of Galician megalithic landscapes: a case study from the Monte Penide region (NW Iberia)

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It is well known that Neolithic megalithic landscapes are the result of complex locational logics governing where communities chose to site their funerary monuments. These logics in turn respond to broader environmental and cultural affordances, and the relationship between these has been a major topic in the megalithic archaeological literature for the last few decades. Thanks to both new approaches in spatial statistical modelling (and a further novel method for testing site hierarchy that is introduced here), there is now considerable opportunity to revisit traditional megalithic locational concepts from a more systematic point of view, not least in Galician studies (NW Iberian Peninsula). In this research, we apply such a modelling approach to a large set of megalithic monuments located in the south of Galicia (Monte Penide and surroundings) with a view to exploring the locational choices, spatial hierarchy and territoriality in these funerary landscapes.

Poster: Morpho-Technological Analysis of Bifacial Tool Assemblages from the Acheulian Site Complex of Melka-Wakena, Ethiopia

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Melka-Wakena is a site complex located on the shoulders of the Main Ethiopian Rift, consisting of several localities dated to the Early Pleistocene and assigned to the Acheulian Technocomplex. Excavated localities of this complex have produced a wealth of lithic artifacts, among which are large cutting tools (LCTs) consisting of handaxes and cleavers. In order to test competing hypotheses regarding the factors governing LCT shape variability we use a high-resolution 3D homologous landmarks based geometric morphometric shape analysis, combined with a common typo-technological attribute analysis. These methods are applied to a sample of high resolution 3D models of handaxes and cleavers, created by photogrammetry, from two stratified localities. Results indicate that the significant morphological differences between tool types do not stem from differences in production technology or raw material selection and availability. Rather they seem to reflect decisions made by their makers. Furthermore, morphological homogeneity within each type appears to increase through time, and is strongly correlated to the intensity of modification.

Poster: Early neolithic settlement systems along the lower Mureş/Maros river valley

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[1] Eberhard Karls University Tübingen; [2] Museum of Banat, Timişoara

Since 2009 investigations along the lower Mureş river in Banat (Romania) were conducted by the Eberhard Karls University Tübingen and the Museum of Banat in Timişoara. This seasons gained new insights in the establishment of the first neolithic settlements in this region. Zooarchaeological research and palaeoenvironmental reconstructions revealed a clear preference to former river systems and aquatic resources. Our poster will mainly focus on recent work at the sites Bucova Pusta IV and Movila lui Deciov. Preliminary results will highlight the microregion and try to calculate the potential of further spatial analyses. Radiocarbon samples from different sites have been dated and were modelled according to stratigraphic informations using Gaussian Monte Carlo Wiggle Matching and Bayesian Statistics.

Poster: Lake View is Always an Issue

Julia Klammer (juliaklammer@hotmail.com)[1]; Kerstin Kowarik (kerstin.kowarik@nhm-wien.ac.at)[1]; Timothy Taylor (timothy.taylor@univie.ac.at)[1]

