Session 12

Archaeohydrology

natural water supply and cultural water demand in the past

(Session organizers: I. Unkel, T. Kluge, E. Zagana, M. Finné)
Index

Archaeohydrology: A discipline at the interface of archaeology, hydrology, and hydraulic engineerin
(K. Wellbrock) .................................................................................................................................................. 3

Flood Risk Management in Classical Antiquity. The case of the sanctuary of Amphiaras at Oropos
(A. Androvitsanea) ........................................................................................................................................... 4

Archaeology between the Danube and the Timiş rivers: multi-proxy investigations of the Pančevački
Rit alluvial plain near Belgrade, Serbia (D. Filipovic) .................................................................................... 5

Monsoon, climatic anomalies and society in late medieval India: introduction to the MANDU Project
(A. Casile) .......................................................................................................................................................... 6

The remain of supply water systems in soltaniyeh plain, Zanjan, Iran (M. Feizi)........................................... 8

Reconstruction of Vaqf-Abad Qanat in the Urban Landscape of City of Yazd in Two Historical Periods
(13th and 20th Century) (S. Ali Asghar) ........................................................................................................... 10

Mediaeval and post-mediaeval artificial water reservoirs like a sources of information about
landscape, vegetation and subsistence practices changes in Czech republic (L. Petr) ................................. 11

Hydrogeological investigation in ancient region of Stymphalos (E. Zagana, keynote lecture) ............... 12

Stalagmites as archaeohydrological archives: a case/cave study from Korinthia (N-Peloponnese,
Greece) (T. Kluge) ......................................................................................................................................... 13

Resilience patterns in the Argolis - a model approach to investigate land-use characteristics under
changing climatic conditions (W. Hamer) ........................................................................................................... 14

Water management for bathing facilities: its effects in the landscape and cityscape of Catina and
Syracuse (1st BC – 4th AD). (P. Santospagnuolo) .............................................................................................. 15

Evaluating the influence of climate on the Late Bronze Age collapse in the eastern Mediterranean
(L. Bowler) ........................................................................................................................................................ 17

Water availability and hydrological soil properties around the ancient settlement of Stymphalos
(Greece) (I. Unkel) ........................................................................................................................................... 19
Archaeohydrology: A discipline at the interface of archaeology, hydrology, and hydraulic engineering

Kai Wellbrock (Technische Hochschule Lübeck - University of Applied Sciences)
Co-author: Matthias Grottker

The need of hydrological approaches became increasingly evident in archaeological projects within recent years. This is even more applicable in arid and semi-arid environments when water availability had to be ensured by means of specific water management and engineering. Water abundance and reliability including the development of innovative water management has been the major cause for the development of early permanent occupations in arid environments or promoted the sustainable city life. Diverging archaeological and hydrological understanding and concepts in hydraulic analysis created an urgent need of a discipline at the interface of both subjects.

Works of this discipline, to be called archaeohydrology if defined from the hydrological and hydraulic perspective, are presented by several archaeohydrological case studies from prehistory and antiquity. The contribution will focus on the technical methods needed in archaeohydrology; hydrological approaches and appropriate support from sub-disciplines will be explained. It is stressed that not only hydrological concepts, but also the technical manipulation of natural water resources by means of hydraulic engineering should be taken into account. It is highlighted which additional questions are likely to be answered by archaeohydrological approaches.

Hitherto, hydrological research in archaeology is dominated by rather technical (hydrological, engineering) than societal (archaeological) aspects and aims. Research practice in water history projects clearly points out the imperative need for multidisciplinary approaches, with methods and research agendas of their own right, in order to achieve the understanding of hydraulic structures and the lessons they might provide for present-day sustainable water management.
Flood Risk Management in Classical Antiquity. The case of the sanctuary of Amphiaraos at Oropos.

