ACTA IMEKO
ISSN: 2221-870X
September 2023, Volume 12, Number 3, 1 - 8

Back to the Past. The paleogeography as key to understand the Middle Palaeolithic peopling at Grotta dei Santi (Mt Argentario – Tuscany)

Enrico Conti[1], Simona Arrighi[1,2,3], Niccolò Bigliazzi[1], Francesco Boschin[1], Albachiara Brindisi[1], Kevin Brogi[1], Allegra Burgassi[1], Jacopo Crezzini[1], Clarissa Dominici[1], Lara Latragna[1], Tommaso Luzzetti[1], Giulia Marciani[1,3], Ivan Martini[1], Adriana Moroni[1,2], Sara Pitzianti[1], Stefano Ricci[1], Matteo Rossini[1], Alessandro Salvi[1], Sem Scaramucci[1,2], Vincenzo Spagnolo[1,2]

[1] *Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Università di Siena, via Laterina 8, 53100 Siena, Italy*
[2] *Centro Studi sul Quaternario (CeSQ), Via Nuova dell'Ammazzatoio 7, I, 52037 Sansepolcro (AR), Italy*
[3] *Dipartimento di Beni Culturali, Università di Bologna, via degli Ariani 1, Ravenna, Italy*

ABSTRACT
The mobility of hunter-gatherer groups is crucial in understanding Palaeolithic settlement dynamics. The concept of mobility cannot be separated from the space in which it occurs, including landscape components, localization of critical resources and of other sites, and routes between them. Nevertheless, the landscape is not constant in time due to the geomorphological changes that occurred in the long timescale of Prehistory. Here we present a paleogeographic reconstruction of the coastal area around Grotta dei Santi during the Neandertal occupation. A GIS-based approach, combining geological, bathymetric, and sea-level fluctuations data, allows us to reconstruct the landscape around the cave at about 45 ky BP. The cave today opens onto a cliff facing the sea. The Neandertal occupation occurred with a sea-level 74 m lower than present-day. Consequently, the cave faced a vast coastal plain, playing a strategic role due to its position, allowing both proximity and control of essential resources.

Section: RESEARCH PAPER

Keywords: Palaeolithic mobility; landscape archaeology; paleogeography; GIS; Central Italy

Citation: Enrico Conti, Simona Arrighi, Niccolò Bigliazzi, Francesco Boschin, Albachiara Brindisi, Kevin Brogi, Allegra Burgassi, Jacopo Crezzini, Clarissa Dominici, Lara Latragna, Tommaso Luzzetti, Giulia Marciani, Ivan Martini, Adriana Moroni, Sara Pitzianti, Stefano Ricci, Matteo Rossini, Alessandro Salvi, Sem Scaramucci, Vincenzo Spagnolo, Back to the Past. The paleogeography as key to understand the Middle Palaeolithic peopling at Grotta dei Santi (Mt Argentario – Tuscany), Acta IMEKO, vol. 12, no. 3, article 35, September 2023, identifier: IMEKO-ACTA-12 (2023)-03-35

Section Editor: Michela Ricca, University of Calabria, Italy

Received February 14, 2023; **In final form** July 18, 2023; **Published** September 2023

Funding: This work was supported by the National Geographic Society/Exploration Grant Program (grant NGS-61617R-19 to I. Martini), the Comune di Monte Argentario, the UniCoop Tirreno of Orbetello and the Banca di Credito Cooperativo di Castagneto Carducci.

Corresponding author: Vincenzo Spagnolo, e-mail: vincenzo.spagnolo@unisi.it

1. INTRODUCTION

Each monocausal approach to the analysis of human societies is invariably destined to fail. Human societies are not a simple sum of abstract and independent elements. On the contrary, their structure is shaped by a complex entanglement of co-dependent components (e.g., demography, social relations, economy, exchanges, physical and biological environment, resources) dialectically related [1].

The language and theory of the Social Network Analysis well express this concept. From the one hand, indeed, this modern analytical approach yields the typical nodes-and-edges graphs, intuitively representing not only the relational structure of a given system, but also some of the specific functions played by its components. From the other hand, robust statistics set implements the reading of the graph. The statistical parameters (e.g., density, connectivity, centrality, cohesion) help to identify the role of each component (the "node") in the given system (the network), highlighting the metric and relational properties of the reciprocal interactions. For instance, the centrality of a specific node (e.g., economy) is given by the number of links with other nodes. The greater the number of links, the greater the centrality, and consequently, its strategic importance in the specific context under analysis [2]. Consequently, a contextual, multivariate and integrated approach is the fundamental prerequisite for a proper understanding of a human society. This is particularly true for the Past, due to the residuality of archaeological record [3].