[1] University of Vienna, Austria

Within the framework of the project “Beyond Lake Villages”, supported within the joint projects funding scheme D-A-CH (FWF, DFG and SNF), the prehistoric lake village sites of Austria, Germany and Switzerland and their wider region are being brought into sharper focus through new archaeological and interdisciplinary research. The aim of the international project is to evaluate human impact in terms of land use dynamics during the Neolithic, with special emphasis on the 4th millennium BC. The Austrian part is hosted by the University of Vienna and the University of Innsbruck. Our research activities are archaeological as well as on paleoenvironmental. One of our objectives is to get a deeper insight into the use and perception of space by Neolithic societies through the application of different kinds of spatial analysis. One of these analyses, which has been run in the Austrian research area, is showcased here. The project research field in Austria is situated in the northern foothills of the Alps within the Attersee-Mondsee region (Salzburg and Upper Austria). It covers a zone of approximately 1400 km^2 and is dominated by mountains and lakes, forming barriers and open space. Based on idea that vision is arguably the most important sense in human spatial perception, and respecting the distinctive topography of the research area, we were interested to see if sightlines in the sense of having a “lake view” was a desideratum that might be reflected in the distribution of sites. To this end, viewsheds from the shore and center lines of four lakes have been calculated (Irrsee, Mondsee, Wolfgangsee and Attersee). Every 50 m, observer points have been placed on a digital terrain model (10 m). The observer height was set to 1,5 m (eye level). The computations result in a total of 3299 single viewsheds, which have been combined accordingly and derive one single accumulated viewshed. The developed surface was used to determine whether a site is located within or outside the visible range of the lakes. For this analysis we accessed an archaeological database provided by the Federal Monuments Authority Austria (BDA). Not only Neolithic but also prehistoric as well as undated sites were correlated with the visual extent of the lakes and generated interesting results, especially regarding type of site. It appears that settlements have a distinct tendency be positioned in areas with lake view, by contrast to burial grounds and single find spots, and the phenomenon is strongly marked for Neolithic sites. Though the known lake shore sites are included in and influence these analyses, a spatial relation between settlements and lake view zones is undeniable. These results prompt some new questions such as (i) whether people, living within the same visual field, form a sense of community? (ii) whether the outline of the accumulated viewshed is also a cultural limit? And (iii) if so, what does this mean for those who are outside the range? It is hoped that the showcased analyses provide a new basis for future research on such questions.

Workshop

Predictive mapping of archaeological data

Venue location (Room 016, Mittelstrasse 43, 3012 Bern)

Schedule

09:00-10:00	*Block 1*
10:00-10:30	*Coffee break*
10:30-12:30	*Block 2*
12:30-13:30	*Lunch break*
13:30-15:00	*Block 3*
15:00-15:30	*Coffee Break*
15:30-17:30	*Block 4*

Field trip

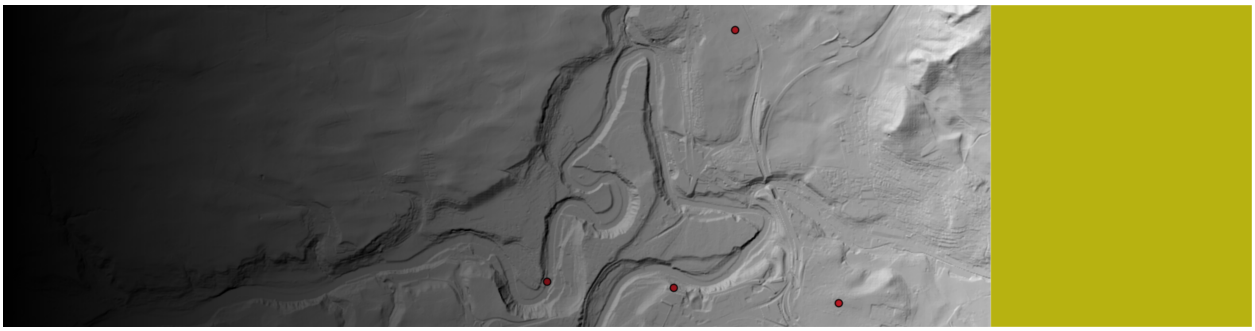
to the bay of Sutz-Lattringen and the Laténium, archaeological park and museum

Schedule

09:00	*Departure from Bern, venue location (Hallerstrasse 12, 3012 Bern)*
10:00	*Arrival in Sutz-Lattringen*
	Guided visit of the dendrolaboratory and diving headquarter.
12:00	*Departure from Sutz-Lattringen*
12:45	*Arrival in Hauterive, Laténium*
	Self-guided walk through the archaeological park.
13:00	*Lunch in Hauterive*
14:15	*Visit of the Laténium*
	Guided visit of the museum.
16:15	*Departure from Hauterive, Laténium*
17:15	*Arrival in Bern, venue location*

Map


Dinner location (Restaurant Zunft zu Webern, Gerechtigkeitsgasse 68)
Colloquium Venue (Hallerstrasse 12)
Hotel Arabelle (Mittelstrasse 6)



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