Anna Androvitsanea (Technical University of Berlin), PhD student

Identifying and interpreting the traces of an ancient water culture is a challenging task. In this paper, we make use of an interdisciplinary approach, drawing from hydrological modeling and archaeological research in order to investigate the effect of flood risk management in ancient hydraulic infrastructures and contemplate on the awareness of flooding risks in antiquity. We focus on the sanctuary of Amphiaraos in Attica. The sanctuary is located in a deep and steep-sloped gorge within which flows a river. The gorge consists largely of lacustrine-fluvial coarse deposits, enabling percolation and seepage and has a steep slope (22 %). The river drains a broader basin of circa 1700 hectares to the Aegean sea. We show that, subsequent to extreme amounts of precipitation, the river would overflow its cross section and flood the surrounding areas, including the sanctuary. As the sanctuary is built next to the river, water management has been a concern, a fact attested to both by the archaeological remains and by inscriptions dated to the 4th century BCE. Using a simple hydrological model, we estimate the basin's response to flooding events of different return periods. Specifically, we make use of the Intensity-Duration-Frequency curve calculated for the surrounding area in previous work. From this curve, we derive the maximum intensity of precipitation over a given recurrence interval, i.e. the likelihood of a given intensity, over this time period. We then use the Rational method to estimate the expected flow rates over each time interval. Conversely, we use the Gauckler–Manning–Strickler formula to calculate the volumetric flow rate that can be accommodated by the river cross section, as defined by the embankment found in situ. With this quantitative information, we can get a sense of the frequency of flooding events at the site. What's more, we make inferences regarding the effectiveness of the hydraulic works, reconstructed in this paper, as mitigation measures against flooding. Informing this analysis with archaeological data, we cast some light on both the engineering and the societal considerations of the era in Attica. Combining hydrological observations and analysis with archaeological data, this paper casts some light into the natural conditions under which building projects in the sanctuary had been designed, tendered and implemented, as well as their significance in a ritual, societal and urban context.
Archaeology between the Danube and the Timiş rivers: multi-proxy investigations of the Pančevački Rit alluvial plain near Belgrade, Serbia

Dragana Filipovic (Institute for Pre- and Protohistory, Kiel University; Institute for Balkan Studies, Serbia)

Co-authors: Milorad Ignjatović, Belgrade City Museum, Serbia Jelena Bulatović, Laboratory for Bioarchaeology, University of Belgrade, Serbia Kristina Penezić, Biosense Institute, University of Novi Sad, Serbia

The area of about 400 square kilometres delimited by the Danube and the old and new beds of the Timiş river near Belgrade was, until mid-last century, a mosaic of low-lying wetlands and dry higher ground, and frequently flooded. Nowadays, it is an area split between densely populated Belgrade suburbs and highly fertile agricultural land. Few decades ago, surface prospection documented traces of potential archaeological sites scattered over this area and dating from different prehistoric and historic periods. This demonstrated that, despite being prone to flooding and waterlogging, the area was an attractive location for anthropogenic activity, possibly including residential use, for millennia before modern day drainage and engineering works. Recently, a multidisciplinary study was completed aimed at evaluating the potential of the area for inhabitation and use during prehistoric and historic times and at identifying the likely locations of short- or long-term settlements. In the initial phase of research, the methods included surface survey by field walking, examination of satellite and aerial photography, geophysical prospection and geoarchaeological coring. The results were used to create GIS-models of the terrain, informed also by the available data on soil and vegetation cover. In the second stage, the assumptions based on GIS were tested in a case study that included excavations of one of the detected sites and the archaeobotanical and zooarchaeological analysis. The multi-proxy approach enabled initial reconstruction of the pre-industrial landscape and an assessment of the favourability of the area for human occupation. It also allowed assumptions to be made about the land use and land management, and the overall quality of life in the past in a hydrologically rich and dynamic environment. This paper presents the research process and outcomes.
Monsoon, climatic anomalies and society in late medieval India: introduction to the MANDU Project

Anne Casile (Research fellow, IRD (French National Research Institute for Sustainable Development), PALOC)

