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AREA DOMENIU

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International Meeting on Paleoclimate: Change and Adaptation

- book of abstracts –

Editores:

Rui Pena dos Reis
Maria Helena Henriques
Luiz Oosterbeek
Pierluigi Rosina
Eduardo Ivo Alves
Gustavo Gonçalves Garcia
Patrícia João

MAÇÃO, 2019



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CHANGE AND ADAPTATION**

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INSTITUTO TERRA E MEMÓRIA

MAÇÃO, 2019



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Foreword

Climate is the planetary response of the atmospheric circulation to its changing composition, to the solar system configuration, to the Earth's rotation and to the oceans' and continents' distributions. It displays, as a result, a restless moving pattern, expressed at a global scale by subsiding and uplifting convection cells.

These changes have long been recognized and documented in geologic objects of all ages. In many rocks, different geologic features, fossil fragments and imprints, prehistoric remains and historic reports, there is a climate signal that can be analyzed and interpreted. All that information should be gathered in order to learn more about past climate changes. Lessons from the past support the view that deep change is the rule, not the exception, even where no reference is available, due to strongly contrasting extremes, chaotically defined by the whole ensemble of extra-planetary, external, and internal geodynamic controls.

Science-based knowledge is crucial to face current challenges, which are focus for research within the UNESCO chair on Geoparks, Sustainable Regional Development and Healthy Lifestyles and the UNESCO chair on Humanities and Cultural Integrated Landscape Management, both partners in this international meeting, which has been organized by the Geosciences Centre and the Centre for Earth and Space Research of the University of Coimbra.

This volume records the contribution of about seventy ongoing projects developed by research teams with a wide range of scientific backgrounds from different regions of the planet, who met at the University of Coimbra on the 18th-19th June 2019. The enriching discussions on paleoclimates in the Solar System, climate changes in geological time, climate memory in the geological record, climate changes and human adaptations throughout the Quaternary, and climatic events and human-environment interactions in the Holocene, indicate that the main objective underlying this initiative will have been fulfilled: to stimulate an observational attitude and to promote an open discussion on paleoclimatic signals in order to improve our look at the present and to ground future perspectives.

The Organizing Committee

International Meeting on Paleoclimate: Change and Adaptation

University of Coimbra, 18th-19th June 2019

SECTION 1

TOPIC 1 - PALEOCLIMATES IN THE SOLAR SYSTEM: EXTERNAL FORCING AND DIVERGENT EVOLUTIONS

Climate Catastrophes in the Solar System

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A Tool for Better Understanding Titan's Paleoclimate

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Abstract: The improvement of the visibility of drainage networks in Titan surface images obtained with the Synthetic Aperture Radar (SAR) on board of the Cassini probe is achieved by combining three images of the same area on the surface of Titan, obtained in three different passages of the Cassini probe. This methodology is more extensively explained in Alves et al. (2018). BIDR (Basic Image Data Record) images are used in "Unsigned byte" format with the best available resolution (175m/pixel) obtained from (PDS, 2017). The images are cut out to cover previously identified drainage networks (e.g. in Burr et al., 2013; Cartwright et al., 2011), are then registered, using one of the images as reference, and finally fused in a RGB image. In figure 1 two drainage networks (network 1 – NT1, left side and center; network 2 – NT2, right side) where this methodology was applied are presented, including: the original BIDR images (a, b, c, f, g and h), the RGB composites (d and i) and the delineation of the drainage networks achieved in this work (based on RGB image) and on previous works Burr et al. (2013) and/or Cartwright et al. (2011) using only one BIDR image (e and j). The morphometric estimates for the networks: total length, mean bifurcation ratio and Shreve magnitude (Shreve, 1966) are presented in table 1, including previous estimates obtained from Burr et al. (2013) and Cartwright et al. (2011). From the observed values changes, it is possible to say that the increased detail of the RGB image will allow constraining previous estimates of erosion times and geomorphologic models for each network area, which is a contribution for better understanding Titan's paleoclimate. The next step of this work is to extend this methodology to all Titan drainage networks that were sampled more than once in the available SAR images from PDS (2017).

Tab. 1 – Morphometric parameters for network 1 (NT1) and network 2 (NT2)

| | NT1 | | | NT2 | |
|-------------------------------|-----------|------|--------|-----------|------|
| | This work | [3] | [4] | This work | [3] |
| Total length (km) | 1040,9 | 412 | 251,9* | 654,6 | 409 |
| Mean bifurcation ratio | 3,4 | 3,6* | 2,5 | 3,1 | 3,2* |
| Shreve magnitude | 93 | 44 | 15* | 63 | 34 |

*parameter not mentioned in the original work; the value was calculated based on the network delineation obtained from the original work.

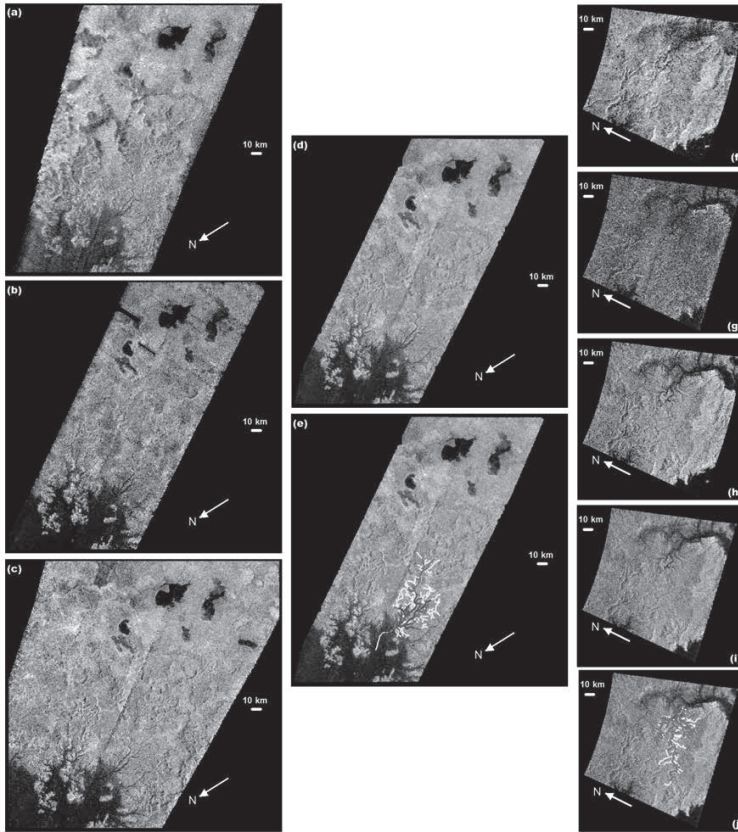


Fig. 1 – Network 1: cut original images T108 (a), T064 (b), and T029 (c); RGB composite (Red- T064, Green- T029, Blue- T108) (d) and Drainage network outlined (e). Network 2: cut original images T025 (f), T086 (g), and T028 (h); RGB composite (Red- T086, Green- T028, Blue- T025) (i) and Drainage network outlined (j). Drainage network outlined in this work (yellow); according with [3] (red); according with [4] (blue).

Keywords: Titan; Hydrology; Image enhancement.

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Laboratory Simulation of Drainage Networks Formation on Titan

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Abstract: Drainage networks were among the first features to be observed on Cassini and Huygens imagery (Porco et al., 2005; Lebreton et al., 2005). They have been interpreted as having originated analogously to Earth drainage networks: precipitation on Titan is assumed to be composed mainly of liquid methane ‘raining’ from a much colder, denser atmosphere than the Earth’s (Turtle et al., 2009). In order to verify the current hypotheses for the formation of drainage networks on Titan, our modelling intended to recreate these features under controlled laboratory conditions. The tested variables were temperature (between -10 and 20 °C), soil granulometry (modal 40, 150 e 400 µm), and water saturation (dry, moist and saturated). The “soils” were composed of quartz grains crushed and sieved to the desired granulometries. Samples were mounted on a TECA AHP-1200CPV thermoelectric plate which is fully programmable so that the time-temperature function can be made to fit our requirements (Silva, 2017). The advantage of our experimental setup is that we can simulate an indefinite number of freeze-thaw cycles – the maximum number we attained were 630 cycles. According to the climatic conditions to model, this can account for 630 sols, if the freeze-thaw cycle is daily, or 630 years, if the freeze-thaw cycle is seasonal. More than 60 tests were carried out, with maximum number of cycles ranging from 70 to the mentioned 630. Each test was stop-motion photographed, allowing the construction of several compilations of images and films that facilitate the analysis of the results. This way, the final appearance of each of the samples was verified, as well as their evolution along each cycle and it was possible to compare them with images of real periglacial features. The relevant results for modelling the formation of drainage networks on Titan occur with a saturated mixture of fine and coarse grains. After 180 freeze-thaw cycles, drainage networks seem to be fully developed having reached maturity (Fig. 1). Synthetic aperture radar (SAR) Cassini images of the banks of Ligeia Mare seem to allow comparison (Fig. 2).

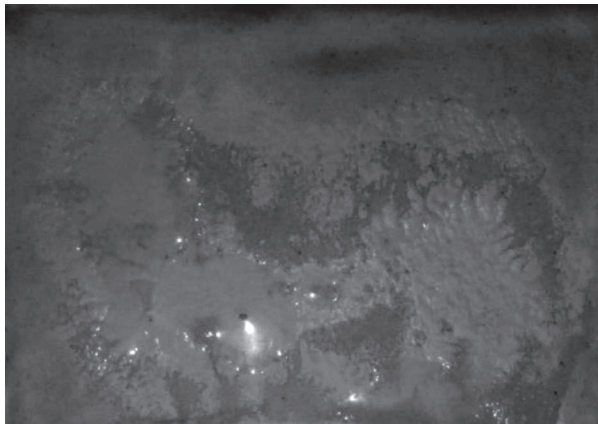


Fig. 1 – Laboratory simulation of Titan ‘lake’ with drainage networks.

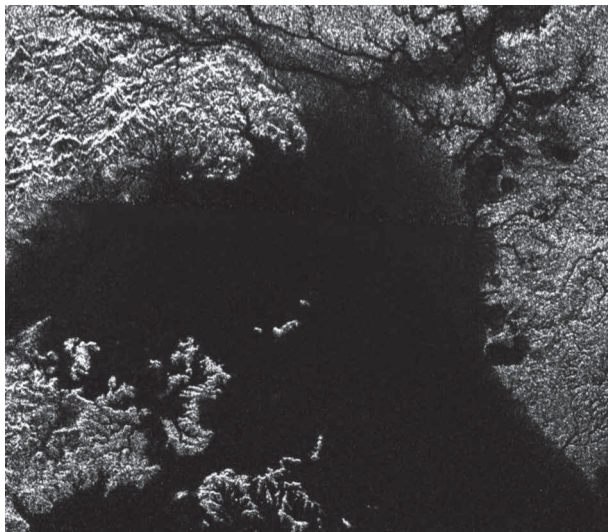


Fig. 2 – Ligeia Mare SAR image PIA19052 (NASA/JPL, 2015).

Keywords: Hydrology; Drainage networks; Titan; Physical models.

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Laboratory simulation of Martian periglacial features

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Abstract: Periglacial features are geomorphic structures created by soil freezing and thawing in non-glacial zones. In order to verify the current hypotheses for the formation of periglacial features, our modelling intended to recreate these structures under controlled laboratory conditions. The tested variables were temperature (between -10 and 15 °C), soil granulometry (modal 40, 150 e 400 µm), and water saturation (dry, moist and saturated). The “soils” were composed of quartz grains crushed and sieved to the desired granulometries. Samples were mounted on a TECA AHP-1200CPV thermoelectric plate, which lowers temperature using Peltier effect and raises it using Joule effect. The thermoelectric plate is fully programmable so that the time-temperature function can be made to fit our requirements. The advantage of our experimental setup is that we can simulate an indefinite number of freeze-thaw cycles – the maximum number we attained were 630 cycles. According to the climatic conditions to model, this can account for 630 sols, if the freeze-thaw cycle is daily, or 630 years, if the freeze-thaw cycle is seasonal. More than 60 tests were carried out, with maximum number of cycles ranging from 70 to the mentioned 630. Each test was stop-motion photographed, allowing the construction of several compilations of images and films that facilitate the analysis of the results. In this way the final appearance of each of the samples was verified, as well as their evolution along each cycle and it was possible to compare them with images of real periglacial features. Our experiments modelled periglacial features that are ubiquitous, such as the polygonal terrains visible on Earth and Mars. Other structures have also been observed which apparently have no parallel in known reality. The results of modelling polygonal terrains (Fig. 1), calibrated circles (Fig. 2), and brain terrains (Fig. 3) are presented. In this last case it was indeed possible to observe modelled features that visually match the real ones on Mars since, as far as we know, brain terrains are specific to the Martian landscape.

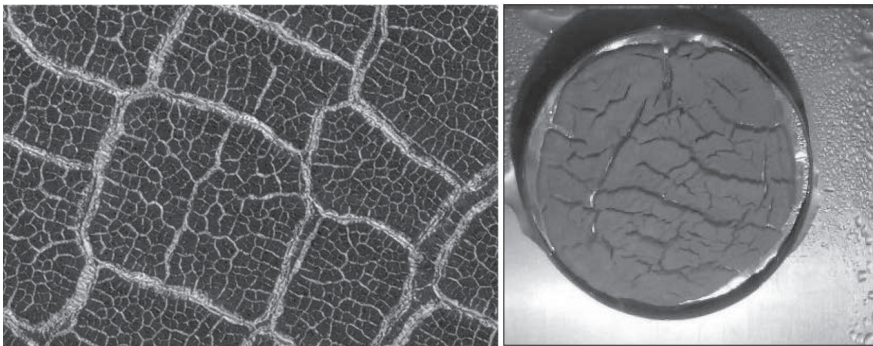


Fig. 1 – Left: polygonal terrain on Mars (El Maary et al., 2010); Right: laboratory simulation.

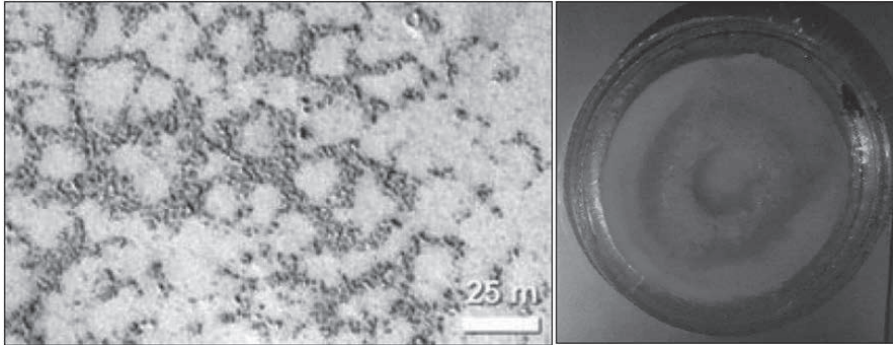


Fig. 2 – Left: calibrated circles on Mars (Hauber et al., 2011); Right: laboratory simulation.

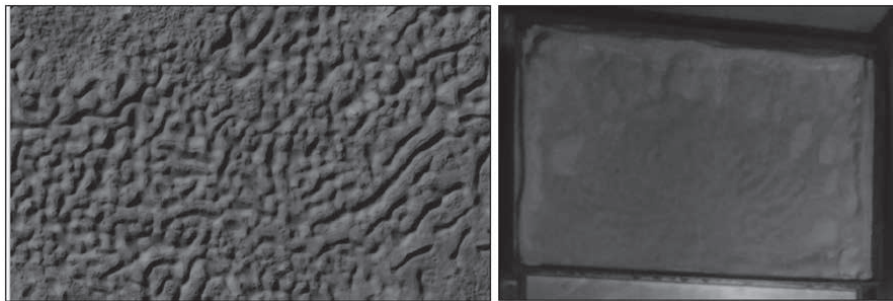


Fig. 3 – Left: brain terrain on Mars (Levy et al, 2009); Right: laboratory simulation.

Keywords: Periglacial geomorphology; Mars; physical models.

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The different forcings of the climatic variations: causal links

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Abstract: Monthly series of temperature parameters measured by three Portuguese meteorological stations from 1888 to 2001 were used to study the effect of different climatic forcings. Three types of external forcings were considered: anthropogenic greenhouse gases and aerosols, volcanic aerosols, and solar and geomagnetic activity variations. Long-term variations of the temperature and other parameters with characteristic periods of decades were studied by various methods including the correlation and multiple regression analyses, wavelet/wavelet coherence analyses and with a method allowing estimation of the causal nature of the found relationships – the convergent cross mapping (CCM). Obtained results confirm the statistical dependence of the temperature variations on the volcanic and the anthropogenic influence as well as variability that can be associated with the solar activity impact. In particular, surprisingly strong bi-decadal cycles were observed in temperature series whereas the observed decadal cycles are weaker and transient. Another interesting finding is the apparent non-stationary of the relations between the solar and atmospheric parameters probably related to periods of strong/weak global circulation or frequent/occasional volcanic eruptions or interaction between the external forcing and internal atmospheric variability. In this study we took advantage of the homogenized data set (Morozova and Valente, 2012) which consist of sets of 12 monthly series for each of the following parameters: monthly means of the daily minimum (Tmin) and daily maximum (Tmax) temperatures measured by three Portuguese stations, and calculated from them monthly means of the mean daily temperature (averT) and daily temperature range (DTR). The stations are Porto ($\varphi = 41^{\circ}08'N$, $\lambda = 8^{\circ}36'W$, from 1888 to 2001), Coimbra ($\varphi = 40^{\circ}12'N$, $\lambda = 8^{\circ}25'W$, from 1865 to 2005) and Lisbon ($\varphi = 38^{\circ}43'N$, $\lambda = 9^{\circ}09'W$, from 1856 to 2008). Three types of external climatic forcings are considered: Anthropogenic forcing described by the CO₂ and the anthropogenic sulfate aerosols; Volcanic forcing represented by the volcanic sulfate aerosols; Solar forcing characterized by the sunspot numbers (SSN) and the geomagnetic indices (GAi). One of the strongest forcings for the studied period is the anthropogenic gases (CO₂). As was shown by Morozova and Barlyaeva (2016), temperature decadal variations show strong relations to the CO₂ forcing. The fingerprints of both anthropogenic and volcanic sulfates are also found in the temperature variations. Weak but statistically significant (bi-)decadal signals in the temperature series that can be associated with the solar and geomagnetic activity variations were found. These signals are stronger during the spring and autumn seasons. The multiple regression models which include the sunspot numbers or the geomagnetic indices among other repressors have higher prediction quality. The wavelet coherence analysis shows that there are time lags between the temperature variations and the solar activity cycles. These lags are about 1-2 years in case of the 11-yr solar cycle as well as in case of the 22-yr solar magnetic cycle (relatively to the solar polar magnetic field observations). These lags are confirmed by the correlation analysis. The results obtained by these methods as well as comparison to results of other studies allow us to conclude that the found (bi-)decadal temperature variability modes can be associated, at least partly, with the effect of the solar forcing. The co-variance of the temperature and different forcing parameters were tested using a method allowing to detect causal nature of the relations between two analyzed series – the convergent cross mapping (CCM). This method is based on empirical dynamics (Sugihara et al., 2012 and references therein) and Takens' theorem, which states that the essential information of a multidimensional dynamical system is retained in the time series of any single variable of that system (Tsonis et al., 2015). The procedure of the CCM analysis allows to detect if the analyzed parameters belong to the same dynamical system or not and, further, to estimate the strength and direction of the causal link. The application of the CCM analysis to the series of the Portuguese temperatures and their probable forcings confirm the results obtained by

correlation and wavelet analyses. The CCM confirm the solar and geomagnetic forcings (SSN and GAI series, respectively) of the ground measured temperatures (Fig. 1).

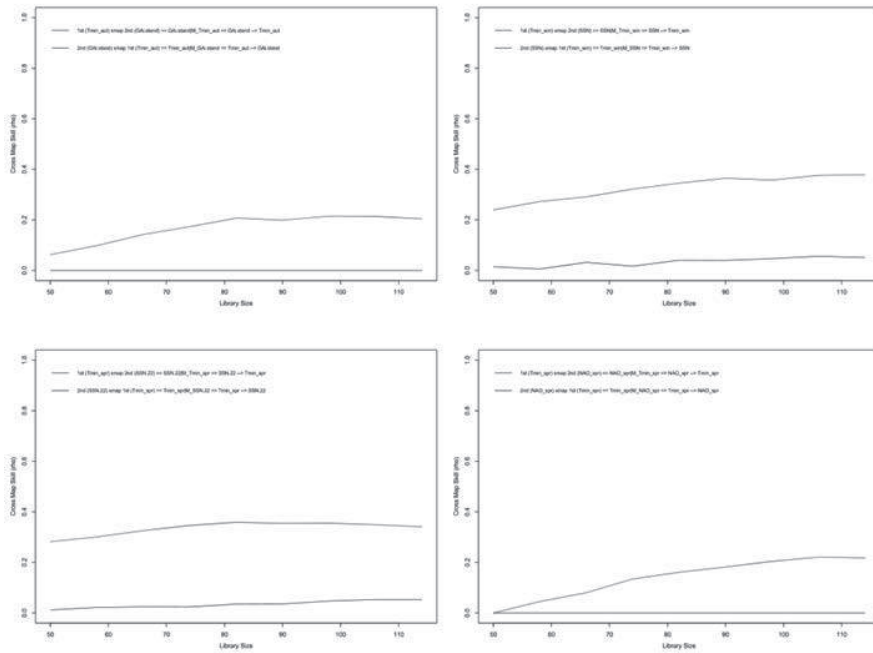


Fig. 1 – Convergence of the predictive skills of the CCM models for the solar and geomagnetic parameters: top left – Tmin autumn vs GAI; top right – Tmin winter vs SSN; bottom left – Tmin spring vs SSN 22 yr; bottom right – Tmin spring vs NAO spring.

Keywords: Space weather and space climate; external forcings of Earth climate

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SECTION 2

TOPIC 2 - CLIMATE CHANGES IN GEOLOGICAL TIME: LESSONS TO LEARN

Climate change and desertification: an in-service teacher training programme for Basic Education

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Abstract: The concept of Sustainable Development emerges from the need to establish a balance between economic and social progress and environmental protection. The balance among these three dimensions requires that citizens understand the need to know the limits of economic progress, as well as its repercussions on society and the environment; acknowledge different social institutions and their social role, which is an essential requirement for living in democracy; and recognize the weaknesses of natural and anthropic systems in time to awaken them to the need for sustainable management. However, there are some elements of imbalance, such as climate change, which have multiple effects, some with unpredictable consequences, for example the frequent occurrence of floods or droughts, which illustrate how disturbances in natural systems can have serious consequences in social and economic terms. The worsening of desertification is one of the consequences of climate change. Soils are complex entities and their dynamics intersects with that of other terrestrial subsystems, namely the biosphere (living beings), the lithosphere (rocks), the hydrosphere (water) and the atmosphere (air). The consequences of desertification for humankind become clear when one thinks of the soil by relating it to everyday activities, such as agricultural production, civil engineering, water supply, water and air quality, sanitation and waste collection. This relevance of the soil led to the declaration of the year 2015 as the International Year of Soils at the 68th UN General Assembly, with the aim of increasing people's awareness and understanding of the importance of soil in the different subsystems, including ecosystems and food security. It is thus evident the need to educate citizens to be informed, participative and committed with the responsible management of the Planet and its resources, namely the soil, in a perspective of sustainable development. This will only be possible by breaking with traditional education systems and deeply rethinking/reorganizing formal and non-formal education. Therefore, in-service teacher training programmes must be designed, based on their needs and expectations, to support and sustain practical Sciences activities in Basic Education (6-15 years old pupils). This paper will present a proposal of an in-service science teacher training programme of 1st, 2nd and 3rd cycles of Basic Education in Portugal (Fig. 1). It is intended that the teachers participating in the programme elaborate a didactic sequence and the corresponding resources to explore the theme soils in a perspective of Sustainable Development, and later implement those resources in their classes. This sequence will be designed in a perspective of continuity between cycles of Basic Education, with the promotion of practical activities properly contextualized.

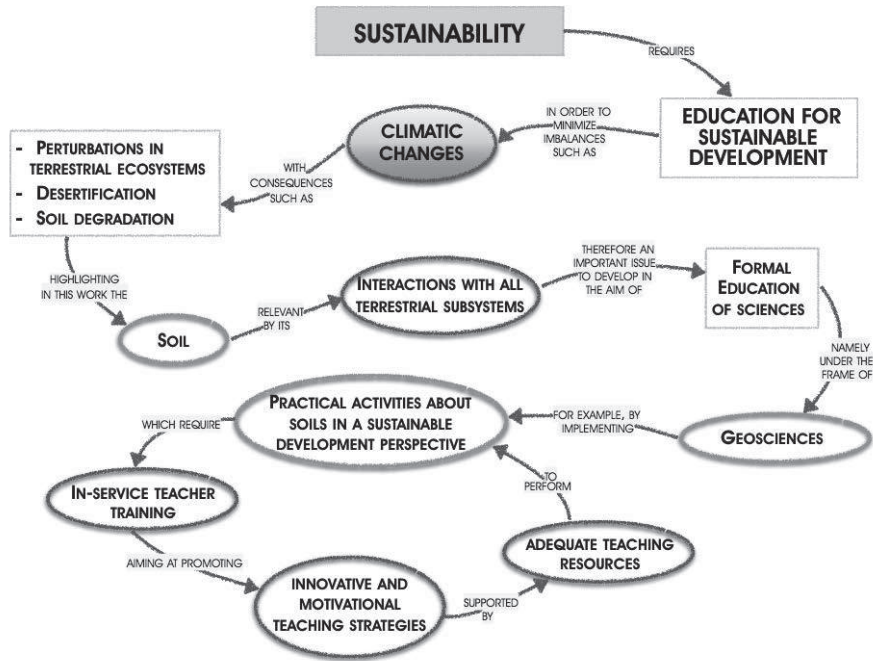


Fig. 1 – Graphical organizer representing concepts and ideas which ground the development of this work.

Keywords: Sustainable Development; Soil; In-service teacher training programme; Basic Education.

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Climate Change: the debate

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Abstract: Climate change (or, as some insist on saying, global warming) is one of the most prominent scientific, political, and even – as many would claim – moral issues of our time. There is an ongoing debate between those scientists (mainstream) who are consensual (A) about the anthropogenic influence in climate change, and those scientists who are skeptical (B) and claim that natural factors are the main drivers for climate change (Table 1). There is a general consensus that climate change is real and that we are witnessing a process of global warming. But there is plenty of disagreement on whether the climate drivers are mostly man-made or are essentially derived by natural causes. In this presentation, we have identified 5 scientists on each side of the fence (recognized by the science community through several books published and hundreds of peer reviewed papers or book chapters) and have tried to summarize, in one or two key factors, the main thesis that drives their investigation. Climate change is an extremely complex and multi vectorial problem. It is not the intent of this presentation to take sides on this debate, but to send an alert to the fact that the nature of science is being skeptical. Therefore we highlight two statements of two scientists which are on different sides of the fence: the skeptical Professor Nir Shaviv states, on his presentation to the Bundestag that “appealing to a majority does not make science correct, because science is not a democracy”! Consensual Professor Wallace S. Broecker states, on his book *Geochemical Perspectives* “I like puzzles of any kind. Hence it is what we don’t understand ... that is of most interest to me. Consequently I speculate; were I, to have written this five years ago, it would be quite different; and, of course it would be quite different if written in 2022.

Table 1 – Consensual (A) about the anthropogenic influence in climate change and skeptical (B) who claim that natural factors are the main drivers for climate change.

| Consensual (A) | Skeptical (B) |
|---|---|
| <p>Wallace S. Broecker</p> <p>PhD (1958) in geology from Columbia University. Professor of Geology in the Department of Earth and Environmental Sciences and the Earth Institute at Columbia University, and a research scientist with Columbia’s Lamont-Doherty Earth Observatory.</p> <p>He passed away in 2019</p> | <p>Lennart O. Bengtsson</p> <p>PhD (1964) in meteorology from the University of Stockholm. He was Head of Research and later Director at the European Centre for Medium-Range Weather Forecasts in Reading in the UK (1976 — 1990), and Director of the Max Planck Institute for Meteorology in Hamburg (1991 — 2000). He is currently Senior Research Fellow with the Environmental Systems Science Centre at the University of Reading, as well as Director Emeritus of the Max Planck Institute for Meteorology.</p> |
| <p>Tom M.L. Wigley</p> <p>PhD (1967) in mathematical physics from the University of Adelaide. He has held posts with Australia’s Commonwealth Bureau of Meteorology, the University of Waterloo in Canada, the University of East Anglia’s Climatic Research Unit (CRU) in the UK, and the</p> | <p>John R. Christy</p> <p>He holds a PhD (1987) in atmospheric science from the University of Illinois. He is currently Distinguished Professor of Atmospheric Science and Director of the Earth System Science Center at the University of Alabama in Huntsville.</p> |

| | |
|---|---|
| <p>National Center for Atmospheric Research (NCAR) in Boulder, Colorado, in the US. He is currently Professor of Climatology in the Department of Ecology and Environmental Science at the University of Adelaide.</p> | |
| <p>Susan Solomon</p> <p>PhD (1981) in chemistry from the University of California, Berkeley. Worked for the National Oceanic and Atmospheric Administration (NOAA). In 2011, she moved to MIT, where she is currently Professor of Environmental Studies in the Department of Earth, Atmospheric and Planetary Sciences</p> | <p>Nir J. Shaviv</p> <p>PHD (1996) in physics from the Israel Institute of Technology in Haifa. He spent a year as an IBM Einstein Fellow at the Institute for Advanced Study in Princeton, New Jersey (2014 — 2015). He is currently Professor and Chair of the Racah Institute of Physics at the Hebrew University of Jerusalem.</p> |
| <p>James E. Hansen</p> <p>Master's degree (1965) in astronomy and a PhD (1967) in physics, both from the University of Iowa. He retired in 2013 as Director of the NASA Goddard Institute for Space Studies, where he worked for four and a half decades. He is currently Adjunct Professor at Columbia University and Director of the Program on Climate Science, Awareness and Solutions in Columbia's Earth Institute.</p> | <p>Richard S. Lindzen</p> <p>He holds a PhD (1964) in applied mathematics from Harvard University. He is currently Professor Emeritus in the Department of Earth, Atmospheric and Planetary Sciences at MIT.</p> |
| <p>Michael E. Mann</p> <p>Undergraduate and graduate studies in geology and PhD in geophysics in 1998 from Yale University. He is currently Professor of Atmospheric Science at Pennsylvania State University. He is also Director of Penn State's Earth System Science Center.</p> | <p>Judith A. Curry</p> <p>PhD (1982) in geophysical sciences from the University of Chicago. She has taught at the University of Wisconsin, Purdue University, Pennsylvania State University, the University of Colorado at Boulder, and Georgia Institute of Technology (Georgia Tech). For 15 years, she was a Professor in the School of Earth and Atmospheric Sciences at Georgia Tech, where she was Chair of the school for 11 years. In 2017, under a torrent of criticism from her colleagues and negative stories in the media, she was forced to take early retirement. She is currently Professor Emerita at Georgia Tech, as well as President of Climate Forecast Applications Network, an organization she founded in 2006.</p> |

Keywords: Consensual; Skeptical; Climate change.