Reading the dialectical relations between the components of a society in the frame of spatial analysis allows to fully catch the dynamism behind the static nature of the archaeological record. From this perspective, Spatial Archaeology [4] plays a pivotal role, given its interdisciplinary, contextual, and multi-scale approach [5]. The space is not only a passive box of "resources", which can be reduced to mere geometric properties. It plays an active role in bounding, dividing, connecting, and catalysing people, "resources" and their relationships [6]. Indeed, changing the observation-scale on a human society, also the relative ranking between its components changes. In the continuum of their functional relationships, indeed, these components play different roles under the different "focal length", namely, the micro/meso-level (or intra-site scale) and the macro-level (or regional/multiregional scale). For instance, the proxemic and social relations (together with other cultural factors), play a central role at the micro/meso-level scales. The economy (and the consequent mobility patterns), instead, is the main component under the macro-level scale [4]. As a corollary, both the descriptive parameters and the research issues used to understand a given context are scale sensitive.

The scientific interest for the Palaeolithic mobility patterns is rooted in the fruitful cultural climate of the *Processual Archaeology* and, in particular, in the pioneering research of some scholars. They combined the attention for the Deep History of Humankind with the potential of the actualist methods, particularly of the ethnographical and ethnoarchaeological observations [7], [8], [9], [10], [11], [12], [13], [14], [15], [16]. Their studies allowed to collect a large set of data from different groups of modern hunter-gatherers. The theoretical models created on these bases are still essential and compelling to also understand the Palaeolithic groups. The aforementioned research, indeed, demonstrated as the organizational diversity of the current hunter-gatherers is ultimately attributable to their socio-economic structure. The need to minimize the bioenergy costs of travel optimizing the energetic input, indeed, regulates the mobility patterns [16], [17], jointly with a complex combination of parameters (paleo-climatic/environmental variables, economic, biological, and socio-cultural factors) [12]. In this way, the different management of territory and resources by foragers and collectors is mirrored by two opposite mobility strategies: respectively the residential one and the logistic one. In turn, these factors, shaping the organization of the territory, influence the general nature of the individual sites (e.g., residential camps, field camps, stations, resources acquisition sites, caches, etc.) and their relationships [8], [9], [11], [12].

These studies triggered the debate towards the identification and codification of the material proxies, recognizable into the palaeolithic contexts, to infer the mobility model adopted by groups who inhabited these sites. Nevertheless, for a long time, this research focused on the intra-site perspective, leaving scantly explored the possibility of a macro-level perspective. The reconstruction of the original regional networks of sites is totally impracticable for the Palaeolithic societies. The low archaeological visibility of survived sites, indeed, hinders this aim, jointly with other factors, as the difficulty of an acceptable estimate of lost sites and the impossibility of a strict chronological correlation between the sites. This latter aspect derives from the dichotomy between the palimpsest nature of landscapes (implying long timescales) and the nomadism of Palaeolithic societies (implying very short timescales, out of range for any dating method). Moreover, the reconstruction of past mobility cannot be abstracted from the idea of moving into the geographical, informational, and relational context in which it occurred. The reconstruction of Palaeolithic mobility cannot be adequately addressed without a paleogeographic framing. The landscape, indeed, is not an invariable component in the time. A preliminary geomorphological assessment is fundamental to recognize the changes in the long timescale of Prehistory. Eustatic fluctuations of sea level, tectonics, fluvial and glacial dynamics, and climate changes, along with other geomorphological agents, determine a difference in the aspect of past landscapes which gets greater and greater as one goes back in time [18]. Recently, the developments of geomatics applications to landscape and economic archaeology returned exciting results, significantly implementing our knowledge of Palaeolithic mobility patterns [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29].

Moreover, the issue of the environmental changes is valid not only following the arrow of time towards the past, but also towards the future. The spectrum of the climate change produced by human activities, indeed, directs towards possible catastrophic scenarios (already partly existing) for many contexts [30, 31]. Under this lens, the macro-level evaluation of the dynamics acting in the territory, act as crucial dataset for a rescue knowledge of the archaeological sites [32].