This presentation will introduce the newly ANR (French National Agency of Research) funded project called MANDU, focusing on the interplay between societal change, hydroclimatic variability and water management from a landscape perspective in late medieval times, a period of both significant climatic disturbances and sociopolitical/cultural upheavals in India. On the archaeological ground, the late Medieval is a most poorly documented period of the history of India, and our understanding of the big scale society change that took place remains limited in a number of ways. Scholars have paid little attention to the environment in general and to the role of climatic variability in particular. Scientific advances on climate change and a growing network of palaeoclimatic proxies from Asia have recently unraveled long unknown aspects of the Indian monsoon behavior over the past two millennia, pointing to important variations of the Summer monsoon and the occurrence of climate extremes in late medieval times. What were the impacts of climatic anomalies and related environmental disasters on society, and on the transformations of the cultural landscape that took place in late medieval times? How society responded to hydroclimatic extremes? How did people live in and transform the environment to adapt to monsoon rain variability in a semi-arid environment? What can the study of the long-term lives of water bodies tell us about vulnerability, adaptation and resilience in the face of climatic disturbances? These interrelated questions are all-inherent in land/waterscape histories, and resonate with present concerns about climate change in general, and water scarcity in particular. The ambition of the MANDU project is to address the same and open ways to interdisciplinary research on impacts and feedbacks between society, climate and environment during the first half of the last millennium in India. To investigate the above questions, the project will aim to trace continuities and discontinuities in the historical land/waterscape, and analyse them in ways that give insight into the nature of change, vulnerability and adaptation, and into the ability to absorb perturbations or shocks. The research will focus on the region of Malwa in Central India (Madhya Pradesh) and carries its field investigations on the area of Mandu, a famous historical place known as the capital of the Malwa Sultanate from c. 1400 CE. Situated in the semi-arid part of Malwa, it is now a vast rural area
inhabited by adivasis of the Bhil tribal community, one of whose major concerns relates to water scarcity and insecurity. Untouched by recent urbanisation, the area of Mandu encompasses rich archaeological records of long-term human occupation, cultural and institutional changes underpinned by a variety of processes, and offers potential from scientific perspective to investigate various facets of the society-climate-water interplay in late medieval times. To explore the landscape and watersheds sensitivity and vulnerability to hydroclimatic variations through time and the ways society adapted, the project will have recourse to a variety of disciplines by bringing together scholars from the humanities, social and environmental sciences.
The remain of supply water systems in soltaniyeh plain, Zanjan, Iran

Mahsa Feizi (PhD Candidate at University of Tehran and Lumière University Lyon 2), PhD student
Co-author: Nasim Feizi (Ph.D. Candidate to university Tarbiat Modares)

Soltaniyeh plain located in the north-western of Iran, approximately 35 km to the east of the town of Zanjan. The plain is very important in term of strategy. The reason for this is that the central and northwestern of Iran are connected together by this plain. Natural condition, including Favorable geological condition, abundant precipitation, geology structure, low slope, and sufficient moisture created a supportive environment for human settlements. In the summer of 2016, an archeological survey was conducted therein, in which 90 sites and a large number of ancient water supply systems were registered. This plain has taken his name from a city which the Mongol Ilkhans built in 1304 A.D therein. The construction of the city lead to a series of changes in the region’s landscape and it marked a turning point in the cultural continuity of locality. The author set out to explain the way in which the human has used the potential environment to reach the water and how this usage changed to provide a systematic network of water supply which must have supported a city. Soltaniyeh plain, with relative height about 1800-2000m from sea level, is surrounded in the north and south by mountains. Calcareous geological structure caused a deeps groundwater, at the foothills, in the mountains, so that, once these aquifers reach hard and impenetrable stones, springs are flows. There are a large number of such springs which irrigate the plain in the north and south. The result of the archeological survey, the GIS analysis and the Statistical Analyses show that the springs are the most important sources to supply the water for human settlement. They profited these springs with different structures such as low-depth dams, canals, watercourse and floodgate which some of them remained until now. There are several deep aquifers in the different part of the plain. In the southern mountains, a network of faults has created a complex and deep underground water which progressed to the center of the plain. In addition, in the plain, there are about 150 to 200 meters of alluvial deposits with high permeability and rich in term of aquifers. However, the underground water of southern mountain and its northern side also join in them. On the other hand, its geological structure keeps the surface of these underground water high. In each part, once the slop of grounds and depth of underground water reached the minimum level, Qanats have been made. As noted in written
sources, with the construction of the city, a large number of Qanats were made, such immense construction required an adequate knowledge of the hydrology science, a huge number of workers and a supportive power which were provided very well during the construction of the city. The result of the archaeological survey, the study of written sources, the GIS Maps and the cluster analysis show that there is three group of human settlements in the different part of the region. In addition, in three group, springs, rivers and Qanats, are three manners of supplying water, respectively. In the second group, which located in the central and southeastern of the plain, and is at almost 1949 m above sea level, are situated the sites of around and inside the city. These sites have maximum coherence with Qanats and springs. In addition, several canals carried the water from the southern mountain to the city and a large number of Qanats were used for water supply and the irrigation of garden and farms.
Reconstruction of Vaqf-Abad Qanat in the Urban Landscape of City of Yazd in Two Historical Periods (13th and 20th Century)