Paleoclimate archives from Southern Portugal: An overview

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Abstract: Paleoclimate events, either short or long in time, can be recorded in a variety of archives along the geologic timescale, several of which are present in Southern Portugal where the geologic history spans almost the last 400 Ma. The type of paleoclimate archives will define both the type of paleoclimate event that can be studied and the resolution of the proxy used to study it. In the Algarve Region, the most abundant paleoclimate archives correspond to metasedimentary and sedimentary rocks, representing depositional environments ranging from Devonian to Quaternary periods. Several proxies such as lithology, mineralogy and organic geochemistry and biology, have been used on these archives to describe paleo-environmental changes, as for instance oceanic anoxic events and sea-level variations linked to glacial cycles. Other proxies, such as the fossil content and isotopic signatures, have also been analyzed for documenting paleoclimate systems. Concerning the Quaternary period climate record, the Algarve has no ice or lake archives, but it has continental deposits, such as estuarine sediments, calcareous tufas and speleothems, as well as archeological and historical archives, allowing reconstructing more recent paleoclimate conditions. Studying all these possible archives and paleoclimate records is a demanding task and it is thus still a work in progress. Nevertheless, significant scientific contributions in this research area already exist and are being used as a geological heritage for the Loulé-Silves-Albufeira Aspiring UNESCO Global Geopark. Indeed, the territory encompassing the Loulé-Silves-Albufeira Aspiring UNESCO Geopark has several archives and records across the geological timescale that are worth presenting. As a first example, this territory has a unique record of Triassic rock formations, the Silves Sandstone succession (known as Grés de Silves *sensu lato*) in which a recently discovered amphibian species, *Metoposaurus algarvensis*, has recently been described for the first time, based on a large concentration of bones (Brusatte et al., 2015), and new fossil remains of Henodontidae are under determination. All the studied proxies describe a transitional continental environment, characterized by arid conditions that led to the existence of temporary ponds, and ultimately the formation of evaporites, in the transition to the Jurassic, after a short marine incursion into the basin (Fechner, 1989). The coral and echinoid fossils from Jurassic limestones formation can be presented as a second attractive example of this territory paleoclimate record, allowing documenting the tropical sea conditions existing at that period. Finally, a third example of the paleoclimate archive included in the aspiring Geopark territory, is linked to the extensive and magnificent karstic landscape near Loulé, that presents speleothems and springs, with calcareous tufas, in which preliminary isotopic and palynological studies are very promising (Fig. 1).

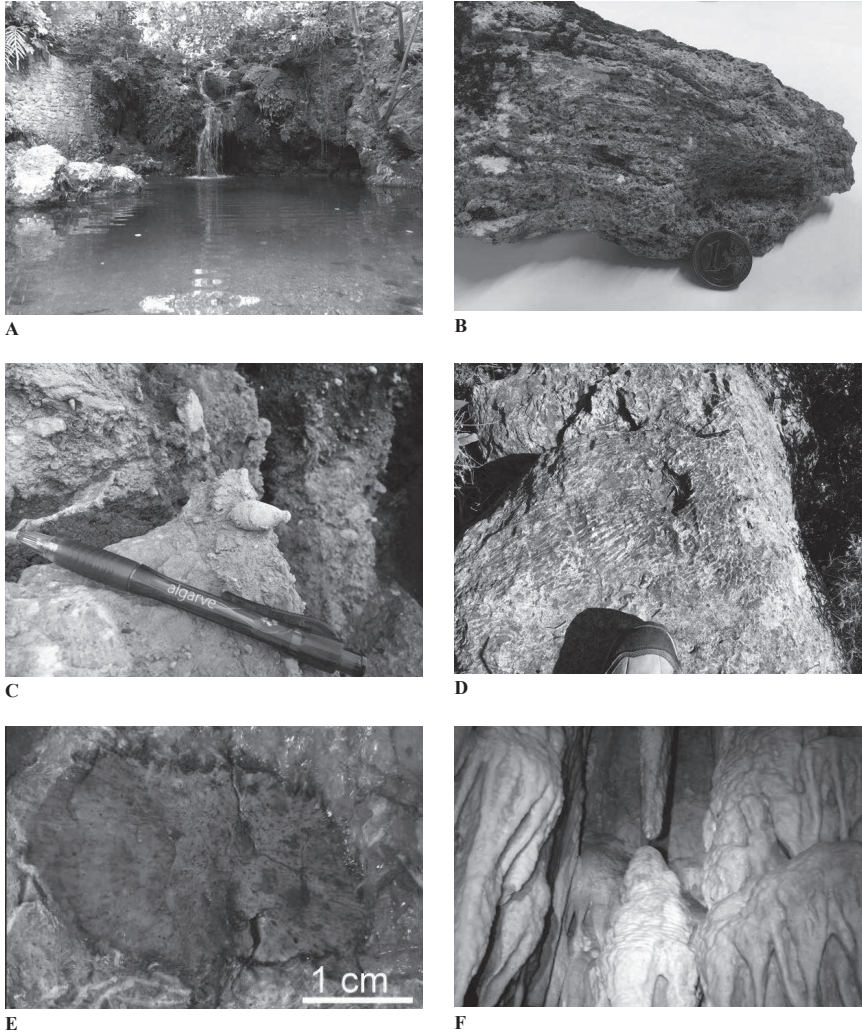


Fig. 1 – Examples of paleoclimate archives from the aspiring Loulé-Silves-Albufeira Geopark territory: A – Water fall with present day calcareous tufa formation; B – Calcareous tufa sample; C – Fossil Cidarroid's radiolaria; D – Fossil of colonial coral; E – Fossil of Placodontia's osteoderm; F – Speleothems

Keywords: Geodiversity; Aspiring Geopark; Paleoclimate archives.

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Paleoclimatic sites in Mixteca Alta UNESCO Global Geopark (Oaxaca, Mexico) and its contribution for local sustainable development in the scope of the SDG13

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Abstract: The Mixteca Alta UNESCO Global Geopark (MAUGG), located in the Oaxaca State, south of Mexico, it is characterized by their eroded land forms such as badlands, gullies, erosive amphitheatres and alluvial deposits profiles. The last ones are true well preserved archives of the environmental changes since 14,000 BP, were it is possible to identify the last four cut-and-fill cycles in palaeosols, being evidences of the climate transitions and human settlements behaviors and practices (Fig. 1). Between Pleistocene and Holocene, the climatic fluctuations allowed the establishment in this region of a dry, warm seasonal climate and of open canopy forest and secondary vegetation. After 4000 BP the human sedentary groups settle in the region and due the growth of population and feeding demand started a cross-channel agricultural system of terraces, were they modified streams intentionally by constructing stone and rubble dikes designed to trap sediments. These terraces are called *lamabordos*, (lama = soil + bordos = dikes). The lamabordos system with more than 3000 years of farming activity, induced changes in vegetation, hydrology, soils and landscape (Fig. 2). The referred sites constituted elements of the geological and cultural heritage of the MAUGG. Some of them, due their characteristics and scientific content, were selected to be used as geosites for educational, scientific and tourism activities. These are representative sites to arise awareness about paleoclimate, edaphology, erosion, ecology, history, archeology and culture. The MAUGG was established in a territory of traditional cultures, where main group corresponds to the Mixtec culture, which have a traditional ancient organization system based on the community involvement, locally known as *usos y costumbres* (= practices and customs). This region has low profitable opportunities and its main economic activity is the agriculture. In this context, it is less suitable for agricultural practices every day due to permanent erosion, which destroy agricultural soils and change continuously the economic and political context, which keeps this region in a kind of a “state of marginality”. Since 2015, the MAUGG promotes educational and touristic visits to its territory, in order to create dynamics of geotourism and a local sustainable development. In some of the main geosites the visits are carried on to observe the alluvial profiles of paleosols and the *lamabordos*. In these sites, the geological and paleoclimate interpretations are focused on the multiple horizons of paleosols, as examples of climate changes events and their interpretations, looking for predictions for present and future scenarios. By the other hand, the visitors are invited to interact with these outcrops, taking a handful of clay, in order to try to make a piece of pottery with the help of the women artisans, or even trying to create a dike of a *lamabordo*. This interaction engages the visitor with the cultural and historical value of this region. The geosites of MAUGG with paleoclimate affinity became important resources for the science promotion, education, recreation and tourism, creating also a new dynamic in this territory in the framework of the SDG 13, especially regarding the 13.1, 13.3 and 13.b targets.

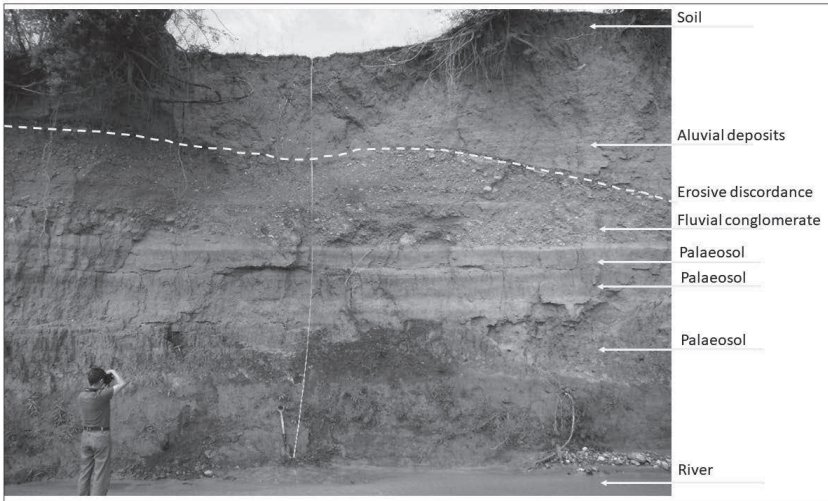


Fig. 1 – Geosite of alluvial deposits profile

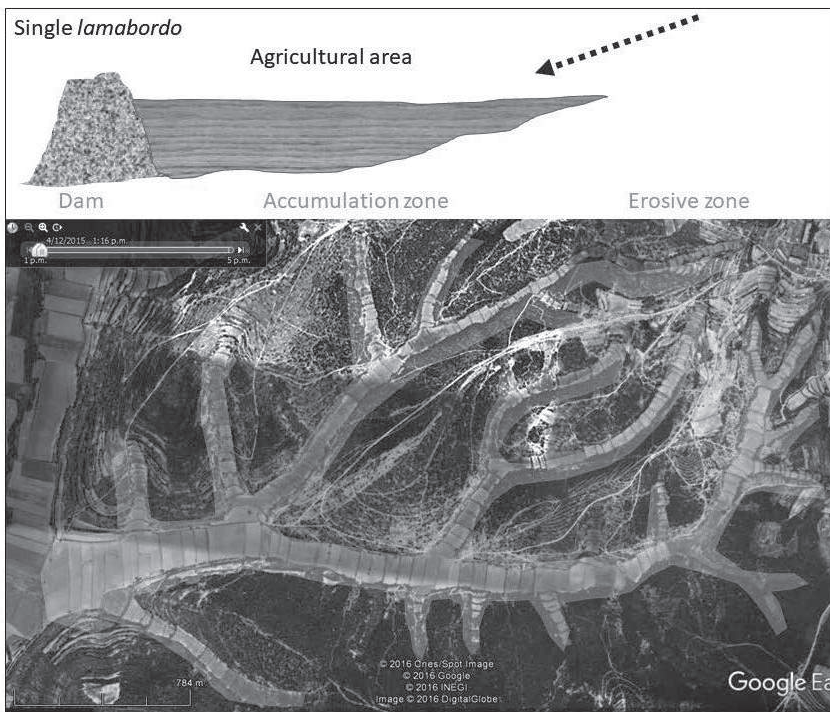


Fig. 2 – Lamabro structure and system

Keywords: Mixteca Alta UNESCO Global Geopark; Paleoclimatic sites; Local development; Geoheritage.

Paleoenvironmental controls on size and abundance changes in the loxolith coccolith *Tubirhabdus patulus* over the Toarcian/Aalenian of São Gião (Lusitanian Basin)

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Abstract: Biometric analyses were performed on 28 Toarcian/Aalenian samples from the São Gião Section of the Lusitanian Basin (west-central Portugal), Upper Toarcian/Lower Aalenian in age. The Lusitanian Basin was originated during the onset of the oceanic spreading of the North-Atlantic Ocean from the Late Triassic to the Early Cretaceous (Wilson, 1988), on which a thick sequence of marls and argillaceous limestone rythmites was deposited (Azerêdo et al., 1988). The Lusitanian Basin testifies an ocean circulation shift that triggered an important turnover in marine biota (extinction of some species, radiation of others, changes in abundance and diversity; Henriques et al., 1994), changes in the availability of nutrients and climate perturbation (Korte et al., 2015) during the Toarcian/Aalenian. São Gião Section is characterized by such rhythmic alternations which make up an expanded sequence of an outer-mid ramp zone during the Lower/Middle Jurassic (Azerêdo et al., 2003). The purpose of this work is to improve the taxonomic and stratigraphic characterization of *T. patulus*, and to evaluate the role, if any, of the paleoenvironmental conditions on such a species. The biostratigraphy of Upper Toarcian/Lower Aalenian calcareous nannofossils has been investigated in São Gião allowing the use of nannofossil zonation scales of Boreal and Tethys settings (López-Otálvaro et al., 2018), and constrained through detailed ammonite-based (Henriques, 1992, 1995) and benthic foraminiferal biostratigraphic data (Canales et al., 2010; Henriques and Canales, 2013; Canales Fernández et al., 2014; Henriques et al., 2016) providing confidence in age interpretation. *Tubirhabdus patulus* is very well represented in the Lower/Middle Jurassic of the Lusitanian Basin due to its high abundance, good preservation and its consistent record. Size shifts show a morphological variability related to loxolith coccolith length and central area sizes. The biometric trend was assessed using the polarized and natural lights of the Light Microscope (LM) at the Laboratory of Sedimentary Geology and Fossil Record of the Department of Earth Sciences of the University of Coimbra. This study reveals that *T. patulus* increases by 2 µm, in agreement with the increase in its abundance and the total absolute abundance of the nannofossil assemblage from Toarcian/Aalenian; as a consequence, the amount of *T. patulus*-derived carbonate rises upwards. Calcareous nannoplankton radiation, changes in coccolith size and in the coccolith carbonate variability have been reported for the Lower and Middle Jurassic of the Iberian basins (Fraguas and Erba, 2010; Suchéras-Marx et al., 2012; López-Otálvaro et al., 2012). Accordingly, the fossil archive has the faculty to decipher helpful insights into species response to environmental fluctuations. Using nannofossil counts, biostratigraphy and biometrics, this research reflects a multiproxy approach that contributes to the knowledge of the influence of the opening of new marine connections.

Keywords: Biometrics; *Tubirhabdus patulus*; Toarcian/Aalenian; São Gião; Lusitanian Basin; Portugal.

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Sedimentology of the lowermost Tejo River terrace upper division, c. 43–35 ka, at Vila Velha de Ródão (eastern Portugal) - interpretation of the environmental and climate conditions

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Abstract: The lowest terrace (T6) of the Tejo River (Cunha et al., 2012), at Vila Velha de Ródão, comprises a lower gravel bed (c. 0.4m thick) and an upper division, c. 5.60m thick, consisting of fine sediments: (i) from the surface to a depth of 4.33m, comprising sandy silts; (ii) from 4.33–5.40m, micaceous very fine to fine sands with some interbedded thin gravel stringers; (iii) from 5.40–5.60m, comprising Mousterian artefacts and fossil bones in a matrix of micaceous fine sands. Colour is yellowish to bright brown. A large number (c. 30) of thin (1–3cm thick) levels with calcium carbonate concretions and rhizoliths, 1–2cm wide, occurs. At the depths of 4.55–4.57m and 4.73–4.82m, quartzite and quartz clasts (<10cm) and rolled concretions are dispersed in micaceous very fine to fine sands. A thick calcium carbonate level is present at a depth of 5.33–5.36m, just above laminated fine sand. The levels containing calcium carbonate concretions do not show evidence of any erosive surface and they dip (up to 5 degrees) toward the Tejo channel, progressively increasing in thickness. The upper unit is clearly dominated by coarse silt, but sampling at the 1cm scale documented significant grain-size oscillations as well as major grain size cycles (Fig. 1). From the 0.05–0.30m depth, the average mean is 41µm, being very poorly sorted and very fine skewed. In average, the sediment comprises 49% sand, 41% silt and 10% clay. For the 0.31–5.00m depth, the average mean is 40.6µm, being very poorly sorted, fine skewed, leptokurtic and with bimodal distributions in the silt fraction (6–20µm and 40–60µm). In average, the sediment comprises 44% sand, 45% silt and 9% clay. The grain-size distribution curves of the studied sediments show at least three particle subpopulations, which are related to various transport dynamics, with the following modes: (i) 245–88µm (fine to very fine sand), usually being the main mode; (ii) 61–38µm (very coarse silt); 20–12µm (coarse silt to medium silt). The deposits of subunit (ii), micaceous very fine to fine sands with the main mode being 245–128µm, with some interbedded thin gravel stringers, can be interpreted as floodplain sandy deposits; the deposits of subunit (i), comprising sandy silts with the main mode being c. 140–88µm or 61–38µm, deposited on slope, as loess – wind blow sandy silts. This interpretation is also supported by similar grain-size characteristics of loess blown up from the underlying floodplain sediment (Vandenberghe, 2013; Varga et al., 2017; Vandenberghe et al., 2018). This indicates that local deflation from the floodplain, aeolian transportation and deposition processes were efficient during the Late Glacial Period. The floodplain sandy deposits worked as a deflation source under the action of wind during dry periods. Aeolian fine particles were deposited on the slope of the easternmost river margin. The occurrence of levels containing carbonate concretions and rhizoliths in all the T6 profile is an evidence for episodic pedogenic evaporation, in agreement with the rare occurrence and poor preservation of phytoliths.

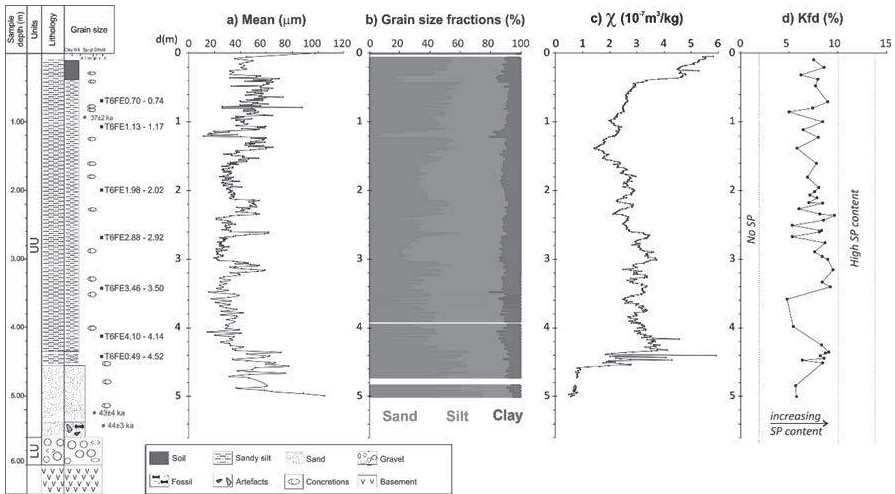


Fig. 1 – Stratigraphic log of the T6 terrace sequence at the Foz do Enxarrique archaeological site (adapted from Cunha et al., 2019), also showing the (a) mean grain-size diameter, (b) main grain-size fractions in % (sand, 2000 to 63 μm ; silt, 63 to 4 μm ; clay, <4 μm), (c) mass specific magnetic susceptibility (χ) and (d) frequency-dependent magnetic susceptibility (Kfd in %), indicative of supermagnetic particles (SP). Black squares beside the stratigraphic log correspond to the sample intervals where palynological analysis and identification of clay minerals were conducted. Red circles indicate the stratigraphic location of OSL dated samples, with ages shown. LU—lower unit (gravels); UU—upper unit (dominated by very fine sands and coarse silts).

Keywords: River terrace; Loess; Marine Isotope Stage 3; Environmental interpretation; Paleoclimate.

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SECTION 3

TOPIC 3 - CLIMATE MEMORY IN THE GEOLOGICAL RECORD

A 7 Ma continuous palaeoclimatic record of the Oligocene-Early Miocene in NW Iberia inferred from palaeobotanical data

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Abstract: The As Pontes Basin (Galicia, Spain) formed as a consequence of intense tectonic activity in NW Iberia during the Oligocene. It consists of ~300 m thick sedimentary successions that have yielded exceptionally diverse and well-preserved microfloral assemblages. A high-resolution palynological study of the basin has allowed an accurate definition of the vegetation evolution throughout the Rupelian, Chattian and the earliest Aquitanian. The interpretation of the stratigraphic variation of taxa in terms of their palaeoenvironmental and palaeoclimatic significance reveals that two major vegetation types co-occurred in the study area: the zonal and the azonal vegetation, each of which provides different palaeoclimatic information. The azonal (hygrophytic) vegetation developed in the surroundings of a lacustrine system and its dynamic reflects the effect of the orbital eccentricity on the precipitation pattern, which resulted in cyclical oscillations of the lake level (~400 ka). During phases of high precipitation rate, the lake level raised and the sediment supply into the basin was substantial, leading to the deposition of claystone-dominated facies and the development of vegetation adapted to long periods of flooding. Conversely, during phases of lower rainfall the lake regressed, thick coal seams accumulated and vegetation adapted to relatively drier conditions became dominant. The evolution of the zonal (non-hygrophytic) vegetation indicates a decrease in temperature throughout the Rupelian and part of the Chattian (from 29.0 to 24.5 Ma). This cooling trend was superimposed to the shorter-term changes inferred based on the azonal vegetation. A decrease in temperature during the Rupelian and Chattian is in line with global palaeoclimatic reconstructions based on marine isotope records. For the late Chattian, an increase in temperature is recorded. Additionally, the microfloral assemblages show the signature of five major glacial events occurred during the Oligocene (Oi2*, Oi2a, Oi2b, Oi2c and Mi1), which are associated with the marine depositional sequence boundaries Ru3, Ch1, Ch2, Ch3 and Aq1. These data illustrate the coupling of the climatic processes that occurred in the marine and continental realms (Fig. 1).

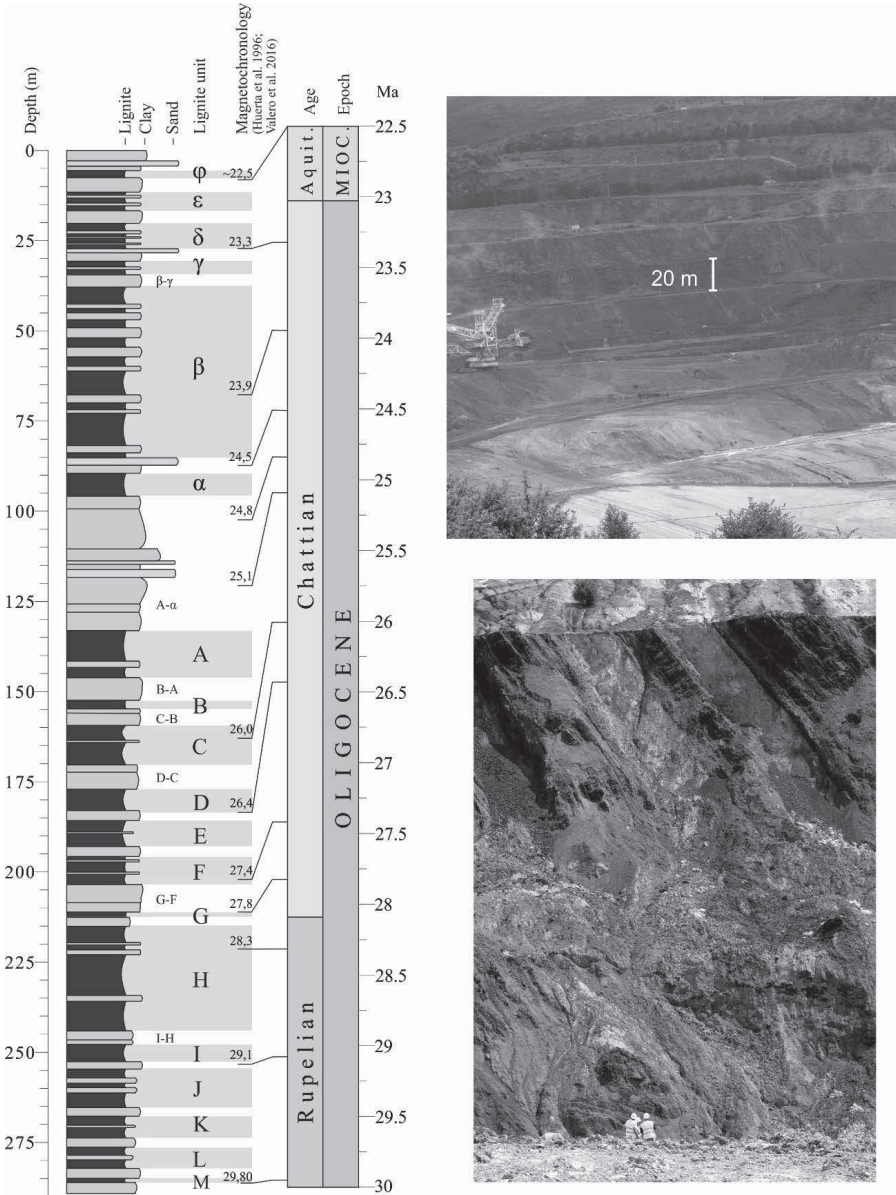


Fig.1 – Stratigraphy of the As Pontes Basin (NW Spain) showing the orbitally-controlled alternance between clays and lignite.

Keywords: Oligocene palaeoclimate; Palaeovegetation; Orbital control; Glacial events.

Climate change in Amazonia during Meso-Cenozoic Times: paleoecological evidences from the southwest of the Acre Basin (Brazil)

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Abstract: This work reports the main results obtained through the analysis of the palynological assemblages recognized in the stratigraphic record of Meso-Cenozoic rocks outcropping in the southwest of the Acre Basin (SW Amazonia, Brazil), at the National Park of Serra do Divisor and at the Juruá Valley. Assemblages from the National Park of Serra do Divisor were collected at the Moa, Rio Azul and Divisor formations, and provided an Upper Aptian to Cenomanian-Turonian age for the first one, Turonian-Maastrichtian for the second one, and Maastrichtian-Paleogene for the last one, all based on palynological evidences. These units were previously related to essentially fluvial-deltaic environments. However, from the analysis of the composition of the palynological assemblages there is a great abundance of marine elements in all the stratigraphic units, namely the presence of acritarchs, dinoflagellates and palynoforaminifera (Fig. 1). The recognized palynoflora is very similar to that identified in the same latitudinal belt during the Cretaceous (Albian-Maastrichtian) from other regions of the globe, such as Colombia, Peru, Venezuela, Congo, Sudan, South Sudan, Senegal, Gabon, Egypt, Nigeria, Morocco, Israel, India, among others, subject to a hot and humid climate, with some aridity, thus perfectly matching the palynological range of the northern Gondwana. Regarding the Juruá Valley, which refers to the Repouso Formation (Middle Eocene-Lower Miocene), a lithostratigraphic unit underlying the Solimões Formation, the assemblages also show the presence of marine elements such as acritarchs, dinoflagellates and escolecodonts, as well as a great amount of algae and spores. The presence of extinct groups of aquatic vertebrates or aquatic/marine or wet environments, represented by toxodontids, crocodylians, chelonians (all large), rodents and various groups of fish, allow to infer the existence of marine to fluvial-deltaic conditions throughout the Paleogene at the southwest region of the Acre Basin. The palynoflora was dominated by aquatic plants, epiphytes, lianas, pteridophytes, grasses, shrubs and some forest islands, represented by arboreal specimens of Poaceae, Fabaceae, Cheilepodiaceae, Arcaceae, Podocarpaceae, Bombacaceae, Ulmaceae, Euphorbiaceae, among others of medium and large size. The palynomorphs and the vertebrate record suggest that the climate in the southwest of the Amazonia, during the Upper Cretaceous to the Lower Miocene, would be hot and humid, displaying ecological conditions very different from those recognized today, characterized by the presence of dense vegetation, with large trees covering almost the entire northern region of South America, where many of the large animals known in the fossil record could not move.

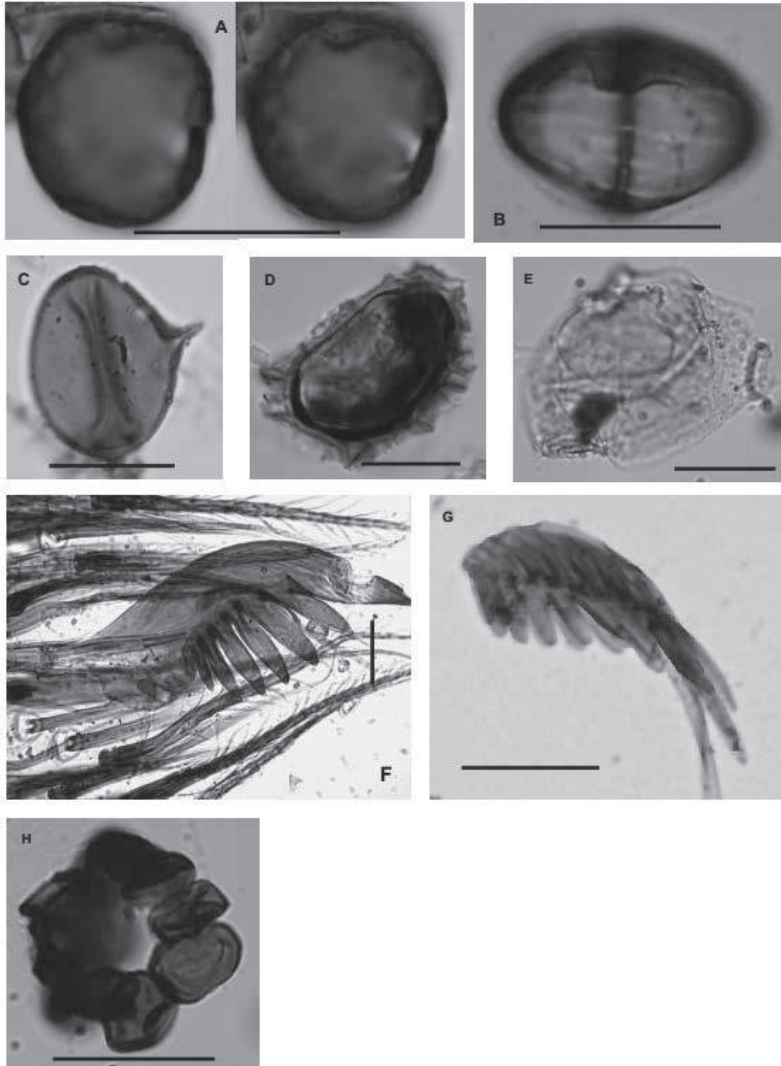


Figure 1 – The occurrence of marine elements in the fossil record from the Juruá Valley, which refers to the Repouso Formation (Middle Eocene-Lower Miocene): A- *Incertae sedis* sp. 7 (PRJ23-D-3-42); B- *Incertae sedis* sp. 8 (PRJ23-D-1-82); C- *Incertae sedis* sp. 9 (PRJ23-D-2-35); D- *Incertae sedis* sp. 10 (PRJ23-D-2-29); E- *Incertae sedis* sp. 11 (PRJ02A-10-4); F- Escolecodont (PRJ12A-B-1-18); G- Escolecodont (PRJ12A-B-2-23); H- Palynoforaminifera (PRJ12A-B-1-6).

Keywords: Palynology; Paleoecology; Cretaceous-Miocene; Acre Basin; Amazonia.

Acknowledgements: This study was supported by FEDER funds through the Competitiveness Factors Operational Programme - COMPETE and Portuguese funds by FCT in the frame of the UID/Multi00073/2019 Project.

Early Cretaceous paleoclimate inferences based on palynology and geochemistry at Sergipe-Alagoas Basin (Northeastern of Brazil)

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Abstract: The Sergipe Alagoas Basin displays in onshore outcrops the record of all the evolutionary stages related to the Gondwana breakup, which makes it an important basin for studies of analogues. Reservoirs research developed in the basin in the last decade has provided new paleontological and geochemistry data which are of great help to understand the complexities and heterogeneities of reservoir facies along the geological record. Palynology allows understanding and reconstructing the paleoenvironmental and the paleoclimatic framework. The analysis of Total Organic Carbon (TOC), total Sulphur (S), Rock-Eval pyrolysis and stable Sulphur isotopes $\delta_{34}\text{S}$ allows identifying the origin of the sulfate oxidation, which helps to ground paleoenvironmental models. This work aims to analyze data from these two sources obtained from samples collected at the Morro do Chaves Formation (Barremian) in order to infer paleoclimate conditions that affected Northeastern Brazil during Early Cretaceous.