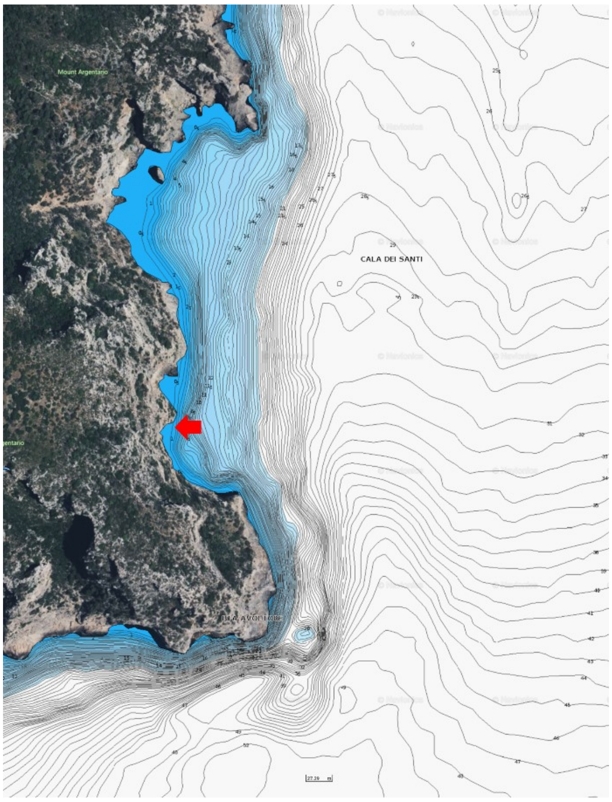

Figure 1. Screenshot of the Navionics SonarChart™ in the area in front of the Grotta dei Santi site (the position of the cave is indicated by arrow).

Table 1. Radiocarbon dates of the bottom and of the top of anthropogenic sequence (modified from [44]). The dates are calibrated using Oxcal v. 4.4.4 [68] with the latest IntCal 20 datasets [59].

MPI Code	Square	Unit	Comments	AMS Nr	14C age	1s Err	Cal +	Cal -
R-EVA 927	H2	1004B (spit 1)	From the hearth	MAMS-20857	44160	370	45611	43755
R-EVA 1533	H2/IV	1004A	From the hearth	MAMS-26362	46350	470	48154	45563
R-EVA 1534	H2/IV	1004A	From the hearth	MAMS-26361	44400	390	45844	43968
R-EVA 928	F7	110 (spit 6)	Flotation in sea water	MAMS-20858	45610	530	47533	44782

2. THE SITE: BRIEF HISTORY OF THE RESEARCH

The scientific discovery of Grotta dei Santi dates back to the middle of the last century, by A. G. Segre [33].

Nevertheless, logistical difficulties hindered further research until 2007, when the systematic excavation campaigns started under the direction of the Research Unit of Prehistory and Anthropology – Department of Physical Science, Earth, and Environment of the University of Siena (Italy) [34], [35], [36], [37], [38], [39]. The extraordinary importance of this site to study Neandertal behaviour diversity with a high-resolution perspective immediately arose with recent interdisciplinary studies [40], [41], [42], [43] [44], [45], [46]. Recent geological fieldwork, founded by the National Geographic Society, allowed the collection of a large amount of sedimentological data. This will contribute to a high-resolution reconstruction of the archaeological stratigraphy formation processes and cave environmental changes.

3. MATERIAL AND METHODS

This paper focuses on the paleogeographic reconstruction of a 45 km wide area around the Middle Palaeolithic site of Grotta dei Santi (Monte Argentario, Southern Tuscany, central Italy).

The study area extends along the coastline between Punta Ala (facing the Elba Island) to the north and the Lido di Tarquinia to the south [40], [41]. This is aimed both to further studies on the reconstruction of Neandertal mobility patterns and to the evaluation of the possible risk factors for preservation of the archaeological deposit (due to the closeness of the cave opening to the sea).

Grotta dei Santi currently opens on a cliff facing the sea. This was not the situation during the Neandertal occupation. The combined contribution of eustasy and tectonics produced a continuous process of large-scale regression/transgression of the sea over time [47], [48], [49], [50].

Consequently, the Digital Elevation Models of both the Terrain (DTM) and Bathymetry (DBM) are required for an accurate palaeogeographical reconstruction of the territory around this key site during the Palaeolithic. This is a challenging task, mainly due to the absence of high-resolution models of the bathymetry. The most accurate open-source DBM covering this area, indeed, is the EMODNET, with a grid resolution of 1/16 * 1/16 arc min (~ 115 * 115 m²) [51].