Semsar Yazdi Ali Asghar (Senior advisor to the International Center on Qanats and Historic Hydraulic Structures (ICQHS))
Co-author: Ameneh Karimian, Architectural Designer and Researcher,

The 700 year old Vaqf-Abad Qanat has provided water for drinking and urban usage in the city of Yazd (Iran) until the late 60s. Recent developmental projects, climate change and the modern city’s infrastructures such as performing the city’s potable water network has affected the role of qanat in the people’s lives and the urban context. As a result qanat, its related structures and its pathway are going into oblivion. The lack of information on the exact pathway of this qanat and its related hydraulic structures led us to carry out this research. Therefore, as a first step the historical texts and documents related to Vaqf-Abad qanat, the interconnected mansions and hydraulic structures has been reviewed. In order to have a better understanding of the city’s texture in the 13th century, the city and its defensive wall has been closely investigated. After compiling and analyzing the existing information, a 2 dimensional image of the city with a focus on Vaqf-Abad qanat’s pathway has been reconstructed. In the second part of the study, the books, documents and endowments of the past 100 years existing on this qanat have been studied. Through field investigations and interviews with the local practitioners of different neighborhoods of the city, the exact pathway of the qanat was recognized. Then the pathway was illustrated on the recent city’s map. Key words: Qanat, Vaqf-Abad, Yazd City, Reconstruction, mapping
Mediaeval and post-mediaeval artificial water reservoirs like a sources of information about landscape, vegetation and subsistence practices changes in Czech republic.

Libor Petr (Department of Botany and Zoology, Faculty of Science, Masaryk University, Czech Republic)

Co-Author: Petr Kočár

First distinctive human impact to major river stream in Czech republic is recorded in Mikulčice. Early mediaeval stronghold on Morava river existed in 9th century AD, there is several bridges and river bank reinforcement. The high mediaeval period brings increasing of human utilisation of water streams and construction of artificial fishponds. Fish breeding was induce by fasting and difficulty of herring import. First fishpond is known from Praha dated to 12th century. The peak of fishpond building is dated to 15th century and early postmediaeval period. Fishponds sometimes cover former landscape including forest remains. Fishpond are still neglected by archaeology research, dam construction was investigated in Smolina in peripheral Western Carpathians region. Fishponds create new wetlands habitats and contains paleoecological record. Mediaeval colonisation and founding of new villages cause urgency of water supply. One way was building of artificial water reservoirs, such as small dammed ponds or pit hole. This structures are preserved in deserted villages, sometimes has still wet infill, which provide excellent pollen record about landscape changes after settlement decline (Petr and Vařeka submitted). The mining activities and metal processing needs water and energy provided by water. This activities leads to construction of metal washing and building of pond for propulsion. This construction had only short life, depending on mining process, quickly were abandoned and vanished due to deforestation and subsequent erosion. Recent remains are investigated in context of mountain archaeology and shows changes in landscape relief. Fishponds and water stream were employ to hemp leaching. First evidence hemp processing in Czech republic is known from alluvial castle in Veselí nad Moravou dated to mid of 13th century. Several early post mediaeval pound were used to hemp leaching recorded in pollen and macroremains record. This activities ended during 19th century. The historical landscape was fill up of small streams and water reservoirs, which keep up water balance in deforested cultural landscape. Industrialization and field connection during 20th century vanished this network and reduced volume of accumulated water. Landscape turn over to drought sensitive.
Hydrogeological investigation in ancient region of Stymphalos