The Morro do Chaves Formation is composed of bioclastic limestones (coquina) alternating with dark green to black mudstones mainly interpreted as having been deposited in lacustrine conditions; however, several levels of the coquina beds include marine and brackish bivalves, also suggesting episodic marine influence during the deposition of the unit (Garcia et al., 2018). A total of 17 samples were collected in the shales (and associated pyrites) levels of the Morro do Chaves Formation which provided specimens of *Dicheiropollis etruscus*, thus supporting the late Barremian age for the lowermost part of the unit. Other palynological occurrences include spores and pollen assemblages related to lacustrine environments, close to herbaceous plants, surrounded by remote mountainous areas with arboreal vegetation, episodically subject to marine flooding. The abundance and diversity of *Cicatricosisporites*, *Equisetosporites* and *Gnetaceapollenites*, which decreases throughout all the studied stratigraphic record, associated with the algae and fluorescent amorphous organic matter increase, suggests a vertical variation from an alluvial deltaic lacustrine system with hot and humid climate, periodically subject to storms and marine waters incursions, to a hot and humid alluvial-deltaic lacustrine sabka system with fresh/brackish waters (Fig. 1). TOC, S, Rock-Eval pyrolysis and stable Sulphur isotopes $\delta_{34}\text{S}$ data were obtained from 16 samples collected from the same levels. The analysis of TOC *versus* S revealed that only one of them does not reflect marine influence, whereas TOC and Rock-Eval pyrolysis analysis show that two samples from the lower part of the unit show high organic contents and the predominance of type I-kerogen, resulting from lacustrine or marine algae. The stable Sulphur isotopes $\delta_{34}\text{S}$ data show a wide range of values throughout the unit pointing out to three different Sulphur origins: high values are related to anoxic environment due to bacterial reduction of Sulphur from the sea water; low values reflect the isotopic signature of meteoric origin; intermediate values represent the influence of both sources. These data suggest lacustrine paleoenvironmental conditions with possibility of marine incursions (Pontes, 2013), matching the palynological results, that suggest a lagoon environment with sporadic marine incursion (Garcia et al., 2018). In conclusion, the results obtained from both the palynological record and the geochemistry record data point out to similar paleoenvironmental and paleoclimatic interpretations regarding the Morro do Chaves depositional context. This integrated approach based on biotic and abiotic proxies can be used as a feasible tool in similar analysis of analogous basins.

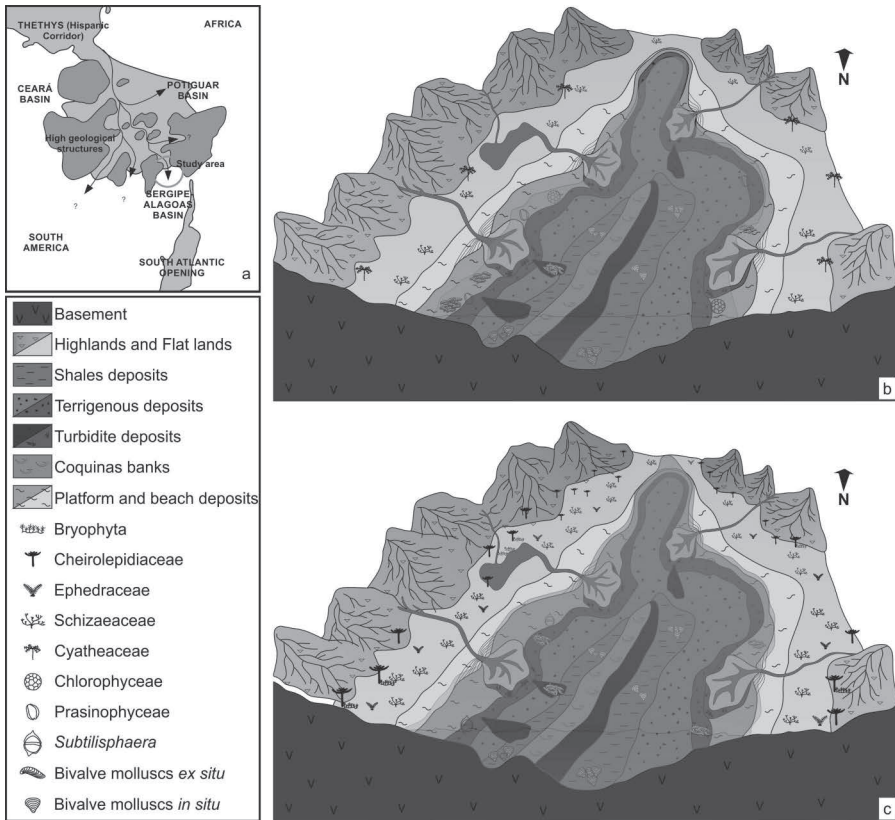


Fig. 1 – Paleogeographic reconstruction of the study area: (A) within the Sergipe-Alagoas Basin; (B) Detailed interpretation sketch representing the alluvial-deltaic lacustrine depositional environment for the lower part of the Morro do Chaves Formation; (C) Detailed interpretation sketch representing the alluvial-deltaic lacustrine sabka depositional environment for the upper part of the Morro do Chaves Formation (Garcia et al., 2018).

Keywords: Paleoclimate; Palynology; Isotopes; Early Cretaceous; Sergipe Basin.

Acknowledgements: This study was supported by FEDER funds through the Competitiveness Factors Operational Programme - COMPETE and Portuguese funds by FCT in the frame of the UID/Multi00073/2019 Project.

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Environmental and climate changes in the Eemian and Vistulian (MIS 4-5) recorded in the lake-mire sediment succession from Poland (Central Europe) based on subfossil Cladocera analysis

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Abstract: Lakes are natural archives with sediments bearing evidence of environmental changes accumulated over thousands of years. The reconstruction of the ecological and biological past of lakes is possible thanks to the remains of organisms preserved in their sediments with bioindication properties. High suitability of Cladocera for the purposes of paleolimnological studies results from their stable ecological requirements and possibility of preserving elements of their chitinous shells, which can identify the species (Fig. 1-3). Worldwide analyses of Cladocera subfossils have revealed detailed results covering mainly the last 13,000 years. Since 2000, in Poland and Germany, analyses of older sediments have also been carried out. The current study concerns the subfossil Cladocera analysis of the lake-mire sediments from three sites - Ustków, Kubłowo and Solniki - of the Eemian and Vistulian, and the inferred environmental modifications. The aim of the study was to reconstruct and compare the development of Eemian and Vistulian lakes located in central and eastern part of Poland as determined on the basis of the changes in subfossil Cladocera composition in the context of local conditions, climate change and natural evolutionary processes. The studied reservoirs, fully developed during the Eemian, were formed at the end of Warta Glaciation (MIS 6) or in the Early Eemian period. In the Early Eemian the temperature of the lake water was low and with oligotrophic state. Lakes were inhabited mainly by pioneering fauna. Gradual increase of water temperature caused that the lakes were inhabited by a more thermophilous species. As the water level increased due to larger precipitation at the Early Eemian, the group of dominant species was enriched by pelagic zone species. The results of Cladocera analyses demonstrate short-term episodes of climate warming during this relatively cold period. The beginning of the Middle Eemian was connected with more favourable conditions for zooplankton, due to a significant rise in temperature and a relatively high water level. In general, the Middle Eemian in the reservoir was dominated by species associated with aquatic plants and bottom sediments. At the end of that period, a reduction in the level of water in the lakes took place. In the Late Eemian there was improvement in Cladocera habitat conditions. The final stage of the Eemian was associated with a significant drop in temperatures; however, precipitation was still relatively high. In the studied paleolakes, the frequency of Cladocera species reached the top level of the lakes. After the first Vistulian cooling, in the next period (Brørup Interstadial) the living condition became similar to the Late Eemian, which led to the development of Cladocera succession again. In the paleolakes the species with a higher temperature requirement existed till the Rederstall Stadial. At the end of the Early Vistulian (MIS5a), Ustków and Solniki did not exist anymore. Kubłowo paleolakes continued up to the Middle Vistulian – without break through the over 70k years.

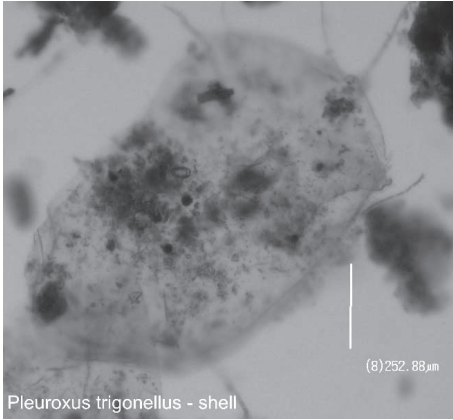


Fig. 1 – Eemian subfossil Cladocera remains
– *Pleuroxus trigonellus* - shell



Fig. 2 – Eemian subfossil Cladocera remains
– *Leydigia acanthocercoides* - postabdomen

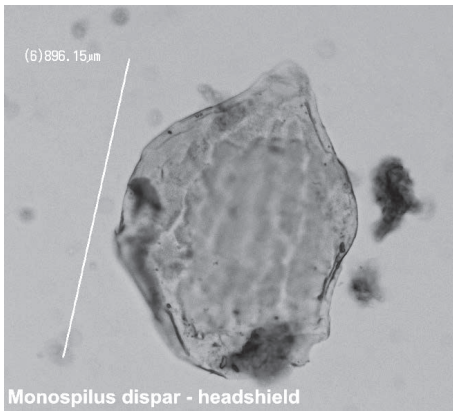


Fig. 3 – Eemian subfossil Cladocera remains
– *Monospilus dispar* - headshield

Keywords: Cladocera analyses; Paleolakes; Eemian; Vistulian.

High-resolution seismic stratigraphy at Guanabara Bay (Rio de Janeiro, Brazil)

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Abstract: Understanding how climate change in the geological record in coastal environment strata is fundamental for Earth's past reconstruction. The worldwide Holocene ~11 ka flooding triggered oscillations of ~100 meters in ocean levels, representing one of the regressive-transgressive Milankovitch, glaciation-deglaciation cycles predominant over the last 500 ka (Rabineau et al., 2006). While low level sea exposed massive portions of continental shelves to subaerial processes, transgression on the other hand developed estuaries, bays and lakes. Quaternary terrains commonly exhibit a complex, subsurface stratigraphic framework that may be preserved depending on, besides global sea level changes, local and regional settings such as geomorphologic and tectonic settings. High-resolution seismic-stratigraphic analyses apply traditional routines of siliciclastic sequence stratigraphy (Catuneanu et al., 2009) predominantly on shallow (50m) coastal environment. Seismic interpretation of submetric resolution profiles of estuaries and bays provide great archive of multicycle progradation, aggradation and retrogradation phases. This research is focused on the interpretation of the Guanabara Bay (Rio de Janeiro, Brazil) in context of seismic data analyzes on Quaternary sedimentary infilling, aiming to contribute to an overall understanding of the intern, regional sedimentary architecture of that environment. The study area location and correspondent seismic lines are shown in Figure 1. Tectonic studies indicate that the Guanabara Graben was formed in the Paleocene (~58 ma) under E-W passive margin movement, part of the 800 km long, Cenozoic aged Continental Rift of Southeastern Brazil. The Pleistocene-Holocene sedimentary evolution of the Guanabara Bay, in the context of the Last Glacial Maximum (LGM – Marine Isotopic Stage 2 – 20 ka) global event was recently presented by Abuchacara (2015), with coring samples analysis and radiocarbon age dating. The present examination of *Boomer* and *Sparker* seismic, high resolution, two way travel-time (TWT) profiles interpretation proposes a regional geological evolution by the identification of seismic surfaces (s0-s7), seismic facies (Sf) and seismic unities (u1-u8) that might have strong correspondence to geologic data described in recent literature (Fig. 2). Between u0 and the erosive surface S1, unity u1 is marked by high amplitude and reflectivity, parallel reflectors with generic NW dip. This unity was interpreted as the Macacu Formation, contemporaneous to the Macacu Rift propagation, with an ultimate Pliocene age. The discordant reflector S2 was interpreted as the LGM erosive surface. Unity u3 downlap terminations, lateral accretion coarse deposits are interpreted as incised-valley channels infill in this dry climate conditions. The vertical transition to the upper transparent, structure lacking reflection (sf4) can be interpreted as a depositional change of high-energy environment to a low-energy, muddy sedimentation stage probably associated with a sea-level stabilization and humid climate. The upper boundary S3 (pink) was interpreted as the Transgressive Surface (or Maximum Regression Surface). The upper seismic facies unity U4 is predominantly a low amplitude and semi-transparent seismic zone, eroded by the upper irregular boundary S4, representative of tidal ravinement surface (TRS). Unity 5 clinoforms of alternated progradational and aggradational patterns were associated with different hydrodynamic sedimentation in Guanabara Bay trough tidal channels infilling. S5 surface was defined as the Maximum Flooding Surface (MFS), marking a change to high stand system tract, muddy, low energy sedimentation of unities U6 and U7. The heterogeneity of these unities in

terms of sedimentary geometry might be related to the Holocene smaller cycles (hundreds of years) of climatic changes, with a possible forced regression $\sim 5\text{ka}$ (downlaps in *u6*). This work shows that high resolution seismic interpretation in Guanabara Bay reinforces geophysics applicability on Quaternary paleoenvironment reconstruction by providing relevant data for further geological research.

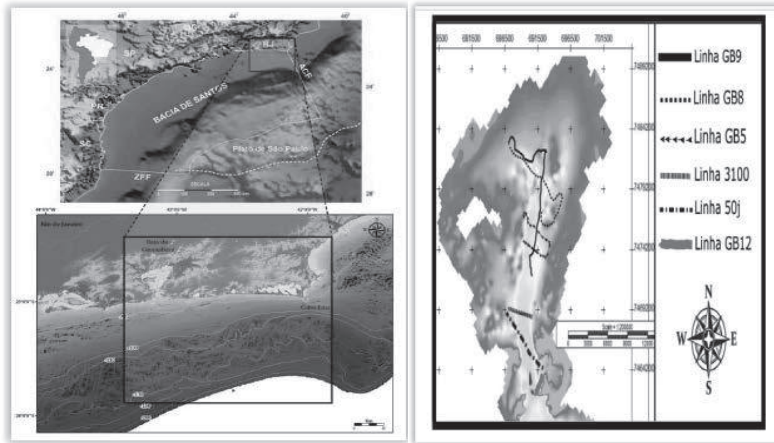


Figure 1 – Guanabara Bay's location (NE of Santos Basin) and seismic lines used in this work.

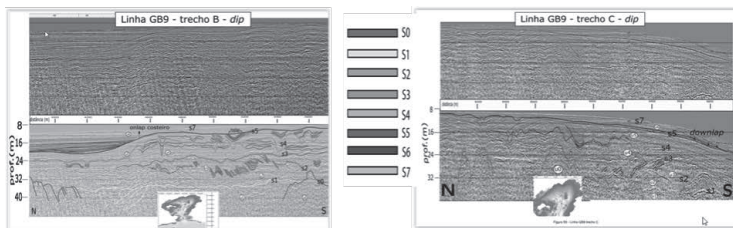


Figure 2 – Horizontal slices of *Dip*, North Side oriented seismic profile (line GB9) of Guanabara Bay.

Keywords: High-resolution; Seismic stratigraphy; Paleoclimate; Guanabara Bay; Brazil.

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How can fossil water trapped in speleothems provide paleoclimate information? Insights from stable isotope analysis of fluid inclusions

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Abstract: Water trapped in speleothems during their growth can be preserved as “primary” fluid inclusions within the carbonate mineral. These fluid inclusions are small cavities within crystals, which contain fossil cave drip-water, isolated from the atmosphere since entrapment. By extracting and analyzing this water the average composition of the meteoric water that recharged the epikarst at that time can be obtained. In particular, the fluid inclusion stable isotope ratios ($\delta^{18}\text{O}$ and δD) a corner stone for the knowledge of past hydrological and climatic conditions. Changes in $\delta^{18}\text{O}$ and δD of rainfall through time at decadal to millennial scales reflect local, regional and/or global factors of the climate system including changes in temperature, rainfall amount, rainfall patterns, composition of the oceanic sources of water vapor, and/or changes in the provenance of the moisture caused by modification of winds patterns. Additionally, the $\delta^{18}\text{O}$ values inferred from fluid inclusions allow to calculate absolute paleotemperatures by means of the $\delta^{18}\text{O}$ composition of the speleothem calcite, a geochemical variable commonly used in speleothem-based paleoclimate reconstructions but that rarely can be used as a paleothermometer precisely because the limitation of unknowing the original isotopic composition of the waters feeding the stalagmite growth. $\delta^{18}\text{O}$ and δD are commonly analyzed by the so-called crushing methodology, in which the calcite samples are crushed to release the water trapped in fluid inclusions. The crushing is performed in a high vacuum line, attached to an isotope ratio mass spectrometer (IRMS). The method has proven to be successful, but is still far from being a standard technique. The selection of the appropriate samples and the preparation are key points for getting robust and accurate results. These include the preservation of the samples at environmental conditions similar to those of the cave and a detailed petrographical study which includes a fluid inclusion genetic characterization. In this work we present the results of a study of fluid inclusions in a Late Pleistocene (dated radiometrically as 120-108 ka BP) calcitic stalagmite. The stalagmite, retrieved in Cueva del Tortero (Valencia province, eastern Spain), is characterized by a relatively large amount of fluid inclusions, mostly located along growth layers. Contribution to Projects CGL2013-43257-R and CGL2017-83287-R (AEI, Spain). The Generalitat Valenciana is thanked for permissions and collaboration during cave work.

Keywords: Fluid inclusions; Speleothems; Stable isotopes; Paleoclimatology.

Interpreting Late Pleistocene paleoenvironments through the geosites of the Estrela Geopark (Central Portugal)

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Abstract: The UNESCO Global Geoparks are territories whose geological relevance is the starting point for a territorial development strategy. As territories of the 21st century, we want them to be places of science, culture and education, through a holistic vision, which intends to establish strong connections between the geological and cultural heritage. In this context, the geodiversity of Estrela, the richness of its geosite's diversity and the scenic character of its landscapes make this territory a unique geography, whose structured approach allows for a solid interpretation of the paleoenvironmental evolution of the Estrela Mountain. The Estrela Geopark, with 2,216 km², centered on the highest mountain in mainland Portugal (1993 m), is a reference for glacial geomorphology in the southwest European context. The territory shows the most significant glacial, fluvioglacial and periglacial landforms and deposits in Portugal, some of them of international relevance. The Geopark shows a diversity of granites and metasedimentary formations, with evidences of contact metamorphism. The geological history of the Estrela Geopark dates back to the Neoproterozoic, with ages older than 650 Ma, represented by an extensive sequence of metasediments dominated by schists and greywackes. These were deformed by the Variscan orogeny, during which, intrusions of granite batholiths occurred. At the end of the orogeny, the relief was razed by erosive processes that extended until the Miocene, when Variscan faults were reactivated leading to the uplift of the Estrela as a pop-up structure. The summit plateau, showing an elevation close to 2000 m, was key for the development of Estrela's glaciers during the Pleistocene. These were responsible for a remarkable set of glacial landforms and deposits that drive the geological relevance of the Estrela Geopark. The interaction of the Pleistocene glaciers with the geoheritage reflecting the long geological history of the territory, together with the current geomorphological dynamics, long history of human settlement resulting in rich land use features and traditions, lead to the high international relevance of the territory of Estrela, a UNESCO Global Geopark candidate. The Estrela Geopark inventoried and classified 124 geosites, 40% of them related to glacial and fluvioglacial phenomena and periglacial processes (Fig.1). These include glacial valleys, cirques, glacial overdeepenings, several types of moraines and till outcrops, glacial erratics, glacial polished surfaces, and fluvioglacial deposits. The joint interpretation of landforms and sediments, including the palinological record has been crucial for a better understanding of the paleoenvironmental evolution and significance of the Estrela and of its high sensitivity to climate variability and change as a consequence of its high plateau-dominated morphology, bounded by steep marginal scarps and deeply carved valleys.

Keywords: Geopark; Serra da Estrela; Glaciation; Geoheritage; Paleoenvironments.

Iron behavior in fersiallitic soil during the Quaternary and their paleo environmental significance northern Tunisia

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Abstract: The correlative survey of the data provided by the physico-chemical analyses of iron and the principal components of fersiallitic soils (oxisol) of the northern Tunisia, situated under different bioclimatic areas , allowed us to note the following facts: The biggest part of the free iron, freed of the primary minerals, is "amorphous" or badly crystallized, and it is especially to this kind of iron, whatever its components and its state of hydration, that are due the characteristic rubefaction (reddish coloration) of the B horizons of these types of soils. The free iron / total iron relation remains proportional to the rates of clays. In the case of soils to calcic reserve, iron is well individualized oxides, therefore, an important part left from the free iron, would be immobilized in the clayey minerals or recrystallized as concretions, the fall of these reports seems to be linked to the crystallization of iron as ferranes, or of pseudo particles (association grains of quartz-iron-clays). The amorphous iron formed in soil is immediately adhered to the surfaces of the clayey particles giving a red coloration thus to the matrix of soil that results in the rubefaction. * Crystallized iron seems to be less represented oin the enclosed soils or badly drained one. The role of crystallized iron is not obvious, however the crystallization of iron, that penetrats the cracks of quartzes would explain their ulterior bursting.

Keywords: Iron geochemistry; Fersiallitic soils; Iron oxides; Clayey minerals; Rubefaction; Amorphous iron.

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Late Triassic paleoclimate inferences based on paleobotanical and gamma ray data at the Lusitanian Basin (Central Portugal)

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Abstract: The Lusitanian Basin was developed in the western margin of the Iberian plate during the Mesozoic, as a result of a complex rifting process related with the breakup of Pangea and the formation/opening of the Atlantic Ocean. The sedimentary record of the first stage of the rift in the Late Triassic, is made by continental sediments composed of red conglomerates, sandstones and clay stones known as the Grés de Silves Group. The basal unit corresponds to the Conraria Formation, of Carnian age, which is particularly well exposed in Central Portugal, as well as the underlying unit, the Castelo Viegas Formation, of Norian age. This work aims to recognize paleoclimatic conditions which have controlled the sedimentary deposition of the Conraria Formation during the Carnian through the reinterpretation of gamma ray spectrometry data acquired by Chamorro (2016). The data obtained from the quantity of Uranium (ppm), Thorium (ppm) and Potassium (%) were calibrated in units of API (American Petroleum Institute: $API = K \cdot 16 + U \cdot 8 + Th \cdot 4$) and then they were converted into a Th/K and Th/U relation. Gamma ray data, collected in two outcrops located in Coimbra, spans between two major cycles A2 and B1 (Palain, 1976) in the Conraria Formation, separated by a non-conformity (D2.c), where Th/U is 12.20 ppm (Fig. 1). The B1 cycle is 80 m thick and is mainly composed of reddish conglomerates and sandstones and it shows a range of API levels between 70 to 140. The Th/U and Th/K vary from 0.8 to 14.2 and 0.5 to 4.3, respectively. The A2 cycle is 27 meters thick and it shows API levels ranging from 101 to 261 with variation on the average amplitude in gamma ray. The Th/U and Th/K vary from 1.6 to 12.8 and 1.25 to 5.1, respectively. This cycle comprises the A2.1 and A2.2 terms, separated by a non-conformity (D2.b), where Th/U is 12.80 ppm. The A2.1 term is 7 meters thick and it is composed of fine sandstones and shales with parallel lamination (fine-medium grain and sometimes coarse) of quartz and feldspar with a significant micaceous component (moscovite, biotite). It displays API levels from 101 to 181 with variation on the average amplitude in gamma ray. The A2.2 term is 20 meters thick and it is represented by sequence of rhythmic alternation of layers of shales, clays sandstones and levels of organic matter (15-30 cm) displaying horizontal stratification. It displays API levels from 150 to 261. Higher values of Th/U and Th/K relations, which characterize the A2 cycle (A2.1 and A2.2), point to warmer and wetter paleoclimatic conditions, in contrast with values obtained for the B1 cycle. The A2.2 term of the Conraria Formation provided coniferous remains representing important paleoclimatic proxies. They include *Pachyphyllum peregrinum* Brong, associated with *Voltziarembariensis* Schenk and *Voltziapachyphylla* Schenk. *Voltzia* already existed in the Middle Permian and their representatives are usually interpreted as characteristic of humid conditions (Gall and Grauvogel-Stamm, 2005). Such interpretation fits with the data obtained from the gamma ray spectrometry. In fact, the A2 cycle shows relative high values of total gamma ray, Th, U and K, all of them decreasing to lower and steady values along the B1 cycle, and suggesting an episode of humid climate (A2 cycle) subsequent to an episode of quite dry climatic conditions. In conclusion, the results obtained from both the paleobotanical record and the gamma ray spectrometry data point out to similar paleoclimatic interpretations regarding the Conraria Formation depositional context. This integrated approach based on biotic and abiotic proxies can be of great help in interpreting similar paleoclimatic changes in other basins.

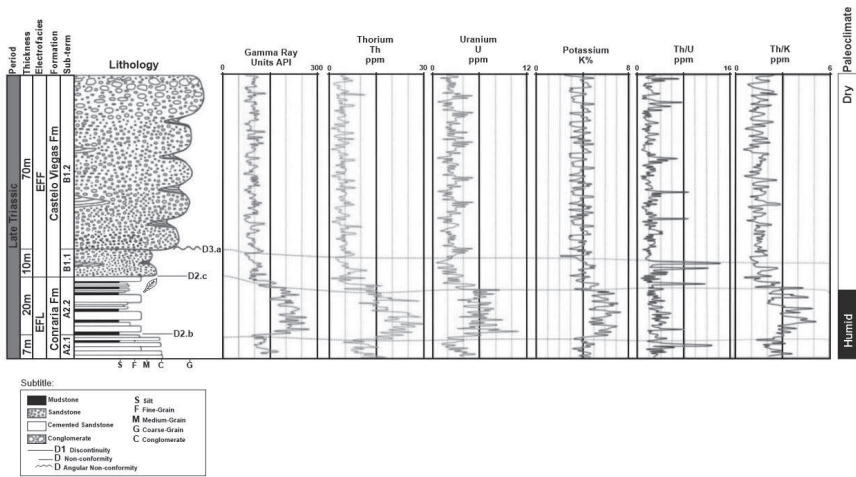


Fig. 1 – Gamma ray spectrometry data of the Conraria Formation and paleoclimatic interpretation (modified from Chamorro, 2016).

Keywords: Paleoclimate; Gamma ray spectrometry; Late Triassic; Conraria Formation; Lusitanian Basin

Acknowledgements: This study was supported by FEDER funds through the Competitiveness Factors Operational Programme - COMPETE and Portuguese funds by FCT in the frame of the UID/Multi00073/2019 Project.

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Magnetic susceptibility signature of climate and environmental changes induced by Deccan volcanism before the Cretaceous–Paleogene mass extinction: Evidence from Okçular and Göynük (Turkey)

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Abstract: The origin of the Cretaceous–Paleogene mass extinction is still under debate, opposing proponents that a large bolide impact caused the extinction event to partisans of the massive eruption of the Deccan Traps (India). Recent U–Pb zircon data showed that the major magmatic pulse of the Deccan Traps volcanism begin some 250 k.y. before the Cretaceous–Paleogene mass-extinction suggesting a substantial contribution in the extinction event. To investigate the climate perturbation induced by the Deccan, current studies provide interesting sedimentary proxies including mercury, osmium isotopic composition and rock magnetic properties. Here, we aim to test the use of magnetic susceptibility (MS) in two sections, namely the Okçular and Göynük sections in Turkey, as an indicator of environmental acidification due to Deccan eruptions. We also compared our data with mineralogical and geochemical data previously published. The Okçular (OC) and Göynük (GN) sections are included in the Taraklı Formation, which crops out in the Mudurnu–Göynük Basin (NW of Turkey). Samples were collected each ~15cm among a thickness of 4.5 and 14.92 m for OC and GN, respectively. The Taraklı Formation is characterized by slope and basinal marine deposits (Açikalın et al., 2015). Late Maastrichtian is represented by a succession of thick marls and alternating beds of turbiditic sandstones, while lower Danian shows a rhythmic alternation of mudstones and limestone beds. The boundary is represented by a very thin reddish ejecta layer (Açikalın et al. 2015). MS analysis is performed with a Dual-frequency MS2 meter (Bartington Ind.) apparatus available in the laboratory of paleomagnetism of the DCT-UC. Data are normalized by the mass and reported as mass-specific MS in $\text{m}^3.\text{kg}^{-1}$. Our results show that the OC section is characterized by a marked decrease in the MS just below the K–Pg boundary. Absence of correlation with phyllosilicate and carbonate content indicates that the decrease in MS is not related to the mineralogy. We hypothesize this link to be due to detrital magnetite dissolution onland due to acid rain induced by Deccan emission, similarly to what has been suggested in other well-know K–Pg sections such as Bidart (France) and Gubbio (Italy). Although more magnetic data are needed to confirm our hypothesis, this first evidence suggests that the massive and rapid Deccan eruptions are synchronous with the K–Pg boundary, and therefore may have played a critical role in the extinction event. MS at Göynük and Okçular is on the order of 10–7–10–8 $\text{m}^3.\text{kg}^{-1}$, similar to marine sediments described worldwide (Font et al. 2018; 2014). The values of the MS are directly related to the mineralogy identified by X-ray diffraction (Lorenzo et al. 2019), namely MS shows a positive correlation with phyllosilicates and a negative correlation with calcite. MS values of the Danian are much lower than in the Maastrichtian marls due to more carbonate affinity of these deposits. Contrarily to previous studies like in Bidart and Gubbio, where the K–Pg and the P0 biozone are characterized by a positive shift and high MS values, this shift is not observed or is poorly expressed in the case of GN and OC. Interestingly, and as in Bidart, Gubbio and Zumaia, an interval of low MS is observed just below the K–Pg boundary in GN (Fig. 1), which do not reflect any change in lithology, but may be linked to iron oxide dissolution during or after sedimentation. However, in OC, this low MS is not as evident as in the case of GN. We interpret the presence of the low MS interval at GN as the signature of the environmental perturbations triggered by the Deccan activity. Following the model of Font et al. (2014), the low MS interval corresponds to a decrease in the content of detrital and biogenic magnetite resulting from iron dissolution by acidification. The heat produced during Deccan eruptions creates buoyancy currents in the volcanic plume where acid aerosols are transported up to the stratosphere, where it can rapidly travel around

the world. Once the acid aerosols react with the stratosphere, acid rains acting on the continent dissolved detrital magnetite before it reaches the basin, resulting in magnetite depleted sedimented (i.e. low MS). The authors also provide a weathering model where the time required to dissolve magnetite from a continental regolith is compatible with the duration of the volcanic emissions. In conclusion, our new data show that the typical signature of climate and environmental changes induced by the Deccan Traps volcanism is also recorded in Turkey, providing a new opportunity to investigate the contribution of the Deccan Traps into the K-Pg mass extinction.

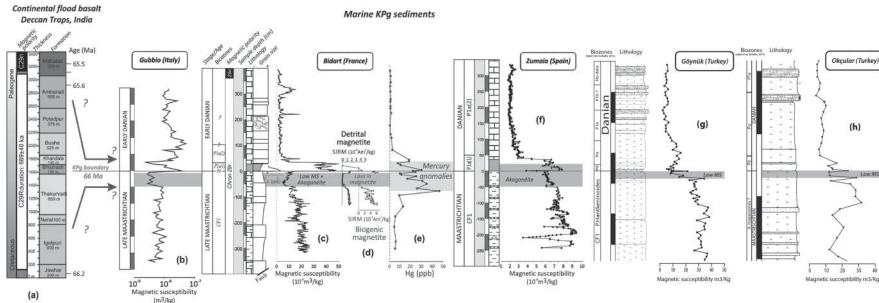


Fig. 1 – (modified after Font et al. (2018)) Correlation of a) the age (U–Pb dating on zircon; (Schoene et al., 2015) of the Deccan lavas flow in India with the KPg marine sedimentary records marked by b) the low MS interval at Gubbio (Italy) (Ellwood et al., 2003); c) the low MS interval containing akaganéite (Font et al., 2011), d) the depletion in detrital and biogenic magnetite (Font et al., 2014), and e) mercury anomalies at Bidart (France) (Font et al., 2016); f) the magnetite-depleted interval containing akaganéite at Zumaia (modified from Font et al., 2017); g) and h) the low MS interval at Göynük (Turkey) and Okçular (Turkey) (this study) and stratigraphy from Açikalın et al. (2015)

Keywords: Magnetic susceptibility; Deccan; Cretaceous-Paleogene transition.