For this reason, a new model has been created by the interpolation of high-resolution data. Raw data have been collected by the HD SonarChart™ of Navionics [52]. The Navionics raster map of the study area includes high-resolution seafloor contours and high-resolution satellite world imagery (the last one is common to ArcGIS®) (Figure 1). This map has been georeferenced (with 84 control points and an estimated error of about 10 m). The contours have been vectorized into a purposely designed geodatabase (set on the UTM WGS 84 zone 32 projection system), with an accuracy of 4 m down to the bathymetric -148 m. A more accurate step has been used in the presence of particular seabed morphologies. Along the coastline, modern dock features have been excluded.

Given its computational efficiency, the Topogrid interpolation algorithm has been used to build the bathymetric model [53], [54], considering the above-mentioned contours and a polygon mask of the submerged study area (used as a boundary). The obtained DBM has been set with a 10 m cell size grid. Currently, it is the most accurate model available for this area (with a resolution significantly higher than the EMODNET). As far as the continental elevation model is concerned, the TINITALY/01 has been used. It is freely downloadable and shares with the above-mentioned DBM the same grid resolution (10 m) and projection system [55], [56]. The area of interest has been extracted with a mask by five frames (W47060, W47065, W47070, W46565, W46570). The choice of the TINITALY/01 instead of the regional Territorial Systems is due to the differences between the raw data from Tuscany and Latium. From an administrative point of view, indeed, this study area mostly covers the Tuscany territory, but a small area of the northern Latium is included as well. The DTM of Tuscany has a raster format, while the one of Latium is a vector file [57], [58]. Moreover, the TINITALY/01 is a homogeneous product.

The obtained DBM model and the continental DTM have been merged with a mosaic to a new raster procedure. The resulting elevation model includes the current continental and submerged relief, down to the depth of -148 m. The slope map (as degree) and the hill shade model have also been produced to improve the reading of this landscape in Prehistory. Finally, to enhance the realism of landscape reading, the value of eustatic sea-level during the Middle Palaeolithic occupation of the cave (corrected according to tectonic data) has been added to the obtained model, by the raster calculator tool. In this manner, the "0" value of the final DTM corresponds to the possible "0" of sea level during the Neandertal presence at Grotta dei Santi.

4. RESULTS AND DISCUSSION

4.1. The landscape during the Neandertal occupation

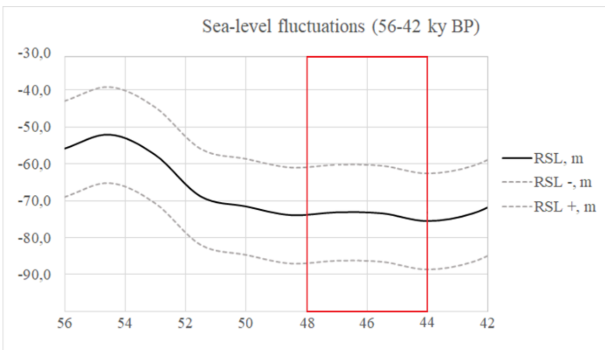

Figure 2. Sea-level variation between 56ky and 42 ky BP according to [47].