Eleni Zagana (Department of Geology, University of Patras, Greece)

Keynote lecture

Co-authors: Eleni-Anna Nanou (Department of Geology, University of Patras, Rion, 26500 Patras, Greece), Ingmar Unkel (Graduate School, “Human Development in Landscapes”, Christian-Albrechts-University, Leibnizstr. 3, 24118 Kiel, Germany)

The karstic environment (polje) of Stymphalia located at Northeastern Peloponnese is known not only from the ancient mythology, the fighting of Heracles with Stymphalian birds, but also from the ancient Greek and Roman periods. The surrounding area is characterized from large karstic springs, the front of Stymphalia – Driza springs and Kefalari spring, which discharge the karstic groundwater system named Ziria. The importance of water in the evolution of the ancient and the Roman city is an issue that our ongoing research aims to investigate. Nowadays the water management of the area is crucial as the springs water is used for drinking water supply of the city of Corinth, while a big debate is in progress for the further use of the spring water for the drinking water supply of city Kiato. Water sampling of the springs is carried out for the last two years in a monthly basis, while the water level of Stymphalia springs is measured in a daily basis. The first results of this study are presented in this presentation.
Stalagmites as archaeohydrological archives: a case/cave study from Korinthia (N-Pelopon-nese, Greece)

Tobias Kluge (Heidelberg University)\textsuperscript{1,2}
Co-authors: Tatjana Sarah Münster\textsuperscript{1}, Elisabeth Eiche\textsuperscript{3}, Martin Finne\textsuperscript{4}, Ingmar Unkel\textsuperscript{5}

\textsuperscript{1} Institute of Environmental Physics, Heidelberg University, Germany
\textsuperscript{2} Heidelberg Graduate School for Fundamental Physics, Heidelberg University, Heidelberg
\textsuperscript{3} Institute of Applied Geosciences, Karlsruhe Institute of Technology
\textsuperscript{4} Department of Archaeology and Ancient History, Uppsala University
\textsuperscript{5} Institute for Ecosystem Research, Kiel University

Caves have been occupied by humans since pre-historic times for various purposes. Indicators are archaeological artefacts such as pottery, but also soot layers that settled on the cave surfaces. Speleothems are carbonates that form quasi-continuously in many caves and allow a precise dating of enclosed soot layers. The speleothem carbonate also contains many proxies that enable the reconstruction of the paleoenvironment and paleoclimate. We analysed several speleothems from the Peloponnese that were carefully selected from caves used for religious devotion in the antique Greek period. U-Th analysis provides age constraints for the individual soot layers to originate between 2.5 and 3.2 ka BP. Independent estimates based on pottery suggests ages of cave occupation between 2.5-2.7 ka BP. Stable isotopes of the speleothem carbonate (\(\delta^{18}O\), \(\delta^{13}C\)) are used together with clumped isotopes and elemental ratios to infer the paleoclimatic history at the cave region. Preliminary data suggest significant variation in the paleoclimatic conditions during the Holocene growth period of the speleothems. For quantitative paleoclimate assessment clumped isotopes will be evaluated together with carbonate \(\delta^{18}O\) to infer rainfall changes and its potential influence on water availability for the local societies. Acknowledgements: We thank Norbert Frank, Andrea Schröder Ritzrau and Rene Eichstädter for support in U/Th sample preparation and analysis; Denis Scholz and Regina Mertz for analysis of elemental ratios. We are grateful for support by Chryssa Contaxi and Dimitris Karoutis.
Resilience patterns in the Argolis - a model approach to investigate land-use characteristics under changing climatic conditions.