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Massive Volcanic Eruptions Control of Climate Paleo-Records

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Abstract: Thermal effects over geological time controlled climate changes these were affected mainly by intense worldwide volcanism and related sea-level fluctuations. The plate interactions affecting the geoid morphology, its crust and upper mantle comprise the ocean basins primeval rifts, fracture zones, hot-spots, sedimentary basins sub-basalt, pre-salt and upper mantle convection. Many of these thermal effects are of opposite polarity having been observed throughout the geologic record by changes in sea-level, ocean-bottom relief topography, impact features. Major localities where abundant lava flows took place are the Columbia River Plateau, NAVP (North Atlantic Volcanic Province), Siberian Traps, Deccan Traps India, Ettendeka – Southwest Africa and Serra Geral volcanism in East Brazil. This paper focus on comparing cause-effect of massive eruptions that took place in two of these localities; the Siberian Traps at the end of Permian, and the Deccan Traps lava flows formed at the K/T transition boundary, these massive eruptions having remarkable correlations with green-house paleoclimates. The abundant volcanism observed at the K/T boundary in the West India region is related to emplacement of dykes and widespread sills. India rifted away from Madagascar in the Cretaceous developing a shallow marine sag basin. Progressive rifting with migration of the basin northwards combined with the Reunion mantle plume initiation that led to uplift, extension and subsidence with the ongoing rifting. The Indian sub/continent drifted into even higher latitudes, collision with the Asia Plate led to mountain building of the Himalayas. The five million yearlong span of volcanism is concentrated mainly around the K/T boundary. Still, a possible cause-effect relationship is the Chicxulub meteorite impact that might have increased the volume of the Deccan lava flows observed along the coast and neatly mapped by seismic in the offshore, these phenomena correlating with higher sea-level and green-house effect at that span of time. A similar yet less understood, identifiable event took place onshore at the end of the Permian in northeast Siberia this phenomena again coeval with higher worldwide sea-level, massive volcanic extrusion and possible link with a meteor impact.

Keywords: Climate; Massive; Volcanism; Eruptions

Acknowledgements: This study was supported by FEDER funds through the Competitiveness Factors Operational Programme - COMPETE and Portuguese funds by FCT in the frame of the UID/Multi00073/2019 Project.

Paleoenvironmental and paleogeographic contexts identified in deposits of the Barreiras group in the Sergipe state and its meanings in the understanding of the paleoclimatic conditions in the Tertiary and Quarternary of the northeast of Brazil

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Abstract: The Barreiras Group constitutes an extensive terrigenous sedimentary unit of predominantly continental origin deposited in environments that range from alluvial fans, intertwined river systems, lacustrine and transitional to marine environments, established in the South American continent during the Tertiary and Quaternary. During its deposition, important climatic changes took place in the interior of the continent, which locally conditioned the paleosol formation on the exposed rocks of the basement, as well as the development of paleosol horizons inside the overlying sediments. This study approaches the river flow conditions, analyzing the types of sediments deposited by the rivers, in the areas of their occurrences in the State of Sergipe. The definition of the main river flow sources and the identification of the intermediate and distal regions of the extensive fluvial system should contribute to the better recognition of the headwaters of the extensive depositional system considered responsible for the Barreiras Group. According to Milliman (1991), the rivers contribute approximately 70% of the total global sediment supply to the ocean. The studies of extensive depositional systems of the past, besides being important in the recognition of the main regions of contribution to ancient deposits of economic interest namely on hydrocarbons, can also contribute to a better understanding of the evolution of the present days great rivers and their role on terrestrial ecosystems. The main study area in the state of Sergipe is the city of Estância, between latitude 11 ° 16 '06' 'S and longitude 37 ° 26' 18 " W, where the deposits of the unit can be analyzed. Another research area in this state is the Santa Rosa de Lima Municipality, where preliminary studies allow the observation of topographic remnants of erosion that contain paleosol records on the basement, as well as outcrops showing structures and associations of faces that indicate a transition context between geological processes from medium positions of depositional systems to more distal depositional situations (Fig. 1).

BARREIRAS SYSTEM ON SERGIPE PROVINCE
ESTÂNCIA SECTOR

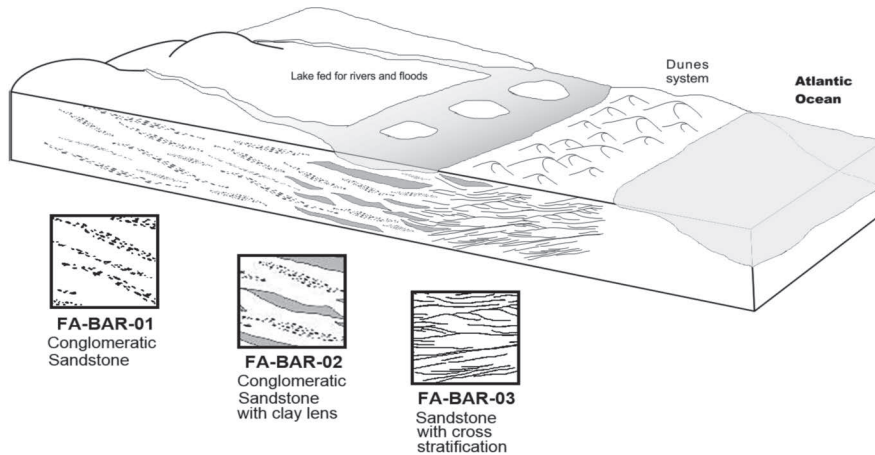


Fig. 1 – Preliminary reconstitution of the Barreiras Group's depositional systems in the Province of Sergipe, Estância region. Middle to distal fluvial depositional systems associated with lacustrine coastal environments associated with coastal sandstones deposits are observed.

Keywords: Extensive river systems; Paleoenvironments and paleoclimates, Paleogeography.

Quinta da Ventosa Formation. Glaciomarine sediments of Cambrian age in Portugal?

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Abstract: Rebelo (1983) defined the Quinta da Ventosa Formation in a small syncline in Quinta da Ventosa, west of Torre de Moncorvo, northern Portugal. It was characterized as a thick conglomeratic formation that is concordant with the Ordovician quartzites and discordant with the schists of the Desejosa Formation (Sousa, 1982), of the Schist-Greywacke Complex (C.X.G.). In the same work, the presence of a similar unit is reported in other nearby location where the Ordovician quartzites is clearly discordant with C.X.G.. This unit is considered lateral equivalent of the São Domingos Formation (Sousa, 1982) at the top of the Desejosa Formation. New geological surveys and petrographic analyzes allowed to confirm a glaciomarine origin for this formation. It is recognized, as a global event, the existence of sediments of glaciomarine origin in the Upper Ordovician (Hirnantian) but the same character is not recognized in the Lower Ordovician. These glaciomarine sediments underlying the Armorican Quartzite, allow together with the structural relations, assign a Cambrian age to the Quinta da Ventosa Formation. Glaciomarine sediments of Cambrian age it has been recognized in places that during part of that period they were in near latitudes (Landing & MacGabhann, 2010). Then, the sediments of Quinta da Ventosa Formation may have been formed during the Cambrian, in front a paleocontinent that has had a glaciation and consequent liberation of masses of ice for the ocean.

Keywords: Cambrian; Glaciomarine sediments; Quinta da Ventosa Formation.

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Reminiscences of Tertiary and Quarternary surfaces in the northeast of Brazil and its records in the state of Sergipe

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Abstract: Erosive processes of large planning surfaces within the continents tend to occur at geological times of low or non-existent tectonic activity (King, 1953), or simply associated with intensive climatic aridity, characterized by low vegetation cover and sporadic and strong rainfall. In this way the rains originate fluvial channels, which promote the clipping of surfaces and their lowering. Considering that any planning surface is more recent than the lithological units on which it is established and older than its covering, the geomorphological surfaces related to the Tertiary-Quaternary interval at the NE Brazil played an important role during the deposition of sediments included in the Barreiras Group, dated as Eo-Oligocene to Neo-Miocene (according to Rossetti & Góes, 2004). The NE Brazilian territory is formed by morphostructural compartments that are the result of tectonic events throughout its geological history. These compartments make up the basement of the South American platform, which in the NE Brazil is composed by the Borborema Province, the São Francisco Craton, the Coastal Plain and the remnants of the Paleozoic and Mesozoic basins. On these substrates the surfaces of planning are installed and between them their remnants, which are being analyzed by the ongoing study. The paleoclimatic evolution during the Tertiary and Quaternary periods led to the establishment of the fluvial courses that resulted in the planning surfaces, as well as the corresponding deposits which resulted from the erosion of the underlying intervals. The studies of the planning surfaces associated to the study of provenance of the coeval sedimentary intervals, can contribute to a deeper understanding of the paleoclimatic conditions involved in both processes. In addition to these aspects, considering that the courses tend to coordinate the denudation of the relief and the lowering of the valleys, from the head of each system to the mouth, the planned surfaces tend to form first on the coast and then extend in the direction of the interior, as it is recorded in the NE Brazil. The center of the study in these evolutions is being carried out in the state of Sergipe, namely cutting it in SW-NE direction from Cristinópolis to Propriá with focus in the region of Santa Rosa de Lima, Riachuelo and Divina Pastora, and in E-W direction from Feira Nova to the Neópolis, as show in figure 1, where remnants of these surfaces can be recognized, acting as a large drainage network that cuts the area to the coast.

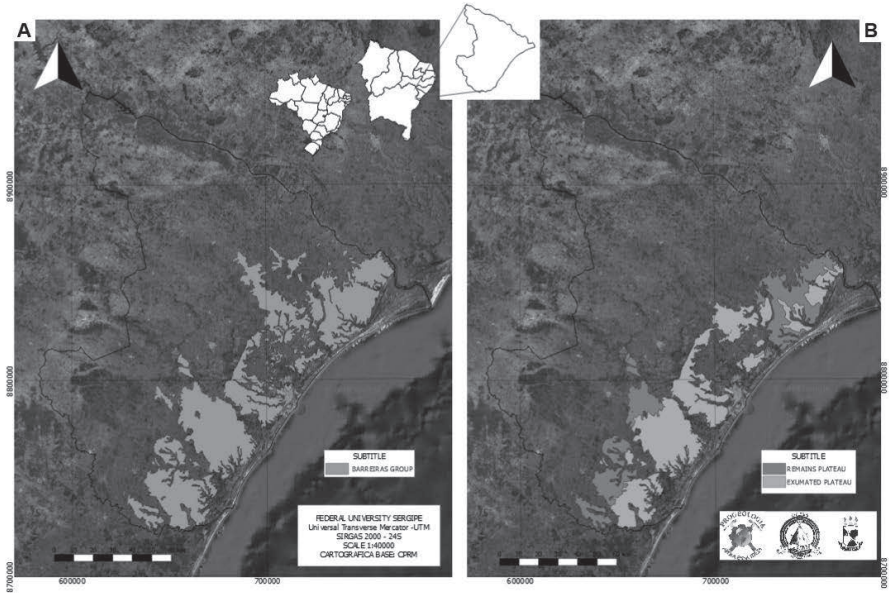


Fig. 1 – Regional distribution of Barreiras Group deposits at Sergipe State, Brazil (A), showing different topographic compartments (B). At B is observed in blue areas the remains of regional plateau related to post-Barreiras surface and exhumated eroded areas in yellow. Paleoclimatic evolution was an important control of the denudation processes of the relief and the lowering of the valleys, from the head of each system to the river mouth, as it is recorded in the NE Brazil. The remnants of these surfaces can be recognized, acting as a large drainage network that cuts the area to the coast.

Keywords: Planning surfaces; Paleoenvironments and paleoclimates; Palaeogeography in the Quaternary.

The paleoenvironment of the Papo-Seco Formation (Lower Cretaceous) of Cabo Espichel (Southern Portugal)

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Abstract: New vertebrate and invertebrate fossilized remains are reported herein from the basal deposits (marls, sands and gravels) of Papo-Seco Formation (Lower Barremian, Lower Cretaceous) Cabo Espichel (Sesimbra, south of Lisbon). Papo-Seco formation lies between Areias do Mastro Formation and Boca do Chapim Formation (Manupella et al., 1999). The very first palaeontological investigations in Papo-Seco Formation took place in the 19th century (Figueiredo et al., 2015, 2016). The geological survey reported dinosaur and crocodile teeth from the Papo-Seco Formation, at Boca do Chapim (Sauvage, 1898). The studied layers were formed in an environment of shallow-marine features (lagoon, estuary). Initial paleontological inspections produced several vertebrate and invertebrate remains; after thorough examination, we identified bones and teeth of fish, crocodiles, dinosaurs, pterosaurs and turtle shell fragments. The sedimentological analysis and taxon identification suggested an evolution from a closed (estuary) to gradually a more open sea environment (pelagic). Examination of the fossil specimens and sediment sample from a paleoenvironmental perspective, revealed that the basal layer was deposited in a lagoon like or estuarine environment whilst the upper layer in a coastal one. The fossilized animal diversity is indicative of the following environments: invertebrate fossils, like *Eomiodon Cuneaus* indicates brackish environment of estuarine type; *Nipponomaia*, is a fresh water mollusc of lacustrine floodplain environments and Naticids (Fig. 1 - Left) live on sandy substrates at a great variety of depths depending on the species (Figueiredo et al., 2016). From the studied material, one species of fish, that of *Lepidotes*, is generally found in environments such as fresh water lakes and shallow seas and shared its habitat with the crocodiles and turtles found. The remains of tetrapods (Fig. 1 – Middle and Right, and Fig. 2) suggest the following environments: Turtles: represent semi-aquatic to marine environments; crocodiles: represent semi-aquatic environments; pterosaurs: generally, are found in the littoral zone and dinosaurs: in both terrestrial and the littoral zone. Specifically, *Anteophthalmosuchus* sp. was a semi-aquatic crocodile, its remains are found in areas of open water environments but more broadly in freshwater wetlands and sub-environments such as marshes, swamps and swampy lakes or ponds, streams and rivers. Pterosaurs (Ornithocheiridae and Ctenochasmatoidea) as fish-eating animals for their dietary habits they preferred locations such as near sea and lagoons; *Baryonix*, for the same reasons, inhabited littoral or fluvial zones, lagoons, and estuarine environments as well (Figueiredo et al., 2016). Some sedimentary studies (like the combined clay mineralogical/palynological study, made by Ruffell and Batten, 1990) suggested that the Barremian paleoclimate was dominated by relative aridity, the fauna and features of the studied layers in Papo-Seco Formation, with an estuary, lagoon and sea environments with aquatic or semiaquatic fauna, suggested a humidity paleoclimatic interpretation.

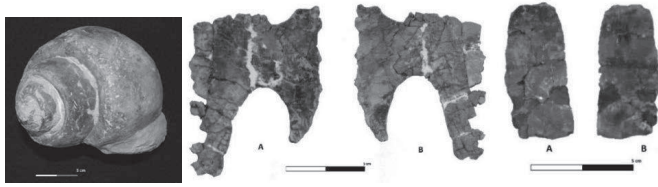


Fig. 1 – Left: Naticidae: predatory sea snails, marine gastropod molluscs; Middle and right: Turtle remains – Plastron (A – dorsal view; B – ventral view); Costal plate (A – dorsal view; B – ventral view).

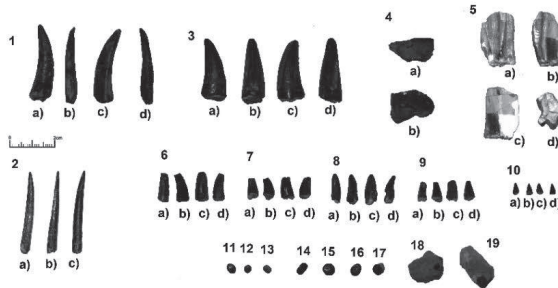


Fig. 2 – Tetrapod remains: 1: Ornithocheiridae CPGP.1.03.2 (a-labial surface; b-distal surface; c-lingual surface; d-medial surface); 2: Ctenochasmatoidea; CPGP.1.09.1 (a-labial surface; b-distal surface; c-medial surface); 3: *Baryonyx* CPGP.1.06.2. (a-labial surface; b-distal surface; c-lingual surface; d-medial); 4: Ornithopoda indet. CPGP.1.03.3 (a-lingual surface; b-top view); 5: cf. *Mantellisaurus*-CPGP.1.01.2 (a-labial surface; b-distal surface; c-lingual surface; d-top view); 6-9: *Anteophthalmosuchus* sp.: 6-CPGP.1.03.1; 7-PGP.1.03.7; 8-CPGP.1.05.9; 9-CPGP.1.06.71; 10-CPGP.1.06.81 (a-labial surface; b-distal surface; c-lingual surface; d-medial surface); 11-19 cf. *Lepidotes* sp. teeth (adapted and modified from Figueiredo et al., 2015).

Keywords: paleo-environment; fossils; Barremian; Papo-Secco; Portugal

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The response of Iberian foraminiferal record to Middle Jurassic Warm/Cool climate modes

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Abstract: Climatic fluctuations are one of the main causes of environmental changes in marine basins. In the last decades, different works have been carried out aiming at increasing the knowledge about climate changes across the Jurassic. Many of them are based on isotopic data from rocks or fossil as belemnites. Thus, in Early-Middle Jurassic, Western Europe was affected by major modifications in the oceanic current patterns, given rise to abrupt Warm/Cool climate modes. Such variations had consequences on the composition of assemblages of different fossil groups, also conditioned by the paleogeographic framework (Fig. 1a and 1b). Benthic foraminifera are excellent proxies as indicators of paleoenvironmental changes, due to the strong relation with the place where they develop, as well as their scarce capability of movement. In the Basque-Cantabrian Basin (north Spain) several cooling and warming episodes were detected from the upper Toarcian (Lower Jurassic) to the lower Bajocian (Middle Jurassic) based on changes of $\delta^{18}O$ obtained from belemnites (Fig. 1c). Foraminiferal assemblages from this stratigraphic interval show changes in their taxonomical composition in each one of them (Fig. 1d). Thus, in the Comptum Cooling Event (lower Aalenian) an increase in the diversity of the assemblages takes place. Across the Bradfordensis Warming Event (middle Aalenian), diversity decreases progressively. Slight variations on diversity is recorded in the Gigantea-Concavum Cooling Event (middle-upper Aalenian) and, finally, a new increase in temperature takes place in the Aalenian-Bajocian transition (Limitatum-Discites Warming Event), when a very strong decrease in abundance and diversity affected the foraminiferal assemblages. All these changes were related with climate changes and paleoceanographic features, conditioning migrations and appearances-disappearances of foraminiferal species that inhabited this basin. Comparison between foraminiferal record from the Basque-Cantabrian Basin and the Lusitanian Basin (west Portugal), for the same stratigraphic interval, allows to establish some similarities and differences. Foraminiferal assemblages recorded in the Comptum Subzone from the Lusitanian Basin display a high diversity, as well as assemblages recorded in Basque-Cantabrian Basin. However, in the São Gião section (Lusitanian Basin), the taxonomical composition of the assemblages is very different, showing a noticeable dominance of miliolids, typical of shallow and warm waters, and an absence of foraminiferal species apparently typical of cool waters. This fact has been related with a possible local hydrothermal activity in the context of the opening of the North Atlantic and/or the hypothetical connection between Western Tethys and Eastern Pacific through the Hispanic Corridor. As a consequence, local conditions may obscure the regional climatic trend. In the foraminiferal assemblages from the Murtinheira section (Lusitanian Basin), where the whole stratigraphic interval is recorded, it is possible to recognize the same changes in diversity variations of the Basque-Cantabrian Basin. The strong decrease in abundance and diversity recorded across the Aalenian-Bajocian boundary has been identified not only in the Iberian Plate, but in other European basins, affecting different groups of macro and microfossils. It could be related to the Limitatum Warming Event, being the beginning of the second order transgression occurred during the Late Aalenian-Early Bathonian. The subsequent biotic diversification recorded from Early Bajocian in many fossil groups may form part of the Mesozoic Marine Revolution.

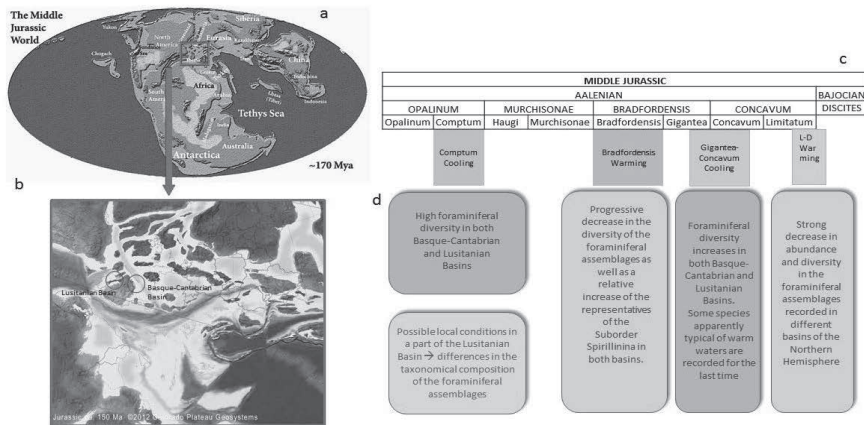


Fig. 1 - Main Middle Jurassic foraminiferal bioevents related to climatic changes in the Basque-Cantabrian and Lusitanian Basins (Iberian Plate): a) Global Middle Jurassic paleogeographic map (modified from www.palaeos.com/Mesozoic/Jurassic/bajocian.html); b) Paleogeographical Middle Jurassic location of the Basque-Cantabrian and Lusitanian basins (modified from @2012 Colorado Plateau Geosystems); c) Middle Jurassic (Aalenian-Bajocian) biostratigraphic chart based on the ammonite record and Warm/Cool climate modes recorded for the Basque-Cantabrian Basin (following Gómez et al., 2009); d) Main foraminiferal bioevents recognized in both Lusitanian and Basque-Cantabrian basins.

Keywords: Warm/Cool climate modes; Foraminifera; Middle Jurassic; Iberian Plate; Mesozoic Marine Revolution.

Acknowledgments: This study was supported by FEDER funds through the Competitiveness Factors Operational Programme - COMPETE and Portuguese funds by FCT in the frame of the UID/Multi00073/2019 Project and is a contribution for the Projects CGL2015-66604-R and CGL2014-52546-P (MINECO) and for the Grupo de Investigación UCM 910431 (Complutense University, Madrid, Spain).

Three granites and three landform types at Valpaços region (Portugal)

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Abstract: Valpaços, in the North of Portugal, is dominated by late- to post-tectonic granites intruded during the Variscan orogeny. The magnetic "fabric" of pluton is characterized by E-W magnetic foliations associated with sub-horizontal magnetic lines, which are weakly inclined towards the exterior of the pluton, suggesting a little thick granite body with laminar geometry. The granite geoforms have been interpreted in terms of climatic geomorphology, or morphogenetic regions, but the field evidence overwhelmingly points to structural control by endogenous features defined during their intrusion. Subsequently, tectonics associated with the Alpine orogeny resulted in a dense network of faults and fractures. However, the final subaerial exposure of the granite bedrock is mainly related to a wide range of erosion processes since Palaeogene times. The granites of Valpaços pluton are of three types with contrasting geomorphologies, which must be considered as Natural Monuments (Fig. 1). G1 Medium grained two mica granite, has a landscape dominated by boulder/block chaos, G2 coarse grained, porphyritic, two mica granite is dominated by the presence of orthogonal diaclasing and formation of balls, often with tafone, while the G3 fine grained two mica granite forms small ellipsoidal balls with rings. The gnammas, designated with the local name "pías", are almost ubiquitous in the G1 granite landscape dominated by boulder/block chaos. They have a subaerial or epigenic origin, in which the accumulation of surface water on a concavity leads to the formation of a hollow by physical and/or chemical weathering. The formation of boulder chaos is related with an erosion process due to the combination of water, frost and wind. At first, granite splits itself or by frost action, then in a second time the water flows in these cracks and converts feldspar into clay. At the end, clays are removed and only granitic block chaos remains. Tafoni are especially well developed in the G2 granite and are considered as forms generated in two stages: the first in which their strain is carried out and the second that takes place when the affected rock is exposed on the terrestrial surface. Clusters of closely spaced alveolus "honey comb weathering type" are developed on the inner walls of tafoni. At a local scale, the distribution of tafoni are puzzling, with some blocks hollowed, and others, immediately adjacent and apparently identical, intact. Spheroidal weathering is the result of chemical weathering of systematically jointed, massive and fine granite G3. Because water can penetrate the bedrock along these joints, the near-surface bedrock will be altered by weathering progressively inward along the faces of these blocks, occurred in the past during periods of humid climates. Depending on local environmental conditions, spheroidal weathering of bedrock blocks may result in the formation of prominent and well-defined rings, which consist of a relatively unaltered core surrounded by concentric, alternating shells which make up the rings.



Fig. 1 – The three types of granites with contrasting geomorphologies of the Valpaços pluton. Top: G1 Medium grained two mica granite; Middle: G2 Coarse grained, porphyritic, two mica granite; Bottom: G3 Fine grained two mica granite.

Keywords: Structural control; Climatic effects; Tafone; Rings; Gnammas.

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Understanding environmental, climatic and biotic changes through the stratigraphic record from an educational perspective: an example from the Upper Cretaceous of Nazaré (West central Portugal)

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Abstract: The stratigraphic record provides us an astonishing diversity of contexts, as a sort of Magritte windows opened towards the deep past where major environmental, climatic and biotic changes have occurred repeatedly. Both bio and lithofacies expressed by the sedimentary bedding and its lateral and sequential organization are important records that allow geologists and palaeontologists to infer main aspects of the local/regional palaeoenvironments and biocenosis, and their palaeoclimatic implications. The availability of these records in many outcrops with adequate conditions of exposure and accessibility for field-work teaching, has proved to be an indispensable non-formal tool for the school community of Earth-Sciences, in order to understand when and how long-term environmental, climatic and biotic changes affected the Earth system. These important topics for the nearest generations are deeply related with science, technology, society and environment (STSE) educational approaches, and focused in all different levels of the European modern school curricula, including the high-school Portuguese ones. A comparison with present-day environmental problems and the anthropic contribution for climatic changes is also obvious and inevitable, allowing students to perceive that if major changes have occurred in past, they also can happen in a nearest future. The stratigraphic section exposed in the promontory of Nazaré is a good example of this versatility shown by the stratigraphic record, which can be explored from different perspectives through pedagogic practices (Fig. 1A-B). From a scientific point of view and considering the overall Portuguese geology, it stands out as one of the best areas to study the Upper Cretaceous post-rift series of the Western Portuguese Margin of Iberia. The diversity of facies recorded in the local succession allow the recognition of alluvial fan, alluvial plain, tidal flat, lagoonal, inner and outer shelf palaeoenvironments, during intervals where humid maritime warm conditions or drier continental ones have prevailed. The involved time span of the succession ranges from the Albian to the Campanian stages, with a strong contribution of lower Cenomanian to lower Turonian platform carbonates contemporaneous of the major sea-level rise and high-stand of “Mid” Cretaceous times. The palaeontological imprint is based on Albian to Early Cenomanian floras with representatives of the first angiosperms, together with a large diversity of Cenomanian and Turonian marginal to fully-marine invertebrates, benthic foraminifera and ostracods, many lagoonal fish, turtle and crocodylomorph taxa of warm surface-waters. Also, at the top of the section, alluvial fan proximal facies are known to yield an interesting assemblage of archaic continental gastropods. Altogether, these paleontological elements can be useful to infer major environmental changes and aspects of the climatic imprint associated to the Cretaceous biotic assemblages, mostly related to long-term evolution of subtropical to tropical conditions within the Tethyan Realm. These aspects could be explored with field-work, adopting sequential procedures commonly used in teaching methods, and following the adopted curricula.

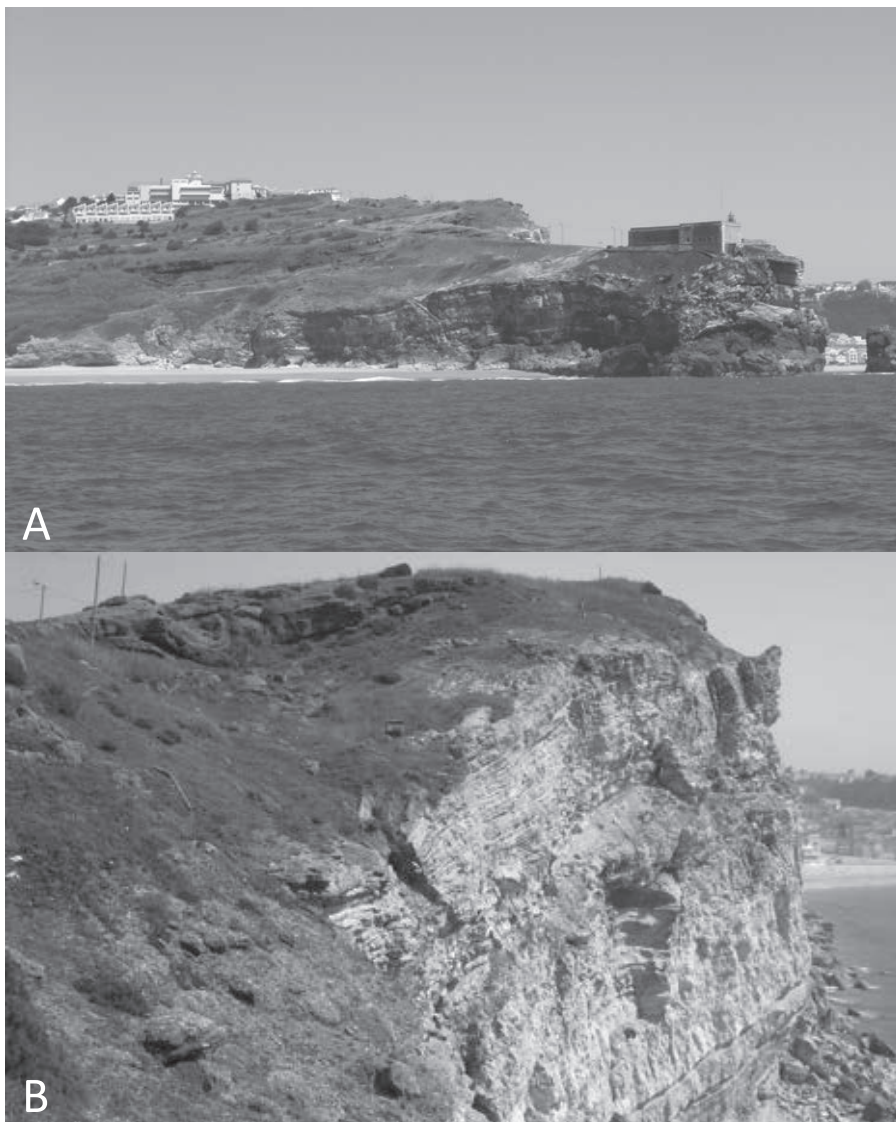


Fig. 1 – Panoramic views of the Nazaré promontory, showing the succession of Cretaceous marine and alluvial strata. A – Northern side; B – Southern side.

Keywords: Environmental and climatic changes; Stratigraphic record; Field-work education; Upper Cretaceous; Nazaré (Portugal).

Variability of the Oceanographic Dynamics of the Cabo Frio Coastal Upwelling (Rio de Janeiro, Brazil) during the Holocene

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Abstract: Along the eastern Brazilian margin there are several upwelling areas, which the Cabo Frio Upwelling System (CFUS) is a focal point. The combination among the predominance of the NE winds, regional topographic features, and the Brazil Current (BC) instabilities allow the upwelling of cold- and nutrient-rich South Atlantic Central Water (SACW) into photic zone producing a significative enhancement in the primary productivity. Sedimentological, geochemical ($\delta^{18}O$, Mg:Ca, Total Organic Carbon-TOC) and micropaleontological (planktonic foraminifera assemblage) analyses were performed in two sediment cores collected on Cabo Frio shelf to reconstruct the variability of coastal upwelling during the Holocene. The results showed that the evolution of the coastal upwelling in Cabo Frio could be observed in five phases during the Holocene. The first phase (9-7 ka) was marked by high abundance of *G. bulloides* and *G. rubescens*, high TOC and low and unstable sea surface temperature based on Mg:Ca (SST-Mg:Ca), indicating the predominance of cold and nutrient-rich waters into the shelf. Between 7 and 5 ka was observed high abundance of *G. ruber* and higher TOC contents with low stratification in the mid-shelf, suggesting intense SACW upwelling events. Between 5 and 3.5 ka was observed high SST-Mg:Ca, with increased mid-shelf stratification, indicating the presence of cold SACW in the subsurface. Between 3.5 and 2.5 ka low abundance of *G. bulloides* and *T. quinqueloba* and high abundance of *G. ruber*, low TOC values, and high SST-Mg:Ca indicates the decrease in the SACW upwelling events. Finally, after 2.5 ka the resumption of the abundance of *G. bulloides*, high TOC content, and low SST-Mg:Ca show the return of the SACW upwelling with the establishment of present-day conditions (Fig.1).

Keywords: Upwelling Evolution; Holocene; Organic carbon.

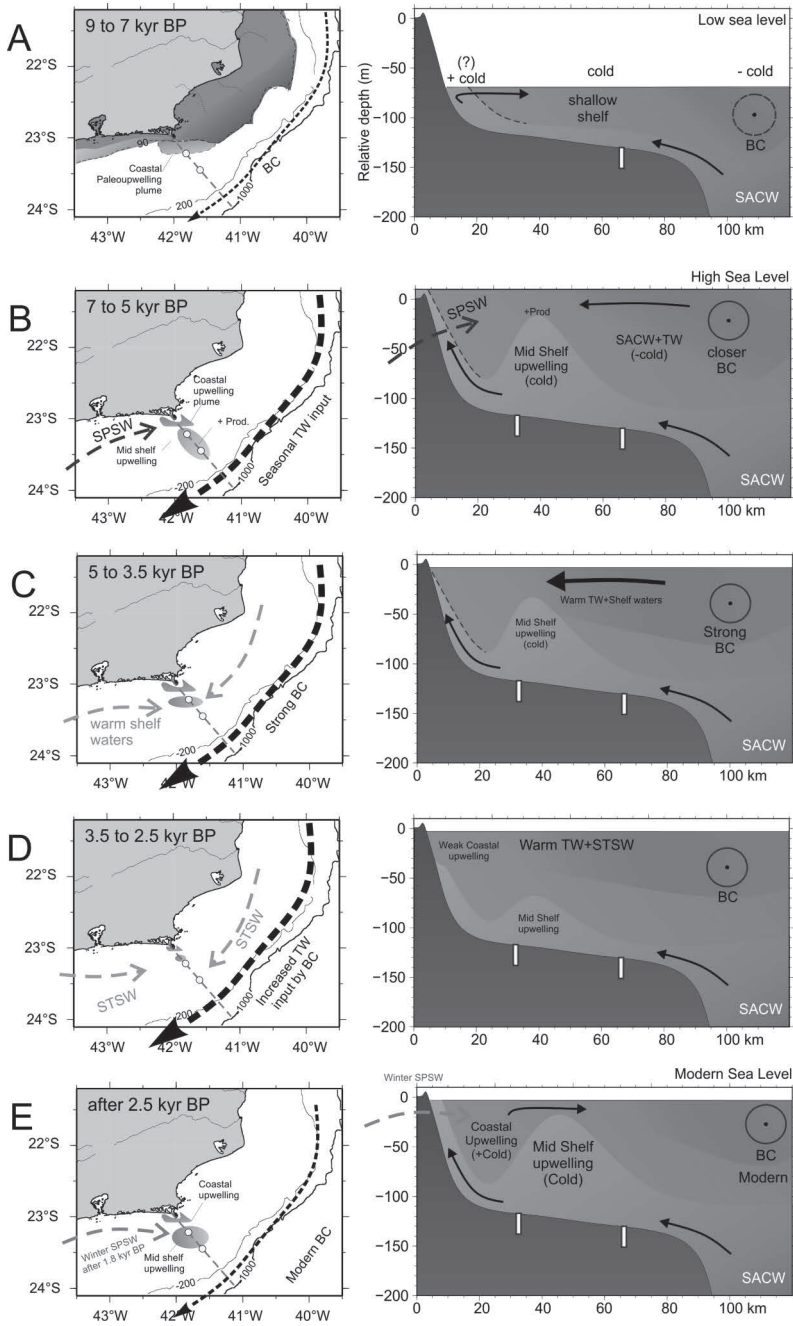


Fig. 1 – Main Holocene oceanographic scenarios for the CFUS shelf, which were reconstructed by geochemical and micropaleontological proxies (a–e) representing the phases I–V during the Holocene.

SECTION 4

TOPIC 4 - CLIMATE CHANGES AND HUMAN ADAPTATIONS THROUGHOUT THE QUATERNARY

Animal extinctions and climate change in the Quaternary period

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Abstract: The causes of animal extinctions are subject to debate in Science from Buffon and Cuvier. Five large animal extinctions have been identified between 450 and 65 million years of Earth history. Then, the eras of the Tertiary and Quaternary did not show mass extinctions. However, significant variations in the climate throughout the Tertiary and Quaternary had a hard impact on evolution or disappearance of many species of animals and more systematically, on changes in the zoocenoses. Since the beginning of the nineteenth century, once abandoned the allegory of the Noah flood, the position of naturalists for animal extinctions in the Quaternary oscillates between a climate-driven and a prehistoric human over-hunting. For the climate origin, Wallace in the nineteenth century, Hay in 1919; and for human hunting, Owen in 1860 in North America, Wallace in 1911 after changing opinion. But the global theory, assigning animal extinctions to human action, is due to P.S. Martin between 1967 and 1984 ("pleistocene overkill"). He concludes two main extinctions: during 50 000 – 40 000, in subtropical Africa and Eurasia and at the end of the last ice age, in Eurasia, the Americas and Australia. This model of "pleistocene overkill" began to be questioned for each case by in-depth studies incorporating data of the archaeozoology, archaeology, more precise climate variations and more and more numerous radiocarbon dates. The question then come back essentially to a climate explanation, even if paradoxically, in the general public, and probably under the action of the ecological movement, the overkill hypothesis knew a strong resilience. However, there was most of the scientific work to achieve, which was to identify the processes, species by species, region by region, for each period and for each climatic environment, which are the cause of the extinctions. This communication is intended to provide several specific examples of animal extinctions: mammoth in Eurasia and North America, large animals in Australia, large mammals in North American, etc. But we will also analyze the great migrations of fauna in latitude and altitude with glacial and interglacial climatic variations taking as an example the Western Eurasia during the stages isotopic 3, 2 and 1. Finally the case of the human species will be also mentioned, for its unique ability to adapt to a glacial climate environments (Neanderthals in Europe) or dry environment (Africa, Australia) and to changes of zoocenoses, by choosing to stay in changing their food resource management, or to change their territory by migration.

Early Holocene paleohydrological and sedimentary indices from the alluvial archives of the Middle Moulouya (the Ait Blal sequence, Morocco)

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Abstract: The Moulouya River is the largest Moroccan river flowing towards the Mediterranean. In the Ksabi basin (Middle Moulouya basin) (fig.1), several holocene alluvial sections have been identified and studied in order to reconstruct the paleohydrological and paleoenvironmental evolution of the river and place it in a very precise chronostratigraphic framework (Paléomex and Paléomar Projects). Some of these sequences have already shown the recording of climate-environmental variations during the Early Holocene period (Lefèvre, 1985; Lefèvre and Ballouche, 1991; Lefèvre and Fontugne, 1993 unpublished). A first reconstruction of the paleoenvironmental evolution was carried out at the Bliroh sequence (Limondin-Lozouet et al., 2013). The objective of this communication is to present the Ait Blal fluvial-tufa archive (fig.2) and to highlight the different climate-environmental phases recorded during the Early Holocene. The various sedimentological, geochemical and malacological analyses have enabled us to observe several hydrosedimentary, hydrological and paleoenvironmental variations in the river-tufa sequence (fig.3). At least four wet phases have been identified, several variations in hydrosedimentary and geochemical parameters could be interpreted with caution, as the manifestation of Holocene RCC (around 8.2, 9.3, 10.3 ka BP), etc. These hydroclimatic successions seem to be repeated along the Moulouya River records, particularly in the eastern tributary basin of the Za-Charef wadi (Depreux et al. in progress).

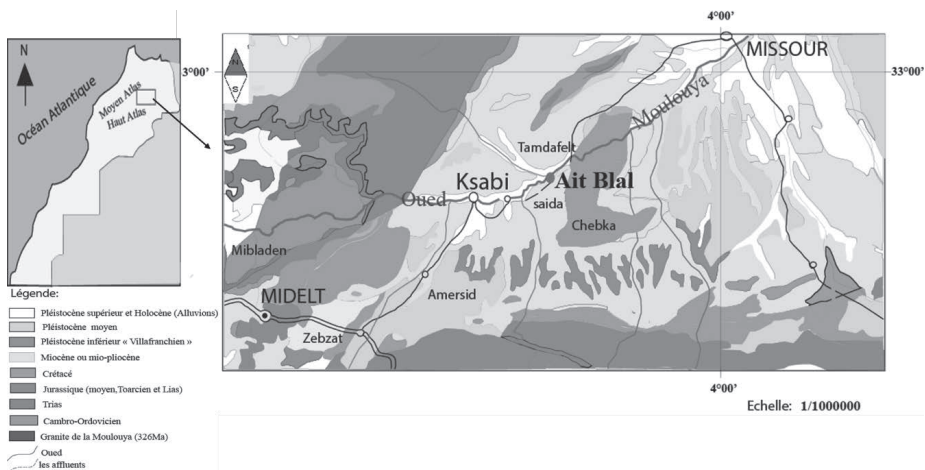


Fig.1 – Location of the Ait Blal section



Fig. 2 – The main stratigraphic units of the Ait Blal outcrop

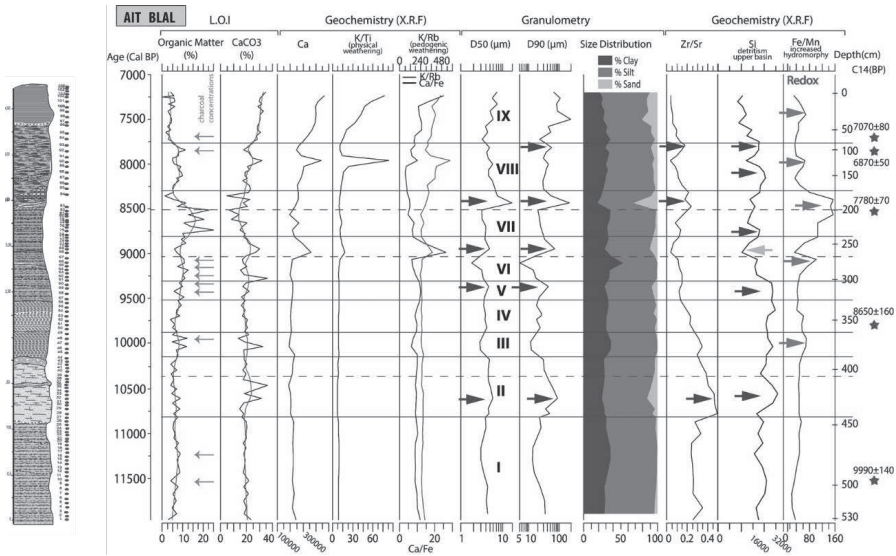


Fig. 3 – Chronostratigraphy and geochemical and sedimentological markers variations of the Ait Blal record

Keywords: Sedimentology; Geochemistry; Climate indices; Holocene; Ait Blal; Moulouya; Morocco.

A tale of two lost villages: Medieval plague or minute changes in climate?

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Abstract: This paper discusses the misconception that the pandemic [Black Death] plague of the mid-14th century was the prime cause for the desertion of medieval villages in England and Wales. At around the same time as this pestilence a slight downturn in annual temperature fluctuation appears to have resulted in the onset of the Little Ice Age (LIA). This was a period of cooling that occurred shortly after the Medieval Warm Period (MWP) and commences around AD 1300. This relative cold snap continued until around 1850 with a hiatus occurring during the 16th and 17th centuries. The LIA extended across most of the Northern Hemisphere and by the 18th century detailed records were being kept which reveal crop and vine failure, as well as the re-advancing of glaciers in the Alpine regions of central Europe. In England and Wales, changes in demography is witnessed by the abandonment of many villages and an increase in population of provincial towns, as well as changes in agricultural practices. Was the LIA partly or fully responsible for these changes? Using available archaeological and palaeoclimatic records, this paper will outline some of the key evidence from two villages in western England that up until the 14th century prospered under a 400-year feudal system; however, by the onset of climate amelioration from AD 1350, changes in the socio-economic fabric of medieval and post-medieval rural England had radically altered for ever, providing the impetus for later socio-political upheaval.

Keywords: Amelioration; Deserted Medieval Village (DMV); Ice Core Sampling; Little Ice Age (LIA); Medieval Warm Period (MWP)

Analysis of rainfall in the city of Aracaju (Sergipe, Brazil) and its implications for urban environmental management focused on climate change

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Abstract: In the last decade, the city of Aracaju (Sergipe, Brazil) has suffered a drastic reduction in its rainfall average both in relation to the climatological norm of 1961-1990 and in relation to the climatological norm of 1981-2010. The city seems to be migrating from a humid tropical climate to a semi-moist tropical (Alves et al. 2007). In the climatological norm of 1961-1990, the average precipitation was of the order of 1600mm per year. In the following climatological normal, 1981-2010, this precipitation had already fallen to 1200mm. In the years approached in the decade of 2010 the average precipitation registered decrease to about 950mm annually (Fig. 1). This reduction is not supported by natural factors such as the "El Nino" phenomenon, which usually brings drought to the northeastern region of Brazil. Precipitation falls were observed even in years of strong influence of "La Nina", which usually brings rainfall within normality to the region or even rains above average. We have not found in the local literature, be it institutional or academic, no report on such a rainfall that is certainly not restricted to Aracaju. The information was generated from a compilation of the historical series of the National Institute of Meteorology (INMET), organ responsible for the administration of the two meteorological stations that exist within the municipality (Sathler). It is noteworthy that rainfall in this region is determined by the masses of warm air arriving from the Atlantic Ocean, so changes in the sea-continent interface can cause irreversible rain gaps and local climate changes in the long term. If this trend is confirmed - in the present year of 2019 there is no evidence that it is broken - this capital will need to undergo a sudden change of paradigms related to the planning of its territory and environmental management, especially in the areas of urban afforestation and management of rainwater and river water. This work intends to establish the initial pillars for this new environment of environmental and urban decision making.

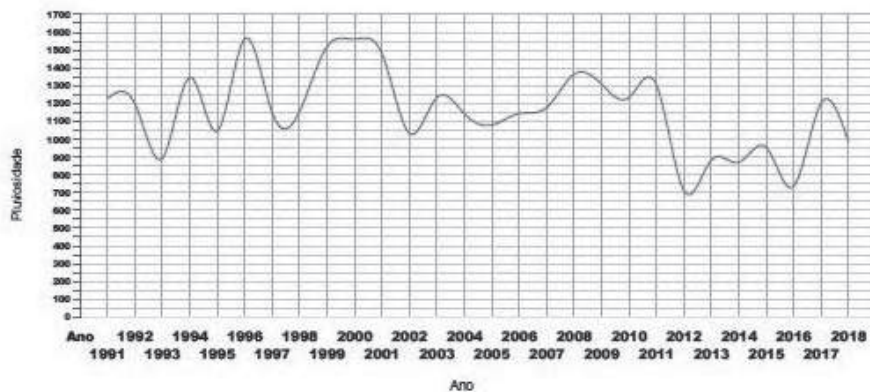


Fig. 1 – Evolution of the accumulated rainfall of Aracaju (historical series between 1991 and 2018).

Keywords: Aracaju; Brazilian northeast; Climate changes; Urban management.

Acknowledgments: Laboratory Progeology and the Federal University of Sergipe for the reception and commitment.

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Analysis of the climate variability in the series of surface air temperature observed in Coimbra (Portugal) since the middle of 19th century

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Abstract: The Meteorological and Magnetic Observatory of the University of Coimbra was one of the first institutions in Portugal to establish a continuous program of meteorological observations, gathering today climate series with more than 150 years. In this preliminary study, we intend to analyze the behavior of the secular series of maximum and minimum of surface air temperature in the period from 1865 to 2016, and show the importance of these historical long series in studies of climate variability. When compared to the Northern Hemispheric series, the evolution of Coimbra's annual temperature series and their respective anomalies (Figure 1) (calculated in relation to the climatological normals of 1961-1990 and 1971-2000) show similar patterns of evolution for most segments of time series. In particular, the same warming trend is evident for the most recent period beginning in the early 1970s. Using the maximum temperatures for Coimbra, the observed warming is characterized by the following incremental increase of the decadal average deviations (anomalies): 0,2 °C (1981-1990); 0,4 °C (1991- 2000); 0,6 °C (2001-2010); 1,0 °C (2011-2016). In addition, and also consistent with the behavior of global series and climate change models, the Coimbra series show that the minimum temperature has been increasing at a faster rate than maximum temperature (resulting in a significant decrease in the diurnal temperature range) since the last quarter of the 20th century. Part of this behavior may result from the heat island effects that are most evident in series recorded in urban meteorological stations such as the Coimbra station. This study shows that the observed climate changing in Coimbra region is in keeping with the global scenarios, and points to the importance of the historical series of Coimbra in the regional and global climate analysis (Fig.1).

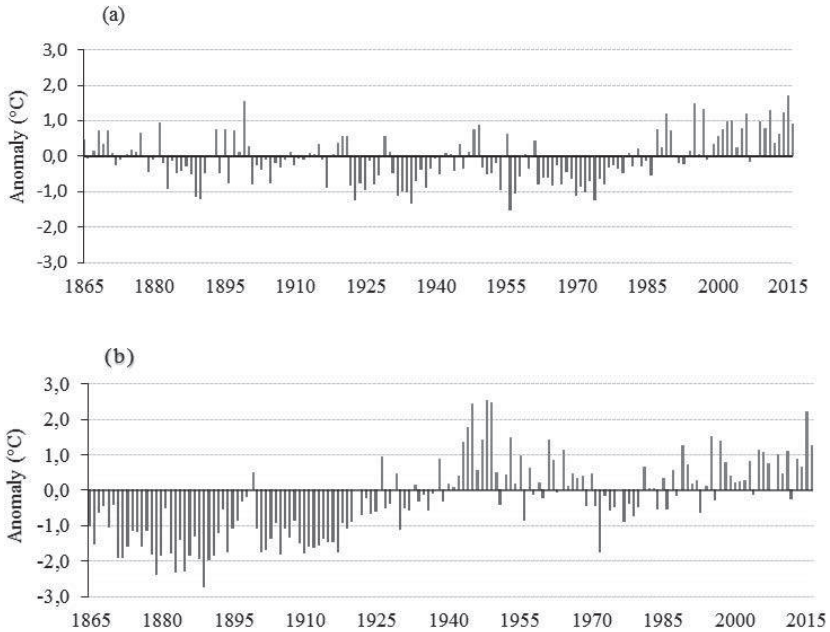


Fig. 1 – Anomalies (relative to 1971-2000) in the minimum (a) and maximum (b) air temperatures in Coimbra.

Keywords: Coimbra temperature series; Climate changes; University of Coimbra

Acknowledgments: CITEUC is funded by National Funds through FCT - (project: UID/MULTI/00611/2019) and FEDER – European Regional Development Fund through COMPETE 2020 – Operational Programme Competitiveness and Internationalization (project: POCI-01-0145-FEDER-006922). This study is part of the HISTIGUC (PTDC\FER-HFC\30666\2017) project.

Could the increasing trend of modern CO₂ be a consequence of the Medieval Warm Period?

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Abstract: Climate changing events underlined by glacial periods are widely documented, from independent criteria and data. The famous Vostok core studies performed by different scientific teams suggests that the CO₂ increase lagged Antarctic deglacial warming by 600 to 1000 years (800 years for other results) These results are considered for Antartida ice cap, although no conclusions are established for other places and types of data. The Medieval warm period, interpreted from 900-1300 AD corresponded to a few centuries of higher temperatures. The colonization of Greenland around the X century AD and subsequent abandon are a strong evidence of the warmer climate at that time. Following this warm event the Little Ice Age seems to have spread a cold climate interval all over the world. It is very well documented in Europe by many direct and indirect evidences. The instrumental data along the XX century presents increasing average temperature and CO₂ rate in the atmosphere (Fig. 1). Nevertheless, the temperature and CO₂ curves in the figure do not seem to follow an interconnected pattern. The temperature trend overlies small oscillations and is disharmonic in relation to the CO₂ curve. Although both are increasing, they do not look like interdependent. The causes may well be different in each case. There are evidences of a global warm since the end of Litle ice Age- The rate of CO₂ increase may, as an hypothesis, be connected with the Medieval Warm period, that just occurred some 800-1000 years before. This time interval could be analog to the lag identified for the Vostok Ice core.

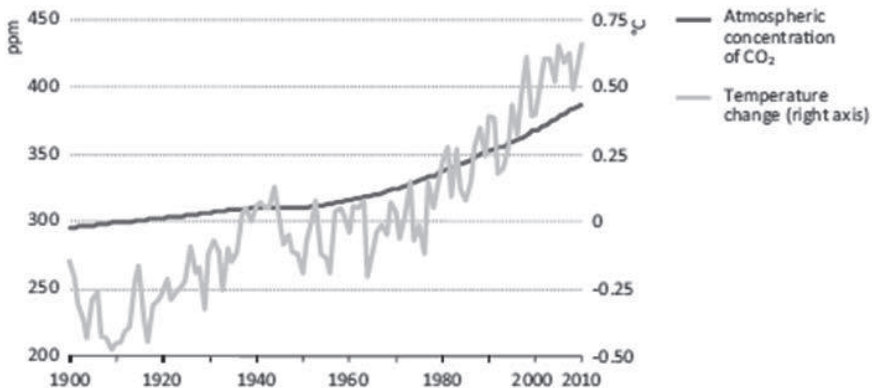


Fig. 1 – World atmospheric concentration of CO₂ and average global temperature change. The temperature refers to the NASA Global Land-Ocean Temperature Index in degrees Celsius, base period: 1951-1980. The resulting temperature change is lower than the one compared with pre-industrial levels. Sources: Temperature data are from NASA (2013); CO₂ concentration data from NASA Earth System Research.

Keywords: Medieval Warm Period; Vostok core; CO₂ increasing; Temperature vs. CO₂.

Acknowledgments: This study was supported by FEDER funds through the Competitiveness Factors Operational Programme - COMPETE and Portuguese funds by FCT in the frame of the UID/Multi00073/2019.

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Temperature data are from NASA (2013). CO₂ concentration data from NASA Earth System Research.

Elk and deer figures in the rock art of northern Italy between the Late Pleistocene-Early Holocene

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Abstract: Recent research on the Palaeolithic rock art of the Italian peninsula highlighted a significant presence of deer and elk figures in northern Italian rock art, revealing a strong link between climate change and human adaptations. At least six cervid (elk and deer) figures were recognised in Luine, Valcamonica, (Fig. 1) and the zoomorph of the Caviglione cave, Balzi Rossi, was reinterpreted as a possible elk figure. Deer can also be found in southern Italian rock art, but the elk theme has a specific northern diffusion area, suggesting a strong influence of the environment and landscape on the symbolic heritage represented on the rocks. Elk (*Alces alces*) is known for having a great paleobiogeographic importance, living in very specific habitats. During the quaternary glaciations it lived in northern Italy as well, moving then northwards, according to the spread of deciduous forests. Elk fossils were found in the Po plain. Some more remains were unearthed in the Ligurian caves of Arene Candide and Balzi Rossi, associated to Gravettian burials too. The animal probably arrived in Liguria through the Rhône plain when the Liguro-Provençal Arc corridor was of easier access. So the elk representations, which are few in western-central European rock art sites, Gargas and Les Merveilles caves, and few as well among the portable artwork findings (an engraved pebble from Tagliente shelter, the sculpted amber elk from Weitsche and the recently reinterpreted Oberkassel carved figure), are an extra key element in the understanding of the cultural and symbolic dispersal processes, together with the environment-human interactions occurred during a moment of strong climatic changes, which pushed the elk northwards. Therefore the presence or absence of specific subjects suggests the dispersal and sharing dynamic among human groups, or possibly social and cultural migration. The proposed work attempts to offer a first insight into this topic, using cervid figures as cultural markers and witnesses of the environment-human interactions occurring at the end of the Pleistocene-beginning of the Holocene in northern Italy and the rest of the European continent.

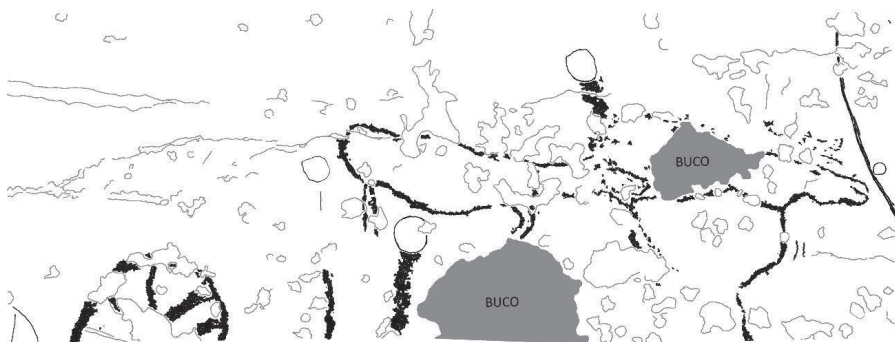


Fig. 1 – Couple of elk figures (H1 and H2) on Rock No.6 in Luine, Valcamonica (tracing D. Sigari).

Keywords: Palaeolithic rock art; Deer; Elk; Late Pleistocene- Early Holocene; Northern Italy.

Pleistocene birds from sedimentary archives of Atlantic and Mediterranean areas of Iberia as paleoenvironmental and paleoclimatic indicators

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Abstract: This is a brief study on paleoenvironmental and paleoclimatic indicators provided by Iberian bird remains present in Pleistocene sedimentary deposits and is based on data resulting from published studies on Pleistocene sites with birds. A characteristic feature of the Pleistocene is that the species we find are the same as the current ones, with few exceptions that are recorded at the beginning of this Epoch. As for the ornithic assemblages – understanding that the fossil associations are samples of the local paleornitocenosis –, beginning with the oldest fossil localities, it is evident that the Iberian Peninsula was divided into the two current bioclimatic regions (Mediterranean and Eurosiberian or Atlantic), although the limits and the extensions of both regions fluctuated throughout all this time. Pleistocene sites are so numerous, in particular, those of the late Pleistocene, that in this work only a few have been chosen in order to illustrate the changes in avian distribution areas to the beat of variations of climatic conditions. In Portugal, the interval recorded by Pleistocene deposits that contain bird remains is between 240 ka (Galerias Pesadas) and 10 ka (Gruta do Caldeirão). In Portuguese sites there was no significant change in environments associated with the bird species (Figueiredo and Rosa, 2014). However, we can see some differences between coastal sites and inland sites: in Furninha cave (*MIS 5*), which is a coastal karstic cavity, the avian assemblage is dominated by seabirds. However, the presence of continental species indicates a connection with continental environments. Some species of birds in this cave point to a colder climate, but other bird species suggest humid and hot to temperate climate conditions (Figueiredo et al., 2017); in Columbeira cave (*MIS 3*), the taxonomic uniformity of birds indicates similar paleoclimatic conditions during their depositional period. In this cave is possible to notice the predominance of the characteristic species from the inland and dry environments, as expected, due to its geographic location, being the marine and wet land species residual. The species identified are mostly from a temperate-cold climate (Figueiredo et al, 2018). In the eolianites outcropping at Ilha do Pessegueiro (*MIS 2*) were found footprints of Charadriiformes (Ichnogenus *Charadriipeda*) (Neto de Carvalho et al., 2016), that are the unique bird's footprints from the Pleistocene of Iberia. The aeolianite unit under has a probable age of c. 32 to 12 ka (Upper Pleistocene). During this interval, cold and dry climate conditions in Portugal (e.g. Cunha et al., 2012) promoted very strong wind dynamics that generated a widespread cover unit of aeolian sands and a drastic decrease of vegetation. In Spain, the complex of sites of Atapuerca, El Castillo cave and Santa Catalina cave have provided the richest and most diverse ornithic associations. The avian fossil assemblages of these deposits, within levels of diverse chronologies, point out to the existence of a wide range of habitats. At the southern tip of Iberia, on the coast of the Mediterranean region, Gorham's and Vargard caves, two of the palaeontological sites with the largest variety of avian taxa in the world, permit us to depict the wide diversity of habitats supported on the regional climatic conditions during the Pleistocene. The most radical change that climatic fluctuations caused in the behavior of birds was the

beginning of long-distance annual migrations. And it was recorded in the Iberian Peninsula (Fig.1).



Fig. 1 – Left: Proximal fragment of a left humerus of a *Pinguinus impennis*, from the Furninha cave. Right: sculpture, made by the sculptor Soares Branco, in 1979 (Museu do Mar de Cascais). The presence of this specie in several Pleistocene deposits in Iberia, point to a colder climate.

Keywords: Fossil birds; Paleoclimate; Caves; Iberia; Pleistocene; Avian long-distance migrations

Acknowledgments: This research was part funded by the Fundação para a Ciência e a Tecnologia, through projects, UID/GEO/04683/2019—ICT (SF), UID/MAR/04292/2019—MARE (PPC). ASM is member of the consolidated research group 2017SGR86, Generalitat de Catalunya. He has also benefited from the CERCA program, Generalitat de Catalunya, and the project CGL2016-76431-P of the State Research Agency and the European Fund for Regional Development. The authors would also like to thank Museu do Mar de Cascais for the photo of the sculpture in Figure 1.

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River sedimentary contexts associated with human occupation of the Middle Pleistocene in the Iberian Atlantic margin and their climatic meaning

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Abstract: In the Iberian Atlantic margin two main biogeographic regions can be observed: the Eurosiberian and the Mediterranean. These two regions show distinct climatic features with relevant constrains in the river regimen and in the human occupation pattern during the Lower Paleolithic. The earliest human presence in the Iberian Atlantic margin is currently dated around MIS 10 (~424 ka), but the main development occurred between MIS 9 and MIS 6, circa 374-131 ka. The archaeological sites from this period show African Large Acheulean flakes (LFB) with the extensive use of large flakes for knapping handaxes and cleavers. Most of these sites are associated with the main hydrographic basins, like those of Miño, Lis or Tagus rivers (Fig. 1). The human activity remains are almost always in fluvial environment, mainly in river terraces with heights between +20-40 m above present-day river bed. A relevant difference between the fluvial pattern of northern (e.g. Miño) and the southern (e.g. Tagus or Lis) rivers can be observed. In the first case, archaeological sites are in fine-grain sediments, mainly of overbank facies, sometimes connected with colluvium deposits, and the remains in high-energy environments (fluvial channels or gravel bars) are scarce. On the other hand, in the lower basin of rivers like Tagus or Lis the largest percentages of the archaeological sites are in high-energy facies and those associated with low-energy environments are less abundant. These important differences in the sedimentary environments in the sites of both types of rivers are, in our opinion, the result of the paleogeographic difference. Northern rivers, like the Miño, do not have a severe and long seasonal low stage and therefore humans developed their activities outside channels, which are permanently occupied by water. On the contrary, rivers with a long and severe seasonal low stage (e.g. Tagus or Lis) and bar-channels are exposed for many months allowing its occupation by hominin groups. So, we suggest that these environmental differences played an important role in the adaptation strategies adopted by humans in these two biogeographic regions.