Wolfgang Hamer (CRC 1266 - Kiel University)
Co-authors: Dr. Daniel Knitter Priv.-Doz. Dr. Oliver Nakoinz Prof. Dr. rer. nat. Rainer Duttmann

The variability of rainfall -- visible not least in the droughts of summer 2018 -- is a threat for all societies, especially in the Mediterranean and sub-tropical climate region, where sufficient precipitation is limited to winter season and evapotranspiration is high. To which degree does this variability of rainfall, in combination with the socio-economic characteristics of a society, influence the resilience patterns of an area? We investigate this questions using the situation in the Argolis in the first millennium BCE as a case study, where geoarchaeological research indicates, that precipitation amounts dropped up to 20 %. We examine the spatio-temporal climatic and environmental dynamics and integrate these in a fuzzy model of available resources, with a special focus on water availability. The latter is of particular importance, as the investigated area benefits not only from precipitation in the direct catchment area but also from more distant precipitation, whose waters are transported in the Argolis by means of extended groundwater aquifers. Based on empirical data and the fuzzy model of resource potential, land use is quantified. Different scenarios are used to estimate potential influences on supply patterns. This allows us to make assumptions about the inter-relationship and dependence of a society on environmental and socio-economic dynamics and offers insights into the resilience patterns of the area.
Water management for bathing facilities: its effects in the landscape and cityscape of Catina and Syracusae (1st BC – 4th AD).

Paola Santospagnuolo (Freie Universität Berlin - Institute of Classical Archaeology), PhD student

Bathing buildings depended on water and represented one of the main places where Romans daily came into contact with it. In a sense, this type of building was the actual link between the natural element and the anthropized contexts, but also the symbol of man’s ability to bend the nature to his needs. In detail, during the Roman period, the presence of volcanic thermalism in Campania (Phlegraean Fields) favoured a twofold consequence: first, the creation of engineering solutions intended to exploit steam and hot water; second, the attempt to recreate these conditions in other contexts, such as in the urban space, led Romans to develop new techniques of water management and water supply. Accordingly, from the last centuries of the Republican period onwards, all cities of the Empire were provided with public baths, which became essential features both of urban and rural areas. This paper centres on the role played by water in the transformations of the rural and urban landscape over time, by focusing on the bathing culture of eastern Sicily, specifically, the provinces of Catania (Catina) and Syracuse (Syracuse) between 1st and 4th centuries AD. The analysis will proceed, firstly, by examining the different geological structure distinguishing the two provinces (the lava stratifications around the volcano Etna and the limestone plateau of the Hyblaean Mountains), its consequences on the water canalization ways (channels carved into the rocks, aqueducts, etc.) and the subsequent use and/or abandonment in the following periods. With special regard to the urban environment, evidence of public baths coming from the two main Roman colonies will be compared: Catina (‘Terme dell’Indirizzo’; ‘Terme della Rotonda’) and Syracuse (Terme Corso Gelone). By scrutinizing the original environmental features of these places (presence of hills, rivers, etc.), their topographic articulation and infrastructures, the paper will try to answer some questions concerning the position of the buildings in the cityscape: which were the reasons lying behind the site choice? Were the already structured urban zoning or the accessibility to the water resource implied? As to the extra-urban environment, different dynamics were involved. In fact, on the one hand, the existence of natural thermal springs influenced itineraries since Prehistory, (e.g. the baths of ‘Santa Venera al Pozzo’), on the other hand, during the Roman period the presence of important routes led to the creation of staging areas furnished with bathing facilities for travellers. In particular, it is interesting to note that
among the baths analysed (Noto – Passo di Miele; Calatabino – Imperio; Fiumefreddo - Torrerossa), those linked to extra-urban roads were characterized by a direct connection to a stream. It is likely, therefore, that these buildings received water directly from these small rivers and streams.
Evaluating the influence of climate on the Late Bronze Age collapse in the eastern Mediterranean

Lydia Bowler (University of Reading), PhD student

Co-authors: Tamar Hodos (Department of Archaeology and Anthropology, University of Bristol, UK), Hai Cheng (Institute of Global Environmental Change, Xi’an Jiaotong University, Xi’an, China; Department of Earth Sciences, University of Minnesota, Minneapolis, Minnesota, USA), Lawrence Edwards (Department of Earth Sciences, University of Minnesota, Minneapolis, Minnesota, USA), Okan Tüysüz (Eurasia Institute of Earth Sciences, Istanbul Technical University, Istanbul, Turkey), Dominik Fleitmann (Department of Archaeology and Centre for Past Climate Change, University of Reading, Reading, UK)

During the 13th and 12th centuries BC a prosperous and globalized Late Bronze Age (LBA) world system came to an abrupt end in the eastern Mediterranean following destruction that swept across the region. Following the twelfth century BC, new cultural forms and societies emerged, heralding the transition to the Iron Age in the eastern Mediterranean and specifically the so-called “Greek Dark Ages” across the Aegean. The causes of this widespread socio-economic transformation, often referred to as the LBA “collapse”, have been debated for decades and remain contentious. This PhD project addresses this debate by examining whether climate may have acted as a contributing factor for the LBA collapse and the Greek Dark Ages.

The main objectives of the project are to (i) present new high-resolution multi-proxy data for the eastern Mediterranean (ii) provide a big picture view of palaeoclimatic conditions across the eastern Mediterranean from 3.5 - 2.5 kyrs BP (iii) integrate new palaeoenvironmental data with the existing archaeology to provide a more holistic explanatory framework. To achieve these objectives this study will develop precisely-dated and highly resolved stalagmite-based records from a number of cave sites across the eastern Mediterranean and Middle East in order to address strong regional climatic variability. Preliminary study has already provided a few records across the region, facilitating precursory understanding of climatic conditions.

Stalagmites are used in this project as they are proven to be a critical recorder of palaeoclimate with numerous advantages over other climatic archives. For example, stalagmites can provide annually-resolved records of effective rainfall through the analysis of stable isotopes, trace elements and annual growth layers (e.g. Flohr et al. 2017). Prior studies have suggested that oxygen and carbon isotopes as well as trace element concentrations (e.g. magnesium, uranium, phosphorus) are excellent proxies of precipitation and effective moisture. For example, Magnesium (Mg) is a useful proxy for effective rainfall due to the sensitivity of Mg to
groundwater residence time while it has also been demonstrated that speleothem Mg provides a potential means of reconstructing past occurrence and severity of dry periods at high resolution (Flohr et al. 2017). The use of stalagmites also permits high temporal resolution (a monthly to annual resolution can be achieved) as well as providing precise and robust chronologies from U-Th dating with low chronological uncertainties (between ±15 to ±35 yrs). This is of significance as many of the existing climate records across this region are of low resolution with high chronological uncertainties. This work also holds relevance to the current hydrological situation in the eastern Mediterranean, as well as the Middle and Near East, as it can inform us about the resilience and vulnerability of past societies to severe and persistent droughts events and thereby contributes to a better understanding of current and future responses to anticipated water scarcity. This is important as the Mediterranean is recognized by the IPCC as one of the world’s global hot spots of climatic change, witnessing increasing frequency of drought events. As a result, the issue of water is and will remain a core concern in the sustainability challenge of the region as well as possessing implications for global food security due to likely increased agricultural stress.
Water availability and hydrological soil properties around the ancient settlement of Stymphalos (Greece)

Ingmar Unkel (Kiel University)
Co-authors: Thomas Birndorfer, Hans-Rudolf Bork, Svetlana Khamnueva-Wendt

The impact of climate events or changes in the environment on the development of ancient societies are often discussed in a very general or simplified way. It is often neglected that in some regions people and the environment they are living in, are more sensitive to changes in hydrology, while in other regions changes in temperature play a greater role. For understanding the critical hydrological thresholds of food and energy supply for a society in the context of land-use and land-cover, it is not sufficient to investigate changes in precipitation patterns alone, but also the characteristics of the geological and pedological regime in the respective region has to be taken into account. We here present preliminary archaeohydrological investigations from the Lake Stymphalia catchment in Greece testing and complementing paleoenvironmental and palaeoclimatic reconstructions from lake sediment cores and archaeological excavations by analysing the fertility and hydrological properties of the different soils in the catchment around Lake Stymphalia, and differentiate according to site characteristics (e.g. topography, climate, bedrock and initial substrate, land use history). As there is hardly any pedological information available from the region, these first analyses shall answer questions like: Which soil types are characteristic of the study area? Are there any differences in pedogenesis, e.g. due to the geological structure of the basin or due to different land use patterns? Is the human impact (footprint) visible in the soils of the study area? Can we identify changes in land use patterns and human activity in the past, especially concerning forest clearing, agriculture, and hydrology?