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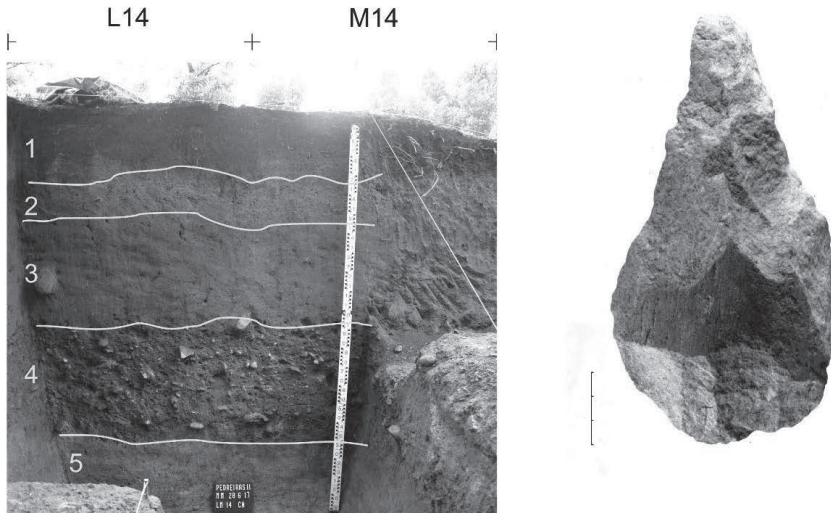


Fig. 1 – Acheulean site of Pedreiras 2 (Messegães, Monção). Pit 1 of the excavation and biface associated with the stratigraphic unit UE4.

Keywords: Biogeographic areas; River Terrace; Acheulean; Middle Pleistocene; Geo-archaeology

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Speleothem record of climate change patterns in eastern Iberia during the onset of the Last Glacial Period

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Abstract: Speleothems from two caves of eastern Spain have been analyzed to reconstruct regional paleoclimate patterns during the first half of the Last Glacial Period. The studied speleothem material consists of broken and fallen stalagmites sampled in Don Juan Cave, near the town of Jalance, and in Tortero Cave, near Tous. Both caves are located in the province of Valencia, and strongly experience the maritime influence of the nearby Mediterranean Sea. The research has been accompanied by cave environmental and hydrochemical monitoring for supporting interpretation of paleoclimate proxies, as well as by detailed microstratigraphic work on the stalagmites to allow reliable series construction. The study yields a composite, high-resolution, Th-230 dated, paleoclimate series based in stable isotope ratios ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$). The record covers two intervals, 120–108 ka and 93–72 ka, and allows, by the first time, to reconstruct the prevailing hydroclimate conditions in the area for the epoch and, more important, to characterize the patterns of climate change. Within a climate clearly colder and more humid than current one, rapid changes in temperature and rainfall can be recognized in both intervals, with marked thermal minima occurring around 116.7, 110.4, 91.4, 86.7, 77.8, and 73 ka BP. These cold intervals are commonly accompanied by environmental changes defined by reduced biological activity in the soils above the caves. Our records were compared with ice-core time series from Greenland and speleothem data from the Eastern Mediterranean and other mid- and low-latitude areas to interpret long-distance teleconnections at centennial to millennial scales during the first half of the Last Glacial Period. There is a significant correlation with Greenlandic and the North Atlantic dynamics record, particularly the early Dansgaard-Oeschger events. Remarkably, besides temperature changes, most of the environmental crisis recorded in eastern Spain have been also recognized in other areas of the eastern and central Mediterranean.

Keywords: paleoclimate; Late Pleistocene; stalagmite; Spain; Stable isotopes.

Acknowledgement: Contribution to Projects CGL2013-43257-R and CGL2017-83287-R (MINECO, Spanish Gov.). Generalitat Valenciana and Ayuntamiento de Jalance are thanked for permissions and support during cave work.

The sedimentary record of fossil elephants: the relevance of the Portuguese aeolianite archive and its environmental and paleoclimatic information of the Last Glacial Maximum

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Abstract: Fossil elephants are present in the sedimentary record of Portugal since the Miocene. There are several remains of Pleistocene elephants in paleontological and archaeological sites (Sousa & Figueiredo, 2001; Figueiredo & Sousa, 2003; Figueiredo, 2012). These occurrences of *Palaeoloxodon antiquus* in Portugal, indicate that since Middle Pleistocene until ca. 31 ka, indicate that this species survived on interglacial and glacial periods, as well as the actions of primitive humans. Here we describe fossil occurrences in coastal aeolianites from the upper Pleistocene of SW Portugal, with trackways, tracks and trampled surfaces of the last elephants in mainland Europe (Neto de Carvalho, 2011; Neto de Carvalho et al., 2016). The aeolianite unit under study has a probable age of c. 32 to 12 ka. The elephants tracks mainly occur at the lower stratigraphic levels of this unit (Fig. 1 - Left) and are under dating by optically stimulated luminescence. During this interval, the fast-changing, cold and dry climate conditions in Portugal (e.g. Cunha et al., 2012) promoted very strong wind dynamics that generated a widespread cover unit of aeolian sands and a drastic decrease of vegetation. This change in environmental and paleoclimatic conditions could explain that the last records of fossil elephants are progressively younger to the south of Iberia, in particular the disappearance of *P. antiquus* in Portugal (the last records at SW). During this period is not expected there were land communications to allow migration to southern (to Africa), from the Iberian Peninsula. The interpretation of the sedimentary record also allows to make some environmental interpretations. The straight-tusked elephants may have travelled along a N-S coastal route controlled by the vigorous relieves of Serra do Cercal, in order to reach feeding areas located in the lower sectors of Sado and Mira rivers or southernmost latitudes, crossing the dune field to access the flat shore. The trampled interdune at Praia da Ilha and the parallel trackways found some hundreds of meters further south from Forte da Ilha de Dentro, suggest gregarious behaviour while crossing the dune field, eventually looking for protection of the dunes to spend the night or during storms. The tracks were produced in moments when the aeolian sands imprinted were humid and therefore more cohesive. Photogrammetric 3D modelling (Fig. 1 - Right) and analysis of the relevant proboscidean track levels allowed revising and supporting previous ichnotaxonomic identification to *Proboscipeda panfamilia* and behavioural interpretations for the producer. Smaller and very large trackways and footprints, attributed to *P. antiquus*, are described and discussed according to new findings.

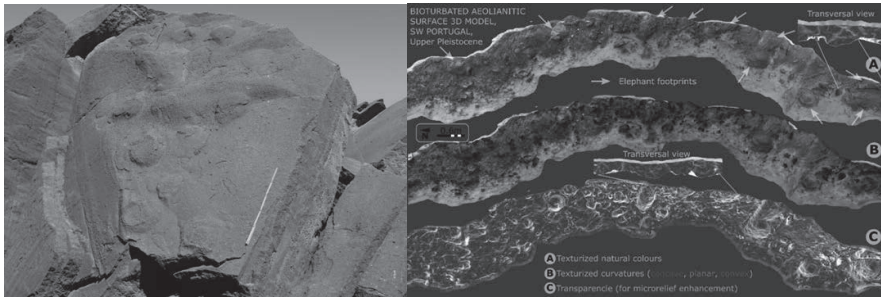


Fig. 1 – Left: Fallen boulder of aeolianite at Praia do Malhão with footprints of *Proboscipeda panfamilia* organized in three parallel trackways suggesting gregarious behavior; Right: An example of the 3D model of the aeolianite bioturbated sole bed at Forte da Ilha de Dentro, showing an elephant trackway together with other footprints produced by animals walking parallel to the dune front.

Keywords: *Palaeoloxodon antiquus*; SW Portugal; Trackways.

Acknowledgments: This research was part funded by the Fundação para a Ciência e a Tecnologia, through projects, UID/GEO/04683/2019—ICT (SF), UID/MAR/04292/2019—MARE (PPC). This research was also funded by Câmara Municipal de Odemira and Centro Português de Geo-História e Pré-História.

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SECTION 5

TOPIC 5 - CLIMATIC EVENTS AND HUMAN- ENVIRONMENT INTERACTIONS IN THE HOLOCENE

The record of the Holocene environmental changes in the polar and mountain ice cores

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A contemporary vision of nature through geoheritage

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Abstract: “Nature” is a polysemic word which has been used since pre-Socratic times with different senses. “Nature” often refers to geology and wildlife, and excludes in general those things that have not been substantially altered by human intervention, or which persist despite human intervention. Several ongoing initiatives launched by international organizations, like the UNESCO, clearly highlight the role of mankind in preserving the equilibrium on which nature is based (Fig. 1). However, they are essentially sectorial approaches to nature and cultural heritage strongly anchored in disciplinary knowledge rather than in multidisciplinary visions. Such perspective makes difficult to overcome the need of looking at nature in an integrative way in order to understand current and past global changes, an essential tool to predict earth’s future scenarios. In this work it is argued that the emergence of social concerns regarding global changes turns the concept of nature to a dynamic entity and extends its limits to the ancient processes of the earth which have modeled and produced the planet’s current biodiversity and geodiversity. The geological heritage corresponds to expressive representations of earth’s geodiversity over time, and both terms also assume different conceptions among the authors. In the broadest sense, geodiversity includes not only the variety of geological environments, but also the link between people, landscapes and their culture. In this sense, only an integrated approach to the evaluation of the geological heritage of qualitative nature, based on the geoheritage contents displayed by geological elements with exceptional scientific, educational, touristic or cultural value can help to guarantee its integrity and valorization (Fig. 2). This perspective considers that the content of a geological object with heritage value depends on both the relevance of the meaning attributed to the objects by scientific communities (defined as *Relevance Grade*) and the public understanding of such meanings related to the social use of the objects (defined as *Abstract Perceptiveness*). Such an open system of qualification of the geological heritage is independent of any national, regional and/or local legislation on geoconservation, whether they exist or not, and it not only highlights the relationship between bio- and geodiversity, but additionally stresses its connection and inter-dependence with humans.

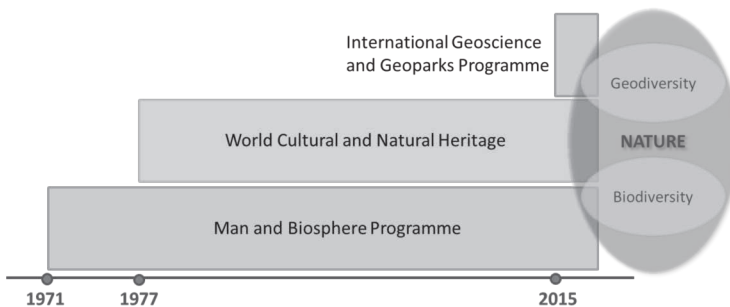


Fig. 1 - The instruments created by the UNESCO since 1971 aiming at preserving nature. While the Man and Biosphere and the International Geoscience and Geoparks Programmes run within the Natural Sciences Sector, the World Cultural and Natural Heritage are managed by the World Heritage Centre, which is the focal point and coordinator within UNESCO and it runs within the Culture Sector (Henriques & Pena dos Reis, 2019).

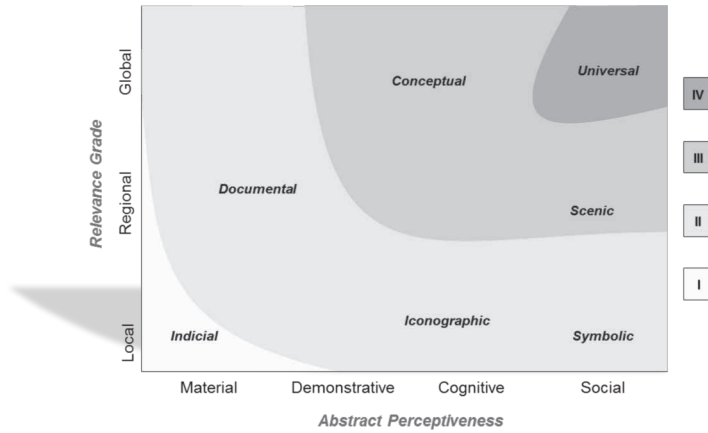


Fig. 2 - An open system of qualification of the geological heritage contents, according to the types of contents of geological objects with heritage value based on *Relevance Grade* and *Abstract Perceptiveness*. Resulting ranks range from I to IV and are bounded by curved lines (Pena dos Reis & Henriques, 2009).

Keywords: Nature; Geodiversity; Geoheritage; Global change.

Acknowledgements: This study was supported by FEDER funds through the Competitiveness Factors Operational Programme - COMPETE and Portuguese funds by FCT in the frame of the UID/Multi00073/2019 Project.

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Contribution of lacustrine sediments to the study of recent environmental changes in the Agalmam Azigza lacustrine system (Moroccan Middle Atlas)

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Abstract: The present work provides a paleoenvironmental study to better understand the recent hydroclimatic functioning of the Lake Agalmam Azigza watershed. The methodology is based on the physico-chemical analysis of the water of Lake Azigza, thus the study of lacustrine sedimentary archives, precisely proxies as the diatoms, and the geochemical analysis of the sediments, which makes it possible to decipher the record of lake's environmental variations during the last decades. The climatic fluctuations of the last decades, that influence the hydrogeochemical and limnological functioning of Lake Agalmam Azigza, involved a significant reduction of the lake level (carrot C2 = 40 cm). This water deficit was accompanied mainly by the decrease in the C / P ratio and the supersaturation of the lake waters in elements responsible for the precipitation of carbonates. Generally, the sedimentation rate shows that the sedimentation mode at Lake Azigza was influenced by the climatic variability during the period of observation. The catchment of the lake has experienced dry periods, which appear to present the dominance of the terrigenous sediments of aeolian origin, in addition to the evolution of the benthic diatoms, which informs about the installation of the pelagic conditions. The increase in the evolution of the central (Fig. 1) diatoms observed in the three cores studied is synchronous with the strong soil leaching of the lake watershed, which was recorded by peaks of elements (⁴⁷Ti, ⁴⁵Sc and ²⁰⁷Pb). At the level of the top part of the series, the decrease in sedimentation rate is mainly due to the limit of surface runoff and permanent flow of all the effluents, in addition to the drought of the springs of catchment.

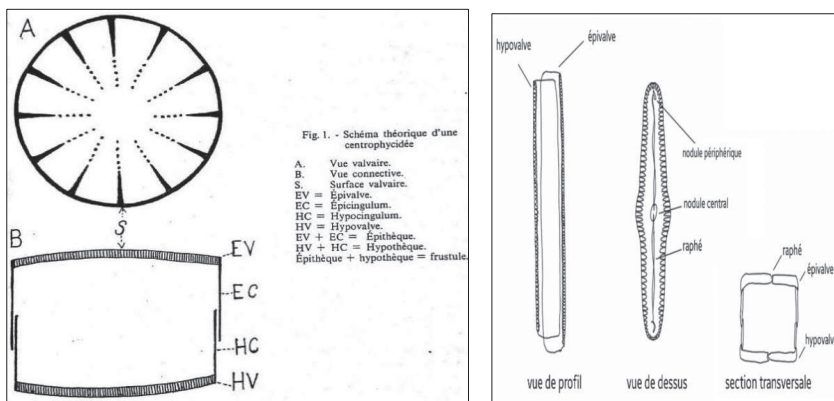


Fig. 1 – Diagram of a *Pennatophycidae* and a *CentropHYCIDÉE* (According to Van den Hoek et al. 1995. *Bacillariophyta*)

Keywords: Lake Agalmam Azigza; Limnology; Physics and chemistry of waters; Sediment geochemistry; Diatoms.

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Cliff erosion susceptibility of Salgados beach (Western coast of Portugal)

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Abstract: A coastal erosion susceptibility study of the rock cliffs of Salgados beach, located 5 km south of the village of Nazaré (Western coast of Portugal), was carried out. The cliffs are affected by erosion processes and landslides which can injure people and perturb and damage the economical and touristic activities. A field survey work was carried out in an extension of approximately 1,000 m, including 12 different stations or cells. The morphological features of the coastal cliffs were characterized. In the studied area outcrop the “Alcobaça Formation” of the Lusitanian Basin, with a Late Jurassic, mostly Kimmeridgian age (Kullberg et al., 2013). The rock cliffs are composed by diverse limestone beds, sometimes marly, oolitic or pisolitic, and marls with coral bioherms and sandstone intercalations (Fig. 1). Two study procedures were established: a procedure to assess rock cliff stability and a procedure related to coastal erosion susceptibility. Various factors were considered in the first procedure: slope length, dip and height, lithology, presence of vegetation, slope movement type, stabilization procedures, slope activity, dimensions, consequences, external and internal cause of slope movements. In the second procedure, seven parameters were considered namely lithology, joint spacing, stratification thickness and orientation, cliff protection and height, swell and current action intensity. A weighting approach to the classification parameters was adopted to study the field survey. The sum of eight parameters allowed the researchers to obtain a weighted total value and to define a susceptibility degree for each of the studied sites. The Schmidt rebound hardness of different lithology was also determined in situ. The most common slope problems are rockfalls, occurring in 2/3 of stations, landslides (Fig. 2) and debris and mud flows. Slope movement can be caused by various external factors. In this study, rainfall infiltration, superficial erosion and costal abrasion were considered to be present in all stations. Schmidt rebound hardness values of lutites, sandstones, limestones and oncolytic limestones range from 15 to 35, from 17 to 23, from 39 to 46 and from 17 to 21, respectively. The cliff costal erosion susceptibility was classified as low, medium and high, for 8%, 50% and 42% of stations, respectively.



Fig. 1 – Rock cliff composed by limestone, marls and sandstones.



Fig. 2 – Landslide failure in Salgados beach.

Keywords: Cliff; Stability; Erosion; Salgados beach; Nazaré; Portugal.

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Climate change and water supply to the people of Huíla Province (Angola)

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Abstract: The present work analyses two climatic variables (temperature and rainfall) in the Huíla Province, Angola, in the past (observed synoptic data for the 20th century) and extrapolated to the future, based on general circulation models (GCM). Climate change is a potential threat to sustainable development. Our work aims to show the trends of climate change in the province of Huíla, SW Angola, and consequences of this variation for the supply of water to the population of the province. The data analyzed were maximum temperatures and rainfall observed in the 20th century (Mitchell et al., 2004). Then, using the MIES / MIROC3.2 general circulation model (Hasumi & Omori, 2004) our variables were extrapolated until the end of the 21st century in four global emission scenarios (Nakicenovic et al., 2000): A1 (energy intensive, stable population); A2 (heterogeneous, traditional world; growing population); B1 (information-intensive, stable population); COMMIT (“blank” identical to present situation). In order to evaluate the dependence of surface water bodies - perennial rivers - and groundwater - phreatic aquifers - with possible variations in the annual rainfall regime, monthly measurements of water level were carried out in Caculuar and Mukufi rivers and in a well, all placed in the urban area of Lubango city, the provincial capital. Comparing the results with the monthly evolution of precipitation it was concluded that: (1) there is a direct link between precipitation and stream-flow in both rivers; and (2) this relationship occurs in the case of the water table, expressing an average delay of about five months. The combination of all analyzed information allowed concluding that, if the forecast evolution of maximum temperatures (Fig. 1) and rainfall (Fig. 2) do happen, in all scenarios, there might be a slight decrease in the pluriennial recharge of water bodies, naturally expected to occur in the shorter term for surface water and middle- to long-term for groundwater. However, extrapolation based on GCM allows foreseeing that the uptake and water supply to the city of Lubango should be secured to the end of the century.

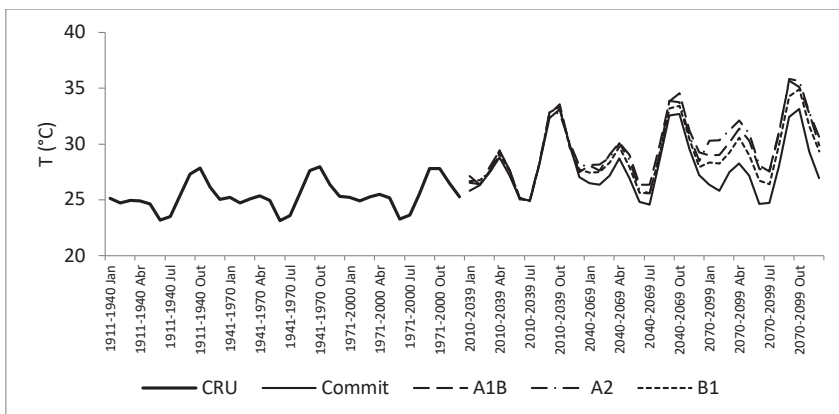


Fig. 1 – Past (CRU) and forecast evolution of maximum temperatures in the Huíla Province according to four different climate models (see text for brief explanation).

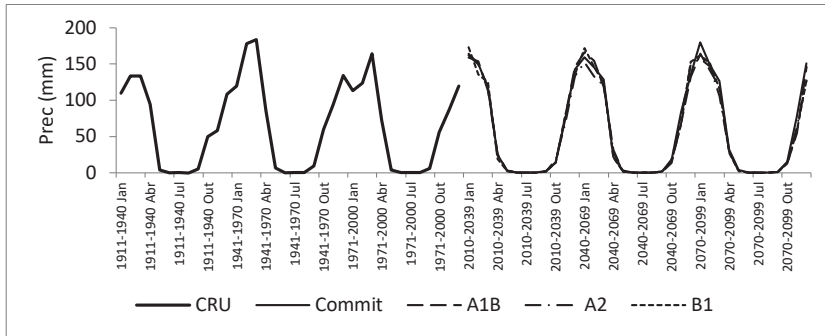


Fig. 2 – Past (CRU) and forecast evolution of precipitation in the Huíla Province according to four different climate models (see text for brief explanation).

Keywords: Hydrology; Climatology; Water supply; General Circulation model; Angola.

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Climatic and hydrological change during MWP/LIA transition – implications for human settlement in the river valley

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Abstract: Palaeoenvironmental studies of moats are rarely undertaken. However, the deposits of wet moats are similar to small palaeochannels and shallow lakes' littoral, and can be examined with the use of multi-proxy studies. The research of Rozprza ring-fort in Central Poland is one of the first detailed studies on the development of a moat system in the context of anthropogenic and natural changes from the Late Middle Ages to the Modern Times. The ring-fort settlement covers termination of Medieval Warm Period (MWP) and the onset of Little Ice Age (LIA). The ring-fort is located in the medium-size Luciąża River valley. It functioned as a seat of a noble family from the mid-14th century AD, in the form of motte-and-bailey. The motte was situated on the surface of a low sandy terrace remnant, protected by the surrounding swampy areas of valley floor with narrow river channels and oxbows. The geophysical data established the presence of both the main ambient moat and a second, additional, trapezoidal moat (F2), which surrounded the inner ring-fort's bailey (Kittel et al. 2015). The sediments from F2 moat were investigated with high resolution for Chironomidae, Cladocera and plant macrofossils, as well as geochemical composition. Both moats are filled with organic (gyttja and peat) and partially inorganic deposits containing remains of wood constructions (Kittel et al. 2018). The F2 moat was created during the early LIA (1453-1645 AD cal 14C), when human communities in Europe generally moved from the river valleys to the higher elevated areas. Hydrological and microclimatic conditions in Luciąża valley remained favorable for human settlement for a long time after MWP. However, the Chironomidae communities indicate at least one exceptionally wet event during F2 functioning. In the sediment record the overbank episode is present, what might influence the settlement conditions. Both Chironomidae and Cladocera analyses revealed two stages of moat development. In the first stage the sediment- and macrophyte-associated taxa are abundant. They indicate fully aquatic, eutrophic conditions and ample macrophyte vegetation. In the second stage, only occasional subfossils are recorded. This may be a signal of the climate humidity and/or human activity in the motte. Geochemical analysis and the climatic reconstructions based on palaeobotanical data support the results of the archaeological investigation. The research project has been financed by the grant from The National Science Centre based on the decision No. DEC-2013/11/B/HS3/03785.

Keywords: Little Ice Age; Moat; Chironomidae; Cladocera; Multi-proxy study.

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Climatic events in the period 6300–3700 cal BP recorded in two peat profiles from Western Pomerania (N Poland)

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Abstract: Peat profiles from two neighbouring sites - Wrzeźnica (W/1) and Noslin (N/1) in NW Poland, were analysed for pollen and non-pollen palynomorphs (W/1 and N/1), macrofossils (W/1) and Cladocera (W/1) with the aim to reconstruct past hydrological fluctuations in both mires. The mires differ with respect to the geomorphological situation and a source of water alimentation, thus it was interesting to see if at least some of the recorded wet/dry shifts co-occurred in both sites. In the period c. 6300—5600 the water table was rather high but unstable in both sites. Strong fluctuations were recorded for the period 5600—5200 cal BP what coincides with the cooling episodes reported from many sites in Europe. After 5200 cal BP the ground water dropped in both sites: in Wrzeźnica a fen developed, while in Nosalin ombrogenic peat-bog plant communities expanded. The results of pollen analysis (including several microfossil taxa representing fungi and some testate amoebae) obtained for a sequence of the ombrogenic peat in Nosalin, point to several dry and wet shifts. According to the medians calculated from the OxCal model for the Nosalin profile, the dry shifts occurred approximately at 4750, 4670—4500, 4250—4150 and 3870—3770 cal BP. The wet shifts have been dated to approximately 4850—4800, 4660, 4420, 4250, 4100—3950 and 3700 cal BP. Considering all the reservations connected with the precision of such calculated dates, we would like to underline that our data just illustrate strong climate variability within the period. However, it is intriguing that the age of some of these shifts (e.g. wet shifts at c. 4850 — 4800 and 4100 — 3950) coincides well with the results from other studies where the age for the hydrological/climatic events was calculated in a similar way (Fig. 1).

INTERNATIONAL MEETING OF PALEOCLIMATE:
CHANGE AND ADAPTATION

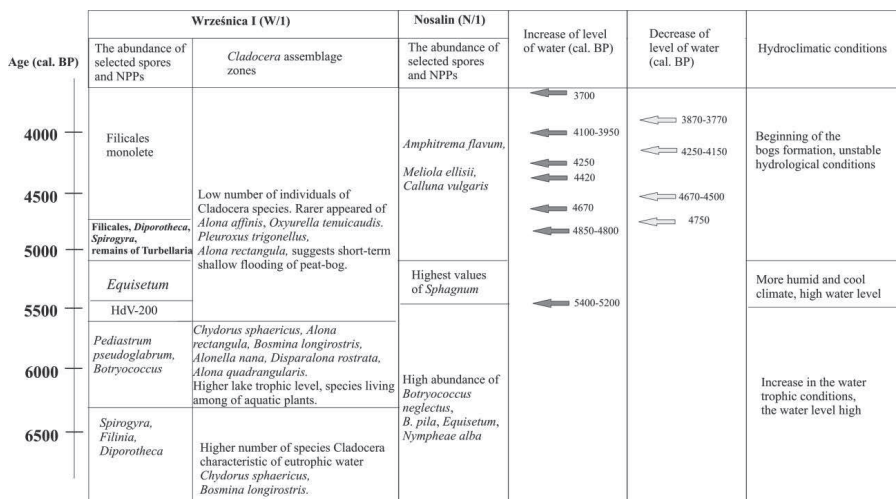


Fig. 1 – Comparison of the palaeohydrological record in Wrześnica and Nosalin mire with palaeoenvironmental changes recorded in mires and lakes of Poland and Europe and global signals.

Keywords: Climatic events; Palaeohydrology; Plant macrofossils; Non-pollen palynomorphs; Cladocera analysis.

Engineering challenges from climate changes

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Abstract: Modern societies rely on a large number of engineering infrastructures that are essential to the economy and wellbeing of citizens. The change in the climate patterns are creating new challenges. Two crucial topics will be focused: global warming and sea level rising. Global warming is creating droughts and floods, more often and more intense than previously experienced. The mitigation of the droughts effects requires efficient solutions, as the lack of water is critical not only to humans, but to all life on earth. Wildfires are another problem triggered by droughts and temperatures rise. The reduction in the consumption of water and its rational use can help to mitigate the problem, but little can be done when there is no water at all. The engineering solutions to increase the availability of water include the construction of dams and artificial water reservoirs (Fig. 1), requiring a major coordination between the populations, the river management and the environment authorities. The construction of dams or reservoirs requires large investments, the availability of suitable places and large amounts of construction materials. Water must also be piped between the reservoirs and the consumption areas. Complementary solutions would include the increase of water infiltration to recharge underground aquifers, the opposite of what happens in most cities where impermeabilization is the rule. The desalination of water, in areas close to the sea, is another possibility. As climate changes also produces unpredicted large floods, associated to extreme climate events, like hurricanes, cyclones or strong storms, the construction of dams also helps to minimize the peak flood and store water for scarcity times. Large floods have now a shorter recurrence interval than previously observed, creating uncontrollable damages to most engineering structures. Dams, bridges, roads, and aqueducts are destroyed (Fig. 2), isolating populations. Power supply is destroyed or interrupted. Sewerage systems are easily flooded, dispersing untreated effluents to the environment, contaminating the drinkable water, being the origin of infectious diseases. The recent floods created by the cyclone Idai and the cholera spreading in Mozambique are a dramatic example of this future, but already present huge problems. The sea level rising conjugated with strong storms, is another well-known problem, as most of the world population lives quite close to the sea level (Fig. 3), or even below sea level, in a few cases. The New Orleans flooding during the hurricane Katrina (category 5) caused an unprecedented destruction with the loss of more than 130 000 homes and 1500 lives in New Orleans. The damages reached 125 billions of dollars (Knabb, 2005). The engineering effort to protect endangered cities must rely on strong and higher levees, complemented by massive water pumping systems to avoid flooding. Alternatively, the relocation of large populated areas could be done, but the costs are incommensurable. The destruction of old cities also destroys their history and heritage. The current design of engineering and hydraulic structures is proving to be unsuitable, and new, more demanding standards based on previously unforeseen conditions, are required for a safer future.



Fig. 1 – Dams and artificial water reservoirs.



Fig. 2 – Road and aqueduct destroyed by unusual flood.



Fig. 3 – Low level large city vulnerable to sea level rising.

Keywords: Engineering structures; Floods; Droughts; Sustainable development.

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Environmental scenarios and prospects for the "pre-historical coast" of the northeast Brazil

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Abstract: Coastal zones configure highly dynamic environments. Coastal occupations cannot be understood without taking into account environmental and paleoenvironmental aspects of their development over time. Based on this perception, the present study is developed seeking to understand the relationship between the evolution of the coastal landscape of the Brazilian Northeast and the processes of formation and archaeological site transformations in the region. From this perspective, we start with the following questions: how have the coastline variations built and altered the different scenarios of human occupation and how can they affect the conservation of the archaeological heritage and the natural patrimony that is now known to constitute it? To advance in this understanding, the studies are being carried out in a smaller geographic cut, focused on the coast of the state of Sergipe (Fig. 1). Studies of geological photointerpretation and geomorphological analysis, associating remote sensing images, contribute to define the evolution of coastal strands and coastlines over time. After this analysis, the field and laboratory works are developed, with the purpose of detailing and integrating results, involving the paleoenvironmental and paleogeographic reconstruction related to the prehistoric occupation of the region. In parallel, a study of the current morphodynamic processes in the study sites will be carried out to understand the risk of destruction of the area's archaeological and geological heritage. Thus, the stretch of the coastal plain studied in this research will be classified according to the risk degree of destruction of archaeological sites, which will be one of the first initiatives in this direction in the national territory. Finally, with the obtaining of this information, a proposal will be made for the geoconservation of the studied deposits, which will also cover the conservation of the cultural patrimony in them. Thus, the use of public policies and the engagement of the resident community in the surroundings of the archaeological sites and geological repositories researched, will be used to elaborate a geoconservation project. One of the main lines to follow is the practice of dissemination and enlightenment activities with the community, before and after the work, in addition to exchanging experiences, different paradigms for the visualization of the cultural and natural heritage studied. The achievement of satisfactory results will make possible the replication of the methodology developed during the research in other stretches of the Brazilian northeast coast. The studies are being developed by the PROGEOLOGY laboratory of the Federal University of Sergipe and have support from the research group of the same university, Archeology of the Atlantic World (AMA).

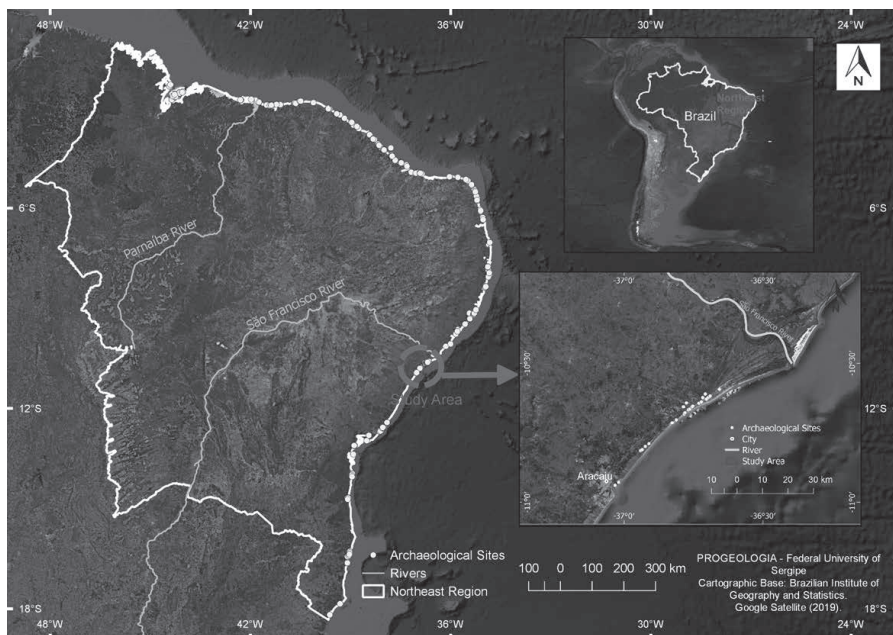


Fig. 1 – Archaeological sites in the Northeastern Brazilian region with indication of the studied area at Sergipe State, close the São Francisco River Mouth.

Keywords: Geoarcheology; Geoconservation; Paleoenvironments.

Environmentally induced rise and fall of societies in Central Asia in the first millennium AD

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Abstract: The ancient societies of Central Asia developed under the influence of favourable conditions in the natural environment that may have existed in these areas in previous millennia in contrast to modern semi-arid and arid climatic conditions. The abundant water supply and fertile loess soils, which are common on piedmonts of the Tian Shan and Pamir-Alay Mountains, played a key role in the development of the agricultural and urban civilizations in this part of Asia. Loess deposits and associated settlements were crucial for the development and functioning of the Silk Road, which crossed the Central Asia (Owczarek et al., 2018) (Fig. 1). Climate change during the first millennia AD, along with human impacts such as deforestation, intensive agriculture and increase of erosion processes, influenced the rise and fall, and in some cases even the emergence of new settlements, in this area. Archaeological data and climate proxy (e.g. tree-ring data, lake sediments, speleothems deposits) allow to trace the causes of these socio-environmental changes. Examples of the close relationship between favorable environmental conditions and social changes may be the ancient rich cities of the Niya, Loulan and Panjikent. Niya and Loulan were located on the edge of Taklamakan desert (Fig. 1). Both of the cities were developed on the basis of irrigation of loess soils on the terraces of the Niya and Tarim Rivers. These rich cities lost their importance after the 2nd century AD, due to long-term drought and shifting and drying of river channels and lakes, and were completely abandoned by the early 5th-7th century (Mischke et al., 2017). Another example of the adaptation to climate change is the town of Panjikent located on loess patches in the piedmont of Pamir-Alay Mountains along the Zarafshan River (Fig. 1). This town, erected along the Silk Road in the 5th century, by the end of the 7th century was the most important urban settlement in this part of Central Asia (Grenet and de la Vaissière, E., 2002; Marshak, 2003). The development of this town was strongly related to the moisture climate and agricultural development based on fertile loess soils (Owczarek et al., 2018). This ancient town was abandoned in the 9th and 10th centuries. Its fall was associated with a political crisis connected with Arab conquest in 722 AD with shift to a drier climate in the 8th-9th (Owczarek et al. 2018; Opala-Owczarek and Owczarek, 2019). An important factor to reduce the role of the city and its collapse was decline in natural and agricultural resources due to human impacts and the soil erosion. The presented data show close relationship between human adaptation to climate change in the first millennia AD in Central Asia. Growth and fall of ancient societies were connected not only with natural environment benefits or disasters but also with human-induced negative landscape transformation.

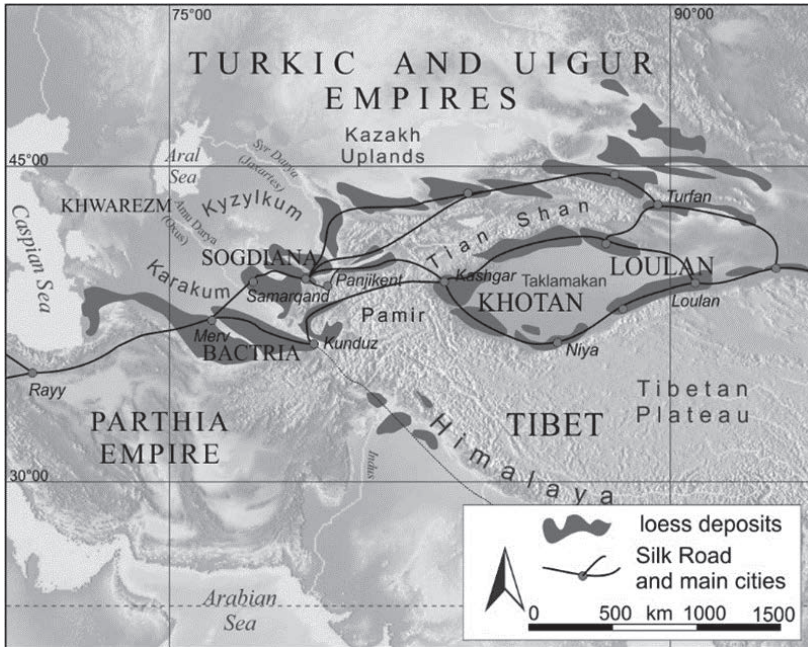


Fig. 1 – Map of loess and loesslike deposits in Central Asia with the locations of the Silk Road branches on the background of political (ca. sixth century AD) and key physiographic units (modified after Abazow 2008; Owczarek et al. 2018; Owczarek and Smalley 2018).

Keywords: Central Asia; Loess deposits; Climate change; Social growth and decline.

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Holocene palaeoenvironmental records in the Lower Tagus Valley (Portugal)

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Abstract: The Holocene was marked by several climatic, economic and socio-cultural changes. Pollen and non-pollen-palynomorphs analyses of two sedimentological cores from Vale de Cavalos (VDC) and Golegã (GOL) in the Lower Tagus Valley verify that vegetation dynamics reflect the influence of several dry and moist climatic oscillations. This is manifested by forest expansion and decline during the last 10000 years. For the sedimentological sequences studied, the phases in which woodland cover variations were observed correspond chronologically to: 10.0-9.8 ka cal BP, 8.4-8.2 ka cal BP, 7.5-6.5 ka cal BP, 5.5 ka cal BP and 4.2 cal BP for dry phases with forest decline; and 6.5-5.5 ka cal BP, 5.0-4.5 ka cal BP and 2.0 ka cal BP for phases of wetter conditions related to times of forest expansion. The various phases of diminishing or relative expansion of forest area coincide with known climatic events and cycles described for the Holocene. Vegetation records show evidence of indicators of agricultural and pastoral practices since 7000 cal BP, although the main anthropogenic impact on the landscape occurs after circa 5000 cal BP.

Keywords: Palynology; Vegetation evolution; Climate changes; Holocene.

Megadroughts and political changes in western Central Asia and Mongolian Plateau over the past 1000 years as revealed by tree rings

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Abstract: Occurrence and duration of drought periods in Central Asia are of great importance in terms of its socio-economic and political consequences (Asimov & Bosworth, 1998). The period of the past 1000 years is particularly interesting, in the context of development of the Mongol Empire. To explain the reasons for the expansions of some empires and the fall of the others, comparison of environmental drivers and the coupled analysis of historical data and natural archives is needed. Understanding long-term drought trends, unfavourable for societies, and their driving forces require reliable records of past drought variability, which are dendrochronological data. To investigate the past climate dynamics we compiled annually resolved, absolutely dated and spatially representative 1000 years-long drought sensitive tree-ring records from Tajikistan (juniper) and Mongolia (pine). We also analysed the impact of atmospheric circulation on precipitation regime changes (Chen et al., 2019). On the basis of performed drought reconstructions, we investigated shifts between exceptionally dry (10th, beginning of 13th, first half of 15th and mid-20th centuries) and wet (11th/12th, end of the 12th, 14th, at the turn of 19th and 20th, and at the turn of the 20th and 21st centuries) periods, which occurred in the area of the western Central Asia (Opała-Owczarek & Niedźwiedź, 2019) in contrast to opposite moisture conditions prevailing over the Mongolian Plateau (Fig. 1). Our reconstructions reveal that changing drought and pluvial patterns significantly impacted on transregional political changes in the Central Asia. An example of the interaction between these two regions was the beginning of 13th century. This period was characterised by the pronounced pluvial conditions in the Mongol Upland and extreme drought in the western Central Asia. Wet conditions favoured the rise of Chinggis Khan, whose hordes relatively easily conquered the rich kingdoms of Central Asia (Khwarezm, Kara-Khanid Khanate), weakened at this time by the scarcity of water. The next centuries show alternately the rise or downfall of societies from Mongolian Plateau and western Central Asia, which was clearly coupled with the shift of the drought periods detected by tree-ring analyses.

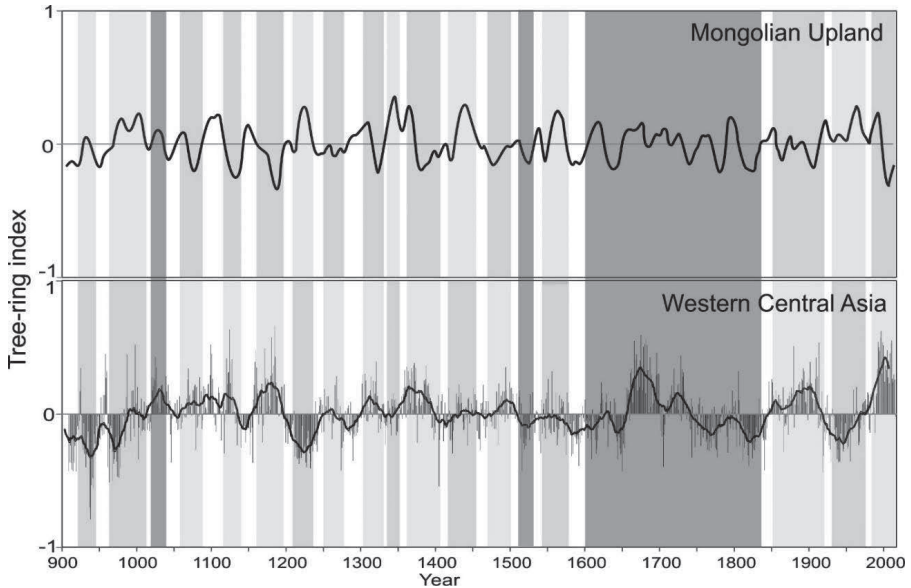


Fig. 1 – Drought (pink) and wet (light blue) periods revealed by tree rings from the Mongolian Upland (source of tree-ring data: Pederson et al., 2014, changed and supplemented) and Western Central Asia (source: Opała-Owczarek & Owczarek, 2019, supplemented). The grey colour shows a slight convergence of the moisture trend for two areas, although the intensity of the pluvial and dry periods is different.

Keywords: Climate change; Dendroclimatology; Drought; Mongol invasion of Central Asia; Last millennium.

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Microclimatic Analysis and Thermal Aging Cycles in the Gypsum of *Risco de las Cuevas* of Madrid (Spain)

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Abstract: *El Risco de las Cuevas* is an archaeological site in a gypsum escarpment, in which cavities have been excavated. This rockwall is in *Perales de Tajuña*, province of Madrid (Spain). The microclimate conditions have been measured with iButtons sensors of temperature and humidity (model DS1923-F5 and software One Wire Viewer version 3.04). The sensors were placed in the rockwall with direction (SW-NE) and were programmed to record data every four hours for one year. In order to analyse the effect of humidity and temperature on the gypsum, three accelerated artificial ageing tests of 24 hours cycles were performed in laboratory for 105 days: The freezing/thawing tests consisted of 17 hours of total immersion in room temperature water (20±5 °C), and 7 hours of freezing at -16 °C. The wetting/drying test consisted of 17 hours in room temperature water immersion followed by 6 hours in a laboratory oven at 50 °C and 1 hour in a dryer for cooling to room temperature. Another accelerated ageing test by wetting/drying was performed, which consisted of cycles of 17 hours in a laboratory oven at 50 °C and 1 hour in a dryer, and complete immersion during 6 hours in room temperature water. The material decay evaluation has been carried out by ultrasound propagation velocity and by means of the control of its weight loss. The temperature changes on the rockwall, which is directly exposed to sunlight, were very pronounced throughout the analysed year. The temperature oscillated between a maximum of 45.5 °C and a minimum of -2 °C. The greatest thermal variations in the same day occurred in winter: 38.6 °C difference between night and day. The lowest was during the summer, 29.5 °C. The thermal difference averages for a day ranged between 20.2 °C in autumn, and 16.6 °C in spring. Changes in temperature of the rockwall produce important natural cycles of wetting/drying and freezing/thawing on the gypsum. The results of the laboratory ageing tests have determined the gypsum response to cyclical changes in temperature and humidity. Although the deterioration process takes place in different ways, water plays an important role in each one of them. The clay mineral content of the gypsum rocks (illite, smectite and caolinite) was the key factor that determined the decay. The freezing/thawing test was the most aggressive ageing test, with the fastest material loss and highest reduction of ultrasound velocity of the samples. The knowledge of environmental conditions in the present makes it possible to infer the use that these cavities had in the past, as well as the magnitude and frequency of phenomena affecting deterioration processes.

Keywords: Gypsum; microclimatic analysis; archaeology

Past and present climate variations recorded by subsurface temperature; an example from Northern Québec (Canada) and its geothermal implications

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Abstract: Climate events affect the Earth's near-surface temperature. Such perturbations propagate downward by thermal diffusion over a time period of million years, influencing the crustal temperature. Temperature profiles measured in boreholes keep a record of these climate events, which have to be considered when modeling the deep crust temperature to adequately evaluate geothermal resources. Several surface temperature changes occurred in Canada during the Quaternary period. The territory was covered by the Laurentide ice sheet during the last four glaciations. Climate optimum was experienced during the Holocene thermal maximum and the Industrial Revolution. Recently, the subsurface temperature has been increasing due to recent global warming. The averaged undisturbed ground temperature at a latitude of 55° in northern Québec is estimated near -1 °C according to Kuujjuaq climate normals 1981-2010. However, temperature profiles measured in northern Québec point to a sharp increase of this temperature of about 2 °C since the beginning of this millennium. The impact of the past and present climate variations on the geothermal gradient and heat flow was evaluated for temperature profiles measured near Kuujjuaq (Northern Québec, Canada), in the scope of geothermal resource evaluation. The temperature profiles were acquired in three shallow boreholes (80 – 120 m). Two of them are located in the Labrador Trough while the other is near the town of Kuujjuaq. The harmonic averaged thermal conductivity measured on samples from the three wells revealed values ranging from 2.4 to 3.0 W m⁻¹ K⁻¹. The geothermal gradient estimated based on the temperature profiles ranges from 9 to 12 °C km⁻¹. The resulting surface heat flow varies from 21 to 28 mW m⁻², when applying Fourier's law of heat conduction. However, due to the aforementioned surface temperature variations, these uncorrected values can underestimate the geothermal gradient that prevails at depth. A numerical inversion approach using COMSOL Multiphysics was applied to correct the heat flow for the described climate events. Based on this solution, the heat flow increases to 38–46 mW m⁻². An underestimation of the surface heat flow can impact the assessment of deep geothermal resources. Assuming the uncorrected heat flow in Kuujjuaq, the calculated temperature at depth is not of economic interest (37 to 52 °C at 5 km; Fig. 1). However, when performing the paleoclimate correction, the temperature field at 5 km is now estimated to be about 72 to 92 °C (Fig. 2). A high uncertainty remains because only shallow boreholes were available for the area. However, the results of this work highlight not only the importance of carrying out corrections for paleoclimate in geothermal research, but also how geological formations can keep a record of the surface climate events.

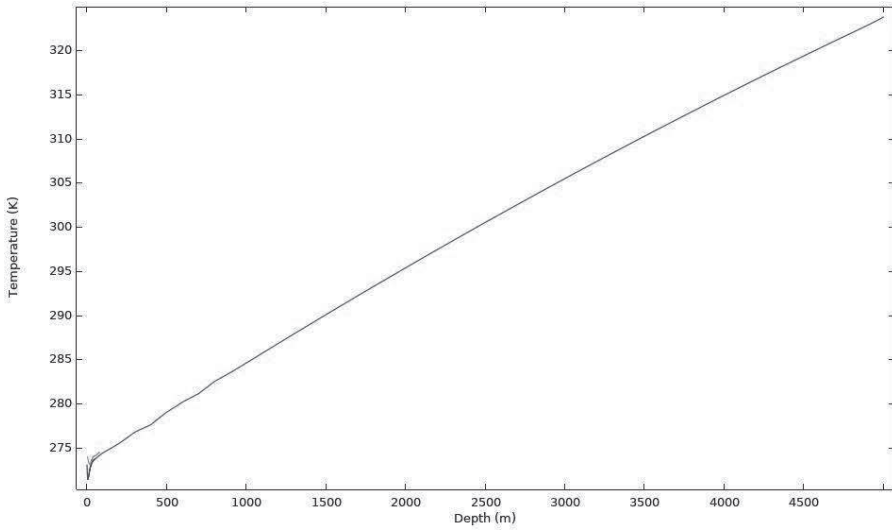


Fig. 1 – Numerical simulation of the temperature field at depth assuming an uncorrected heat flow of 28 mW m^{-1} . At 5 km the temperature is 325 K (= $52 \text{ }^\circ\text{C}$).

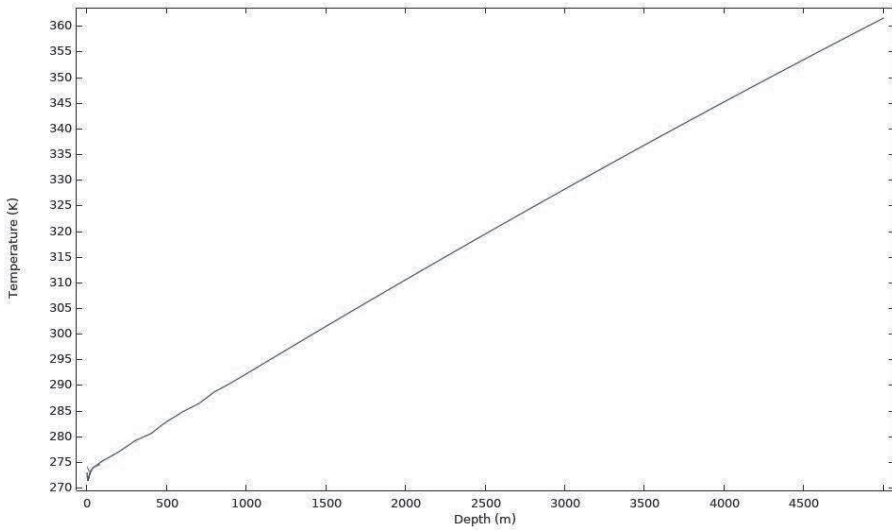


Fig. 2 – Numerical simulation of the temperature field at depth assuming a corrected heat flow of 46 mW m^{-1} . At 5 km the temperature is 365 K (= $92 \text{ }^\circ\text{C}$).

Keywords: Paleoclimate; Geothermal gradient; Heat flow; Geothermal energy; Nunavik.

Saharan dust fluxes in northern Iberia during the Middle to Late Holocene revealed by speleothem Sr-isotopes

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Abstract: Strontium isotope geochemistry is a useful and versatile tool in diverse geology fields. In speleothem-based paleoclimate research, the ⁸⁷Sr/⁸⁶Sr ratios measured in the appropriate samples can yield key information about past atmospheric conditions not provided by other geochemical proxies such as stable isotopes. Since no fractionation occurs during speleothem calcite precipitation, the Sr isotope ratios measured in the carbonate mineral reflect the Sr isotopic composition of cave waters, which in turn depends on the different Sr sources in the karstic system. Among these sources are the host-rock, the soil above the cave, and the atmospheric air, which transports dust from distant areas as well as sea spray. Given that each of those sources can show a distinctive isotopic signature, the speleothem isotopic composition will reflect the mix of the sources, and changes in this composition through the speleothem stratigraphy will reflect changes in the sources. As those changes derive essentially from climate variables such as rainfall, wind and temperature, the Sr speleothem record can be used as a paleoclimate proxy of these variables. In this work we present and analyze the Sr isotope record yielded by a Middle to Late Holocene stalagmite (radiometrically-dated as 5000 to 900 years BP). The stalagmite was retrieved from Kaite (Ojo Guareña Karst Natural Monument, Burgos province) a cave located in the south-central part of the Cantabrian Mountains, in northern Spain. In order to understand the Sr isotopic record through those four millennia, a specific monitoring program have been carried out for Sr-isotopes in the cave system, which includes Sr isotopic characterization of rainfall, modern speleothem calcite precipitates, cave drip waters, soil and the Upper Cretaceous dolomitic limestones that form the cave host rock. The results allow the characterization of the Sr-isotope composition of the speleothem and the changes occurring through its chronostratigraphy. The main sources of Sr and their relative influence through time lead us, among other aspects, to the reconstruction of the changes in the Saharan dust influx to northern Iberia during those millennia (Fig.1). The results are framed within the climate dynamics of the North Atlantic – Mediterranean area as well as the climatic evolution of Iberia during de Middle to Late Holocene transition. Special emphasis is paid to changes occurring between 4000 and 2000 years BP.

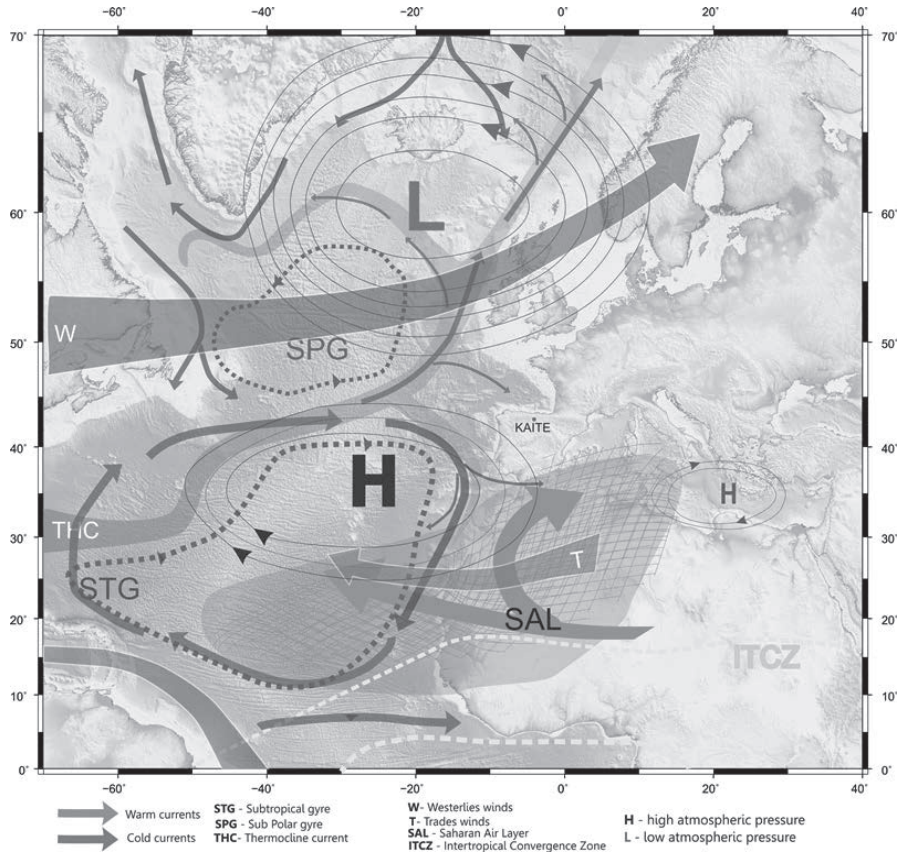


Fig. 1 – Map showing the localization of the study area, Kaite cave. Present-day oceanographic and atmospheric circulation (under the positive NAO mode) is represented, as well as the main dust-transporting winds.

Keywords: Paleoclimate; Holocene; Speleothem; Spain; Sr-isotopes.

Acknowledgement: Contribution to Projects CGL2013-43257-R and CGL2017-83287-R (AEI, Spain) and to research group 910198 of the UCM. We thank Junta de Castilla y León for permissions and Grupo Espeleológico Edelweiss (GEE) for support during cave work.

Temperature changes at the Atlantic margin land from 1860

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Abstract: The Portuguese continental territory is located on the eastern North Atlantic margin, where a W-E atmospheric circulation combined with a dominant N-S oceanic current creates an open wide system, strongly controlled by the oceanic heat distribution. Temperature data are of major relevance to assess regional changes in the region since the mid-1800, when systematic instrumental records began. A strong correlation between the atmospheric CO₂ concentrations and the temperatures since the beginning of industrial revolution is currently admitted. Nevertheless, this idea is controversial if one considers the published data and a background steady nonlinear increase in CO₂ since the nineteenth century with. The nonlinear rise of the CO₂ concentration reflects the sum of industrial emissions contribution and the natural background increase, which run at least, from the eighteenth century. This non-anthropogenic concentration increase is similar to the slow and regular temperature rise (0.5 °C/100 years in average), recorded in many places including Portugal. The data set published by the IPMA-Portuguese Institute of the Sea and Atmosphere (Fig. 1) shows, for different Portuguese cities from North to South, a yearly average temperature variation since 1860. The plotted data of the figure show a temperature increase rate of 0.74 °C/100 years. Positive anomalies are detected around the 19-20 centuries boundary, close to 1930, and during the 40-50 and 80-90 decades. There is a small and steady temperature increase, without any visible tendency change, during the last 50 years, when compared with the previous 90 years that was eventually caused by the CO₂ concentration increase as a result of industrial activity. The recorded temperature rise pattern does not reflect any clear change from the second half of the twentieth century, when there was a significant increase in anthropogenic emissions of CO₂. This evidence can be due to: 1 – The recorded temperature rise do not depend significantly on the increasing anthropogenic emissions; 2 – The recorded temperature rise follows a long-scale variation pattern that is not related to CO₂ concentrations.

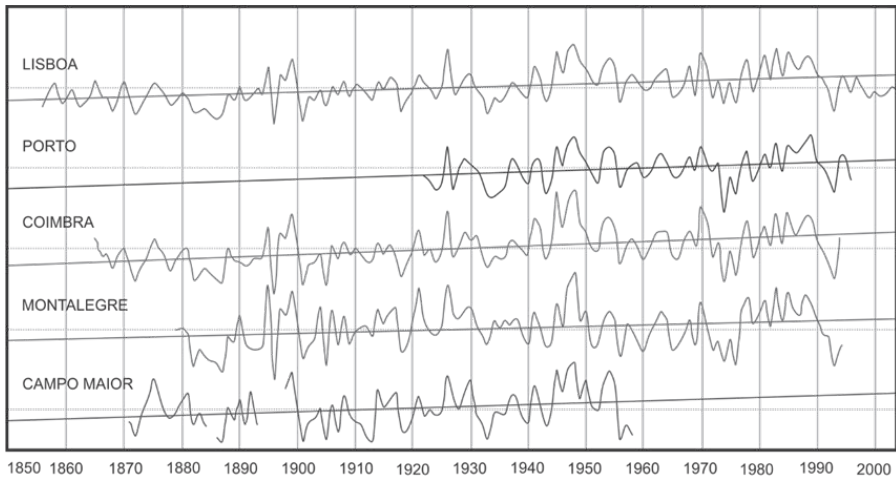


Fig. 1 – Portuguese Institute of the Sea and Atmosphere (IPMA) data set of yearly average temperature variation for different Portuguese cities.

Keywords: Instrumental record; Temperature Changes; Positive anomalies; West Iberian.

Acknowledgments: This study was supported by FEDER funds through the Competitiveness Factors Operational Programme - COMPETE and Portuguese funds by FCT in the frame of the UID/Multi00073/2019 Project.

The HISTIGUC Project: studying the meteorological, geomagnetic and seismological data and history heritage

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Abstract: The Meteorological and Magnetic Observatory of the University of Coimbra (OMMUC), created in 1864, and later renamed Geophysical Institute of the University of Coimbra (IGUC), was one of the first university institutions in the country to establish a continuous program of geophysical observations. Its founding and flourishing is a good example of the efforts of the Portuguese institutions (and in particular of the University of Coimbra) to accompany the accelerated development of European scientific research in the second half of the 19th century, in particular through the establishment of a network of strategic collaborations with leading scientists and observatories. The newly created Geophysical and Astronomical Observatory of the University of Coimbra (OGAUC), which in 2013 aggregated the secular institutions of the Astronomical Observatory (OAUC) and the OMMUC/IGUC, inherited a unique and scientifically valuable collection (in Portugal and in the world) of long series of solar, meteorological, geomagnetic and seismological data, which has an indispensable value in the current geophysical and climatic studies. As a result of 150 years of observations and research, the collections of geophysics scientific instruments of the OMMUC/IGUC are among the most complete and significant in Portugal, their relevance being recognized internationally. In order to study the history and the impressive scientific collections of the OMMUC/IGUC a scientific research project was started in 2018 with FCT financial support (PTDC/FER-HFC/30666/2017). The HISTIGUC Project – ‘150 years of the scientific activity of the Geophysical Institute of the University of Coimbra: history and heritage of the Earth and Environment’ – is based on the study of the enormous collection of geophysical data, the massive documentary background and the important collection of historical instruments of the OMMUC/IGUC. One of the aims of the Project is to re-analyze, catalogue and make available the long series of meteorological, magnetic and seismological data, fundamental for the current geophysical and climatic studies. The first meteorological observations at University of Coimbra began about 20 years before the creation of the OMMUC, in the Cabinet of Physics of the Faculty of Philosophy of the University of Coimbra. The OMMUC was inaugurated in 1864, with the meteorological observations. The first observations made were related to atmospheric parameters, and began with tri-hourly frequency on February 1, 1864. However, only in 1870 was published the compilation of the observations made between September 1864 and November 1866. The OMMUC weather station is still in use today. Throughout its history, this station has had few interruptions in data acquisition, which means that OMMUC has one of the most complete series of meteorological data in the country. The original instruments with which it was equipped were a Welsh barometer with a cathetometer (which currently remains installed in its original place), an Adie barometer calibrated by Kew Observatory standards, a portable Fortin barometer, and a Beckley anemograph. There were also a barograph and a psychograph, both of photographic record; a psychrometer; thermometers; a udometer; an atometer; an ozonometer; thermometers for solar irradiance and radiation to space; and thermometers for extreme temperatures on the grass (Fig.1).

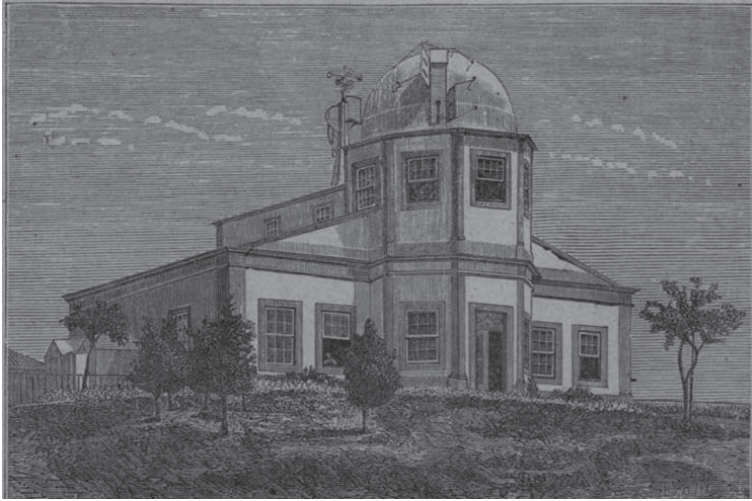


Fig. 1 – The Meteorological and Magnetic Observatory of the University of Coimbra (c. 1860s)

Keywords: Geophysical Institute; University of Coimbra; History of Science; Meteorological data; Yearbooks of observational data.

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Morphological aspects of the São Francisco River (Brazil) in the Sergipan territory and its role in the supply of the sediments to the coast at the south of its river mouth

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Abstract: The São Francisco river has its spring in the county of Medeiros, in the state of Minas Gerais. Its delta in the Atlantic Ocean is situated between the counties of Brejo Grande and Pacatuba, in the state of Sergipe. It has 2,839 km of length and it is used for navigation, tourism, transportation, irrigation, fishing and electricity generation through dams. Its wide basin includes the biomes of the Corral, Caatinga and Atlantic Forest. The Corral vegetation is the second largest biome of the country and it covers about half of the basin, being predominant in the Middle and Upper São Francisco where is located its source. The Caatinga, biome existing only in Brazil, is a typical vegetation of region embracing from the county of Remanso to the Paulo Afonso hydroelectric power plant in Bahia, in the Lower and Middle São Francisco. The Atlantic Forest, predominantly located in the Lower São Francisco, is the most devastated biome. These associated aspects lead to a wide biodiversity in the watershed, resulting from a geodiversity generated by the different geological terrains that are present. During the geologic time, the river in association with the climate contributed to the definition of the different landforms observed in its course and more recently human actions started to affected them also. Therefore it is necessary an integrated perspective so as to better contribute to the preservation of the environments produced by the São Francisco River beyond a more coherent human exploitation of its banks and river mouth. This work investigates the processes recorded in the evolution of the delta of the São Francisco River which has been recognized as developing in different morphological stages, among them: a bay opened, estuary rectilinear and cusped. Regional tectonic factors and sea level variation represent other controlling factors of the evolution of the delta region. The morphodynamic relationships involving the coastal drift, the orientation of the coastline, the bathymetry of the continental shelf and the river discharges over time are highlighted. Anthropogenic actions developed in the last decades have contributed to changes in the natural dynamics at its mouth. Among these actions is the implementation of hydroelectric dams, which caused destabilization along the course of the river with upstream "entrapment" of sedimentary load. The construction of the Xingó hydroelectric plant (Canindé do São Francisco, 1994) at 179 km distance from the mouth, with a 140 m drop, caused the average flows to reach $2000 \text{ m}^3\text{s}^{-1}$ (1996-2002), significantly smaller than the historical average of $2,850 \text{ m}^3\text{s}^{-1}$. Thus the amount of sediment that arrives today to the mouth corresponds to only 10% of the original volume before the construction of the plant. Thus, insufficient sediment supply to the delta results in erosion of its margin and related environmental impacts in the study site (Fig. 1).

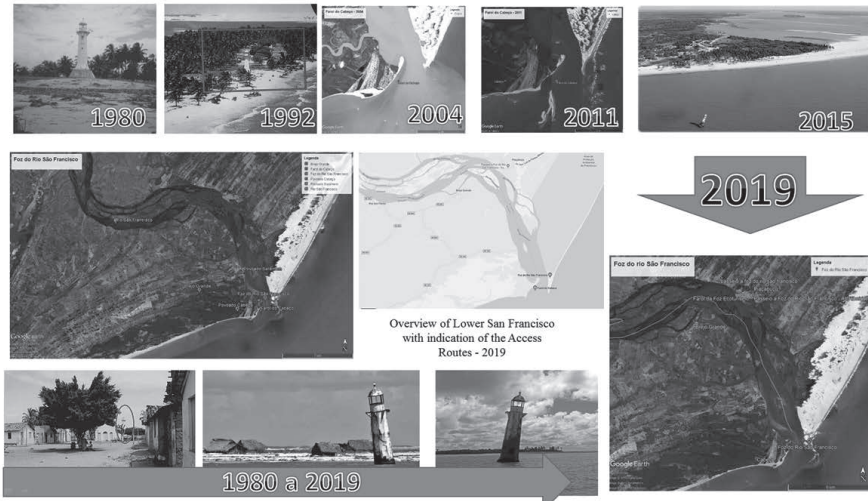


Fig. 1 – Evolution of the São Francisco River mouth showing strong evidences of marine erosion and advancement of the sea on the small Village of Cabeços, from 1980 to 2019.

Keywords: Coastal erosion; Large rivers; Paleoenvironments; Paleoclimates.

The study of the climatic and anthropic impact on the hydrogeochemical functioning of the lacustrine system of Aguelmam Azigza (Moroccan Middle Atlas)

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Abstract: In order to characterize the environment of lake Aguelmam Azigza, using natural archives to discriminate the human and natural impact on the lake's functioning. The Moroccan Middle Atlas contains vital water reservoirs such as Lake of Aguelmam Azigza where lakeside resident directly consume water from the lake, which has been significantly affected by climate change and severe drought, knowing that the lake has a temporary tributaries (North-Est). In fact, these phenomena have negatively impacted the lake and its periphery. There have been some environmental changes (soil erosion, forest recession, etc.) that have affected the human lifestyle and its convenience. These modifications can be recorded by lacustrine sediments that can tell the environmental history of a given place. This study tried to reconstruct the past environmental changes of Lake Aguelmam Azigza. For that, two cores were taken from center the lake, one (C1) measuring 40 cm and the other (C2) 30 cm deep (Fig. 1). Both cores record the different environmental changes. Since 1943 until 2006, the region has experienced wet periods with a significant lake level, materialized by the increase in total organic carbon, magnetic susceptibility and trace elements. The less humid periods are materialized by the decrease of the lake level, the decrease of the total organic carbon, and the decrease of the trace elements (or the rise of the ET, SM and the decrease of the COT that informs on the transport and the erosion wind), The rate of sedimentation is variable, the most important is dated sixties. The analysis of some trace elements (Pb, Sc, Ti, Cu / Sc), reveals a similar variation of the profiles, which makes it absolutely to the natural origin of chemical elements, that means an absence of any anthropic nuisance which could have affected the watershed or the sediments.

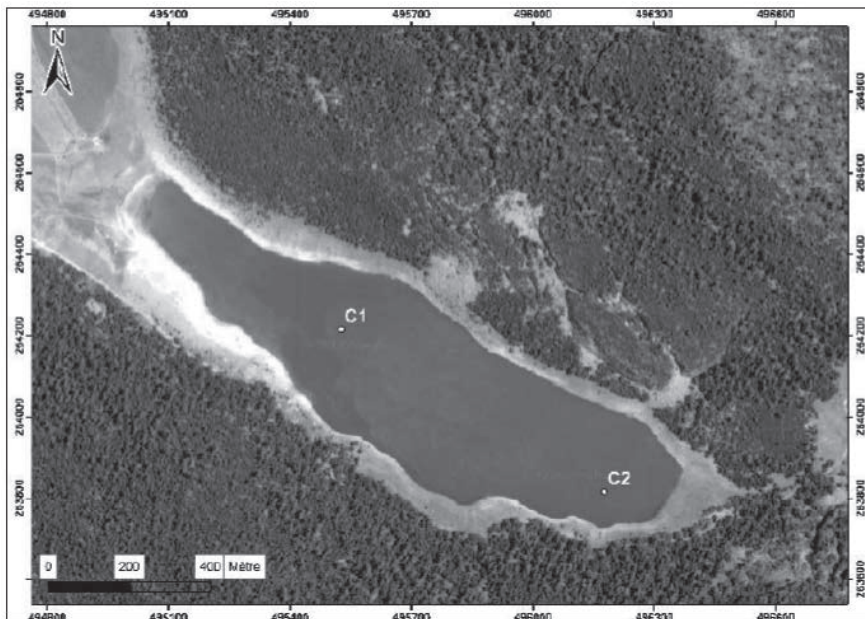


Fig. 1 – Localization of two studied cores.

Keywords: Middle Atlas; Aguelmam Azigza Lake; Hydrogeochemical functioning; Lake's waters; Modern sediments.

Vegetation and human response to Holocene environmental changes in Serra da Capivara National Park (Piauí, Brazil)

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Abstract: The Serra da Capivara National Park, Piauí, Brazil, is known for its biodiversity and important geological and archaeological heritage. In order to understand the paleoenvironmental changes that occurred in this region during the last 12 ka BP, petrographic, X-ray diffractometry, isotopic ($\delta^{13}\text{C}$) and ^{14}C dating studies were carried out on colluvio-alluvial deposits (CAD) and on humic fractions of soil and CAD organic matter. The CAD resulted from weathering and erosion of local paleozoic detrital sedimentary rocks that can be found in the studied archaeological sites of Toca da Ema do Sítio do Brás I (Ema I) and Toca do Baixão do Perna I (Perna I) (Fig. 1). These rocks were frequently used as prehistoric shelters by human groups, since they yield shallow cave-like natural openings. The texture of CAD is similar in both sites, mainly consisting of sub-angular sand (up to 2 mm), some coarser clasts and a high percentage of matrix (Fig. 1). The CAD contain essentially quartz, quartzite, kaolinite clasts, iron and titanium oxides and coal and, more rarely, muscovite, tourmaline and zircon. There is also a second generation of kaolinite resulting from eluviation/illuviation processes that form capped-type coatings and crusts, leading to clasts cementation (Fig. 1). In survey II/Ema I, at 200 cm, a unit of gravel with about 12 ka BP was identified, suggesting the existence of high competence streams during the Pleistocene-Holocene transition. In the surveys I/Ema I and II/Perna I, the illuviation processes reach depths of 1 m to 1.5 m, but in the survey I/Perna I the maximum concentration of kaolinite occurs at 3 m depth, probably due to its location in an extremely enclosed valley, with conditions to maintain relatively high and constant humidity values over time. This fact is supported by the small variation of $\delta^{13}\text{C}$ values in this site (from -23.06 ‰ to -24.54 ‰), pointing to minor modifications in the vegetation cover during that period (with predominance of C3 plants: trees), while in the surveys I/Ema I and II/Perna I the $\delta^{13}\text{C}$ values show an isotopic impoverishment from ca. 6073 years cal BP to the present time, varying between -24.69 ‰ and -26.48 ‰ and between -20.97 ‰ and -25.86 ‰, respectively. The higher variation of $\delta^{13}\text{C}$ values in the survey II/Perna I (ca. 5 ‰) suggest a vegetation modification, from a cover with C4 plants (grass) and some C3 plants, during the middle Holocene, to a more dense coverage with predominance of C3 plants, in the present, indicating a concomitant climate change from a dry period to a more humid period. The survey II/Ema I stratigraphic data also show the occurrence of dispersed coal layers that are older than 3 ka BP, probably testifying Holocene Thermal Maximum paleofires that occurred during the aforementioned dry period. The impact of these climate changes is observed in the local material culture, specifically in rock art typology, with the disappearance of “Tradição Nordeste” at about 7-6 ka BP, but also by the occupation gap at Ema I site, between 8.1 ka BP and 4.7 ka BP.

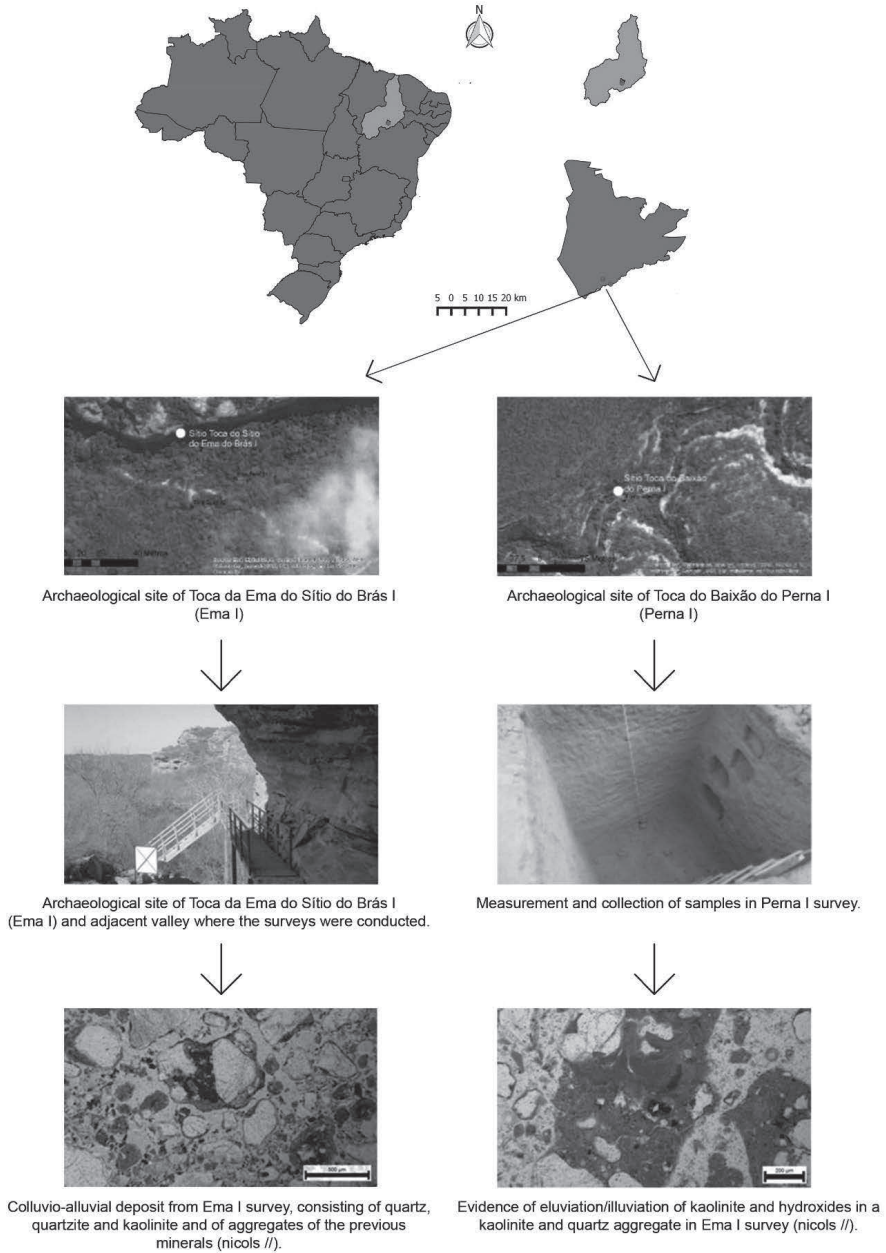


Fig. 1 – Analysed archaeological contexts in the Serra da Capivara National Park, Piauí, Brazil.

Keywords: Holocene; Paleoclimate; Isotopic data; Serra da Capivara; Brazil.

SECTION 6
ROUND TABLE

Climatic change and rock art (Round Table Center Theme)

Hipólito Collado, José Julio García Arranz and Luiz Oosterbeek

| <u>Round Table: Climatic Change and Rock Art</u> | <u>Mesa Redonda: Cambio Climático y Arte Rupestre</u> |
|---|---|
| <p>Climate change is a tangible reality that is exacerbated at times in these last decades. Its effects are tangible in multiple dimensions and among others on the conservation of the Cultural Heritage itself.</p> <p>In this sense, the Round Table "Climate Change and Rock Art", intends on the one hand to analyse the effects that climatic variations have had on the rock art throughout its existence and, on the other hand, to address, from the previous experience, the negative effects that the severe environmental modifications in this last century are exerting for the conservation of the rock art, and through this to generate a forum of debate which may allow to extract conclusions and proposals, in order to alleviate its pernicious effects.</p> <p>Within this objective, two lines of debate are proposed:</p> <ol style="list-style-type: none"> 1.- The relationship between climate change and the changes that are detected in the iconography represented in cave art, both paleolithic and postpaleolithic (species that appear and others that disappear with climate change ...). 2.- The negative or positive influence of climate change on rock art: affections caused by the loss of vegetation cover in areas with rock art, flooding of cavities due to rising water levels, problems caused by drying of supports, appearance of lichens and their uncontrolled growth, disappearance of animal species that acted as prevention of plagues that affect enclaves with rock art, problems caused by the increase in heat and insolation, etc.). | <p>El cambio climático es una realidad tangible que se agudiza por momentos en estas últimas décadas. Sus efectos son tangibles en múltiples apartados y entre otros la propia conservación del Patrimonio Cultural.</p> <p>En este sentido la Mesa Redonda “Cambio Climático y Arte Rupestre”, pretende por un lado analizar los efectos que las variaciones climáticas han tenido sobre el arte rupestre a lo largo de su vigencia y, por otro lado, abordar desde la experiencia previa los efectos negativos que las modificaciones ambientales agudizadas en este último siglo están ejerciendo para la conservación del arte rupestre y con ello generar un foro de debate que permita extraer conclusiones y propuestas con vistas a paliar sus efectos perniciosos.</p> <p>Con este objetivo se proponen dos líneas de debate:</p> <ol style="list-style-type: none"> 1.- La relación entre cambio climático y el cambio que se detecta en la iconografía representada en el arte rupestre tanto paleolítico como postpaleolítico (especies que aparecen y otras que desaparecen con el cambio climático....). 2.- La influencia negativa o positiva del cambio climático en el arte rupestre: afecciones provocadas por la pérdida de la cobertura vegetal en zonas con arte rupestre, inundación de cavidades por subida del nivel de las aguas, problemas provocados por desecación de soportes, aparición de líquenes y crecimiento incontrolado de los mismos, desaparición de especies animales que actuaban como prevención de plagas que afectan a enclaves con arte rupestre, problemas provocados por el incremento de insolación y temperatura, etc. |

Climate change as a destructive agent of prehistoric rock art in the extreme south of the peninsula

Diego Salvador Fernández-Sánchez (University of Cadiz, Spain), José Ramos Muñoz, Hipólito Collado Giraldo, Salvador Domínguez Bella, Antonio Luque, Eduardo Vijande Vila

Abstract: The Strait of Gibraltar constitutes one of the focus with the highest number of enclaves with prehistoric rock art in the Iberian Peninsula. There are at least 300 caves, mostly open-air shelters formed on sandstone, with graphic manifestations ranging from ancient Paleolithic chronologies to the final moments of Prehistory. Among the documented typologies we find hand stencils, points made by fingering, naturalistic and schematic animal figures, sets of schematic anthropomorphs, etc. However, of these 300 caves, less than 10 have real and effective protection measures. In the last decades we have observed a generalized and extremely accelerated deterioration of a good part of the graphic record. In many cases, this deterioration has led to the complete disappearance of the motifs in just a few years. The detailed study of the causes provoking this degradation, puts the spotlight on a series of natural factors that, although they have been present during centuries, have recently been irreversibly intensified by climate change. At the same time, these natural factors interact with each other generating a polygenetic phenomenon of huge magnitude. Two of these natural agents stand out because of their destructive capacity. On the one hand, the relapse of the forest mass of *quercus*, which dominates the vegetation of the area, due to the disease known as “la seca”, has led to the loss of the “protective screen” that until now was an obstacle between the rock art and the wind erosion that originated the rock shelters. The particles of sand and dust in suspension, together with the predominant easterly winds, form a real sandpaper that is literally sanding the walls of the caves and everything contained by them. On the other hand, the thermal contrasts are whipping the panels subjecting them to thermal oscillations that surpass the 40°-50°C (104°-122°F) of difference between summer and winter. This fluctuation causes the cracking of the stone that falls down by gravity. Nevertheless these are not the only elements involved in this process, but they come to join to others such as the depositions of lichens, the acidification of the feces of those animals that see the caves as a refuge from the urban advancement, fires, etc. Nor can we forget the diversity of anthropogenic factors that do nothing but aggravate the already aggressive action of natural factors. It is our aim with this contribution to delve into all these conditions as well as to provide basic data for reflection in the framework of this roundtable. This work is possible thanks to the research project funded by FEDER/Ministerio de Ciencia, Innovación y Universidades-Agencia Estatal de Investigación/Proyecto HAR2017-87324-P, entitled: “Analysis of prehistoric societies (from Middle Palaeolithic to the Final Neolithic) on both shores of the Strait of Gibraltar. Relations and contacts”.

Keywords: Rock art; Strait of Gibraltar; Degradation; Climate change.

Global change, forest fires and rock carvings: towards a preventive management of rock art landscapes

Jose Manuel Rey García (Museo de Pontevedra; Spain)

Abstract: In the northwest of the Iberian Peninsula the rock carvings usually get concentrated in specific areas of the territory, configuring magnificent cultural landscapes which are loaded with significance by the high concentration of prehistoric rock engravings. Nowadays many of these landscapes are severely threatened as a consequence of abandonment or mismanagement of the forest. As a consequence, forest fires have become an endemic phenomenon in Galicia that burn thousands of hectares of forest each year and, therefore, they become the main agent of alteration of the petroglyphs. Available evidences suggest that this phenomenon will be more intense and dramatic, and the Great Forest Fires (GFF) will become responsible for the main catastrophes, contributing with higher percentages to the total burnt area. Keeping in mind that the effects of forest fires on petroglyphs are multiple and cumulative, the answer will be in advancing the preventive management of rock art landscapes. This strategy must consider a multi-proxy approach that contemplates the exhaustive documentation of the rock art through three-dimensional models, the reduction of the combustible load in the vicinity of the engraved panels, the strengthening of the multi functionality of the forest and the elaboration of emergency plans and risk management.

La conservación de la Cueva de Altamira y el impacto del actual cambio climático

Carmen de las Heras Martín (Conservadora y subdirectora del Museo de Altamira, España)

Abstract: La conservación del Arte rupestre en cuevas es una disciplina compleja en términos generales, a la vez que específica de cada yacimiento ya que depende de las condiciones concretas del sitio en cuestión. Altamira, como otras cuevas que han estado abiertas al público, se ha tornado especialmente sensible a cualquier perturbación, incluso de origen natural. La conservación del Arte rupestre requiere del equilibrio de diversas variables ambientales, especialmente de la conjunción de los valores de Temperatura, Humedad y Anhídrido Carbónico con otros factores como la ventilación, la presión, la composición del soporte, el agua de infiltración o de condensación. Con todo, han sido las intervenciones antrópicas las que han generado las mayores alteraciones, que podemos calificar de irreversibles por su alcance. El acondicionamiento para la visita pública, el uso continuado de iluminación eléctrica y la masificación turística han hecho de nuestras cuevas con arte rupestre lugares rotos para siempre al haberse actuado profundamente tanto en el exterior como en el propio medio cavernario. En la actualidad asistimos a un cambio climático cuyos efectos sobre los sistemas kársticos y la conservación del Arte rupestre están por definir. Lluvias torrenciales concentradas en cortos periodos de tiempo pueden alterar el régimen hídrico y el aporte de agua de infiltración; el incremento de CO₂ atmosférico puede generar la acidificación del agua y con ello la disolución de la roca soporte y la disgregación del pigmento; cambios en la Temperatura y en el resto de las variables ambientales pueden producir crisis biológicas de difícil gestión. Se impone el establecimiento de programas de investigación encaminados al conocimiento de las condiciones ambientales y a la detección precoz de las alteraciones. Por otra parte, el desarrollo y aplicación de programas de gestión contribuirá a minimizar los riesgos y a mantener los sitios en las condiciones más próximas al natural, sean las que sean en el futuro.

La estación rupestre de Siega Verde: del Plan de conservación preventiva al Plan de gestión de riesgos y emergencias

Cristina Escudero Ramirez (Coordinadora de la Unidad de Riesgos y Emergencias en Patrimonio Cultural de Castilla y León, España)

Abstract: Enclaves de arte rupestre al aire libre como el de Siega Verde en Salamanca, inscrito en la Lista del Patrimonio Mundial de la UNESCO, presentan motivos grabados en la roca, apenas unos signos en el paisaje del que forman parte, del cual toman significado y al que significan. Estos conjuntos forman parte de un ecosistema concreto y han llegado hasta nosotros en un entorno dinámico, en constante evolución pero –en líneas generales- de lenta evolución. Sin embargo, los problemas detectados se ven acentuados por los fenómenos asociados al calentamiento global propiciando cambios medio ambientales y extremos climáticos: olas de calor de larga duración, sequías asociadas, baja humedad del aire, etc., que junto con el abandono del mundo rural y una deficiente gestión del monte ha aumentado la incidencia y el riesgo de incendios. El patrimonio cultural en contextos forestales se haya en situaciones de riesgo o afectado por incendios sin que exista una conciencia clara sobre el problema. Los incendios no solo lo afectan y destruyen de manera directa e inmediata, también debilitan sus materiales frente a los factores climáticos y las propias operaciones llevadas a cabo para su extinción pueden provocar daños irreparables que podrían ser minimizados; por todo ello es esencial la colaboración entre los organismos encargados de lucha contra incendios forestales y las instituciones culturales. En el caso de Siega Verde, a partir del conocimiento del medio y sus dinámicas se han establecido las pautas de conservación más adecuadas, que pasan por la aplicación de un protocolo de mantenimiento adaptado a los flujos derivados de acciones erosivas propias del paisaje y su interacción con el componente geológico y vegetal. Es decir se ha implantado un plan de conservación preventiva para la protección del arte rupestre ante los agentes de alteración “cotidianos” y acumulativos y un plan de gestión de riesgos y emergencias para poder establecer pautas de prevención, preparación, respuesta y recuperación ante los fenómenos –como los incendios- que de manera súbita o sobrevenida pueden dañar e incluso destruir nuestro patrimonio cultural. Ambos planes parten de la cuantificación riesgo a partir del que se establece el nivel de prioridad de las intervenciones a realizar; el sistema pone de relieve las vulnerabilidades presentes frente a las amenazas existentes, a partir del cual se pueden y deben tomar medidas para que estas no tengan lugar o minimizar su velocidad y virulencia, permitiendo que la actuación ante los factores de riesgo sea de carácter programático.

Recently collected climate data at Coa Valley Archaeological Park: Analysis, trends and insights for rock-art conservation

António Batarda Fernandes (Coa Park Foundation, Portugal)

Abstract: Pre-historic heritage sites can offer significant insights on medium to short term human-time climate trends and shifts. Indeed, the sets of dynamic data, which can be directly or indirectly correlated to different paleoenvironmental contexts, arising from worldwide research allow to compose a global history of climate change and human adaptation to evolving environments. A history that highlights the complexity of how the multitude of intertwined variables interact together. The World Heritage Coa Valley Archaeological Park in Portugal is one of such sites where research carried out since its discovery almost 30 years ago has provided important data that advanced our knowledge on human communities in the region in the past 100,000 years, the emergence of abstract thought as testified by the Upper Palaeolithic rock-art collection, the conservation and management of such an asset, or, of more interest here, present microclimate data and the conservation of prehistoric artistic imagery. In fact, the Park has been collecting climate data comprising a number of variables - temperature, rainfall, solar radiation, wind, etc. - for over a decade. On the other hand, carried out research integrated microclimate trends in the overall regional context also with a view to enhance current understanding of how climate change may affect the conservation of the rock-art (Fernandes 2012). This timely forum is the ideal place to present and analyze weather data collected until 2018, thus upgrading our current definition of discernible climate trends, how they might evolve in the near future, and resulting impacts on the conservation of the Coa Valley rock-art as well as on other sites featuring open-air prehistoric painted and/or engraved imagery.

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Rock Art conservation and climate change: an European view

Ramón Montes (Technical Coordinator PRAT-CARP Cultural Route)

Abstract: No less than 600 rock art sites (caves, shelters, petroglyphs ...) of 160 destinations (in 7 countries) are part of the Cultural Route of the Council of Europe “Prehistoric Rock art Trails / Chemins de l’Art Rupestre Préhistorique” (<https://www.coe.int/en/web/cultural-routes/prehistoric-rock-art-trails>) currently. Its distribution is wide throughout Europe: from Scandinavia to the Iberian Peninsula and from there to the Caspian Sea. The cooperation work of this network allows a basic approximation to several aspects of the daily management of the sites, including the problematic of conservation of the graphic record of the European Prehistory. Different forums and events, as well as direct visits to many of these sites, allow to detect common problems and to know different lines of work in order to stop degradations (both natural and anthropic) and natural processes ongoing that affect the preservation of the first Art of the European humankind, affecting as much to its diverse petrous supports, as to the painted and engraved manifestations. In recent years, a significant decrease in the aggressions derived from vandalism has been detected (although unfortunately there are always cases), but, on the other hand, there is an appreciable acceleration of certain natural processes of degradation, an issue that all site managers are attributing to the environmental changes related to the climate change under way. Three main processes have been registered, quite generally, across Europe: The degradation of the rocks of the sites by extreme and / or sudden changes in climatic conditions. An increase in fires in rural areas with loss of population related with the periods of drought (associated with an increase in the temperature) and the lack of management of forest and vegetation. An enlarged activity of the biological agents (bacteria, lichens ...) possibly promoted by an increase in the average temperature of the regions and important changes in the rainfall regime.

Rock art as evidence: recording and perceiving environmental and climatic changes

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Abstract: Rock art offers two layers of insights into past climate changes: at a material level, it encapsulates evidences of contextual erosive episodes, better studied within conservation studies; at a descriptive and figurative level, it may illustrate past bio-cenosis assemblages and their modifications. Rock art is not a direct representation of the perceived landscape, since it may also stand for symbolic, ritual, aesthetic or other values. However, it offers a sort of “direct contact” with past perceptions of contexts and events, through which we may potentially assess, also, the perceptions on paleo environmental characteristics and change. For instance, the depiction of often exuberant vegetation and the savannah-type fauna in regions such as the Tassili N’Adjer rock art, in Algeria, and the Ennedi Plateau rock art, in Chad, evidences how recent is the current desertification of Northern Africa, after a long period of a Summer Monsoon rainfall regime. Beyond the use of environmental markers, such as pollen, glacier and sediment analyses, for studying paleoclimate, rock art allows not only to assess the cycles of main climatic changes and related environmental modifications, but also to, occasionally, directly associate specific changes to given prehistoric communities. The methods to assess the figurative dimension of rock art require a detailed description, first, and then a cluster of comparative analytics, crossing rock art observed evidences with available paleoenvironmental and paleoclimatic data. The paper presents three case studies where rock art contexts may be related to environmental modifications, triggered by climatic oscillations in the Holocene: the Tagus schematic complex (Portugal and Spain), the Serra da Capivara world heritage complex (Brazil) and the Ebo complex (Angola). The Tagus Valley Complex has a chronological sequence that helps to understand the dynamics of the last Holocene hunter-gatherer in the process of adaptation to climate change. The figure of the deer (*Cervus spp.*) stands as a main evidence of this adaptive process (Fig. 1), both from the economic and symbolic points of view. Deer (*Blastocerus spp.*) are also relevant to assess the climatic oscillations in the North-East of Brazil, in the 7th millennium BC. The rock art from Serra da Capivara (Fig. 2), now with a semi arid climate, displays examples of more humid climatic conditions, between 12 000 and 9 000 BP, with representations of deer, capivara (*Hydrochoerus spp.*) and fish, besides other fauna. Cultural and iconographic changes may be associated to climatic oscillations in the mid Holocene. The Ebo cluster of painted rock-shelters, in the South Kwanza province, in Angola, depicts a vast and rich environmental scenario, including a wide range of faunal evidence (Fig. 3). Corresponding to a much later chronology, while deer are absent from the biocenosis, ungulates (e.g. *Aepyceros spp.*) remain fundamental as indicators of major landscape transformation, after AD 1500.



Fig. 1 – Site of São Simão, rock art complex of the Tagus valley, Portugal: representation of an anthropomorphic figure carrying a *Cervus spp.*, from the middle Holocene. Drawing: Sara Garcês.

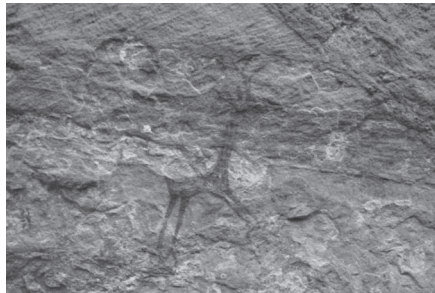


Fig. 2 – Toca do Caldeirão dos Rodrigues, circuit of Rodrigues no Boqueirão da Pedra Furada, Parque Nacional da Serra da Capivara, Brazil: representation of a *Blastocerus spp.*, from the middle Holocene. Photo: Marian Helen Rodrigues.



Fig. 3 – N'Dalambiri rock shelter, Ebo, Angola: representations of the deep forest fauna associated to the Dawn of agro-metallurgic villages, associated to intense rainfall conditions in the end of a climatic oscillation, in the 18th century. Photo: L. Oosterbeek.

Keywords: Rock art; Holocene; Climate changes; Tagus; Ebo; Serra da Capivara.