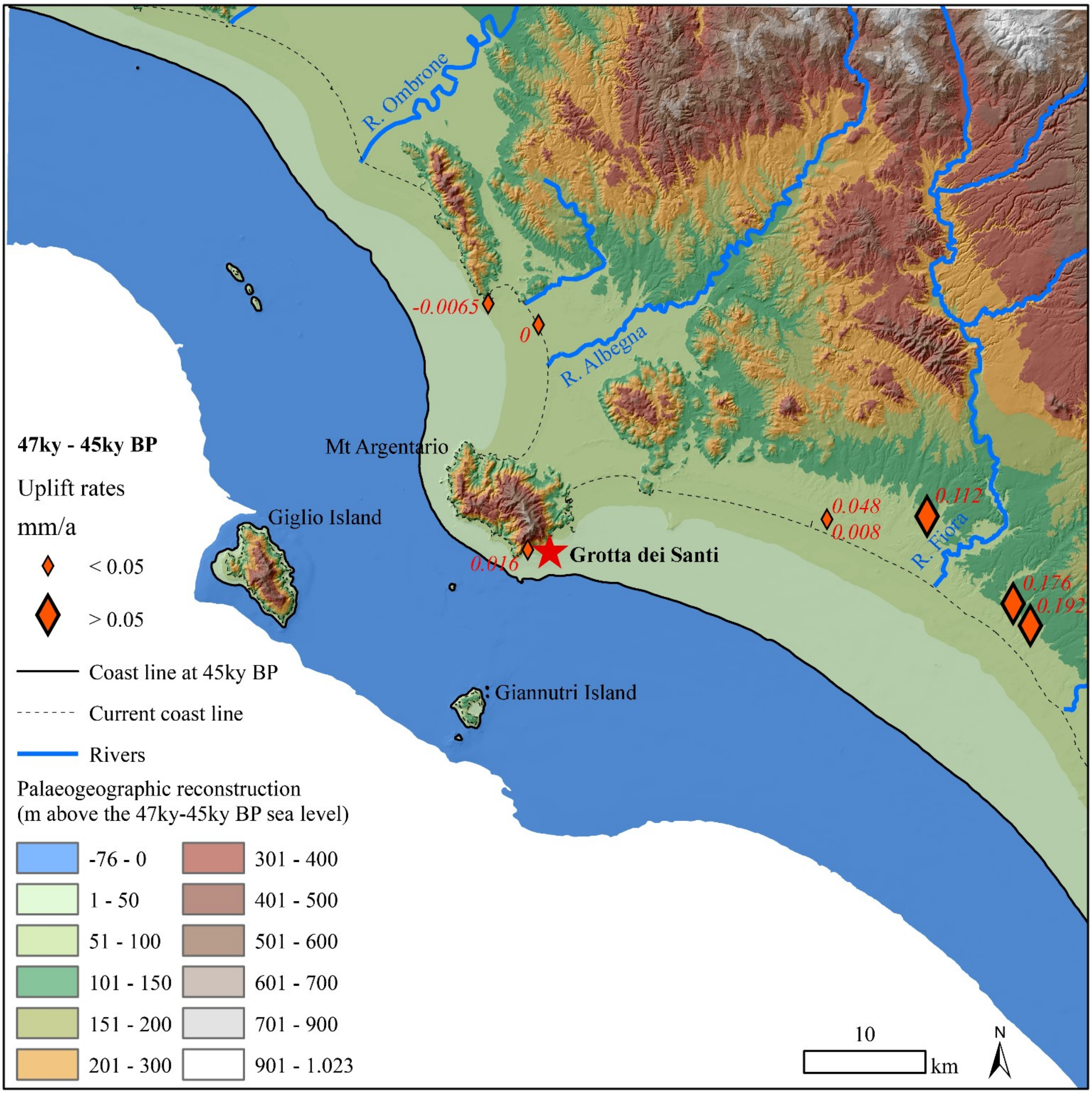

Figure 3. Palaeogeographical reconstruction of the study area about 47-45ky BP.

The High-Resolution model of landscape and seafloor returned by this study is a fundamental precondition for palaeogeographical reconstructions. Nevertheless, this is not the only condition. The proper rendering of the palaeolithic landscape stems from the intersection of multiple information.

Firstly, a chronological framing as accurate as possible is needed. Eustatic fluctuations of the sea level follow a characteristic pattern anchored in time. More precisely, radiocarbon dates from Grotta dei Santi allow for framing the Neandertal occupation of the cave between 50-40 ky BP [44]. Both the reliable radiometric dates calibrated with the new INTCAL20 curve [59] (Table 1) and the paleoenvironmental data from micro- and macro-faunal remains [44] converge in constraining the Neandertal occupation at about 48-44 ky BP (straddling the end of Heinrich Event 5 and the Greenland Interstadial GI-12) [60]. According to the foraminifera isotopic records, the sea level in this range was about -73 m (± 13 m) (Figure 2) [47], [50].

Secondly, the analysis of local geomorphological proxies' points to modest uplift rates, highlighting the relative tectonic stability of the area [48], [49]. In a radius of 25 km from the cave, indeed, the vertical displacement computable from the last 47 ky tends to be less than 1 m (with values between -0.016 and 0.048 mm/yr). Only in the southern part of the study area (corresponding to the mouth of the Fiora River) are some higher uplift rates recognizable. Nevertheless, the estimated vertical displacement is around 8 m (with values between 0.112 and 0.192 mm/yr) (Figure 3). These tectonic displacements appear

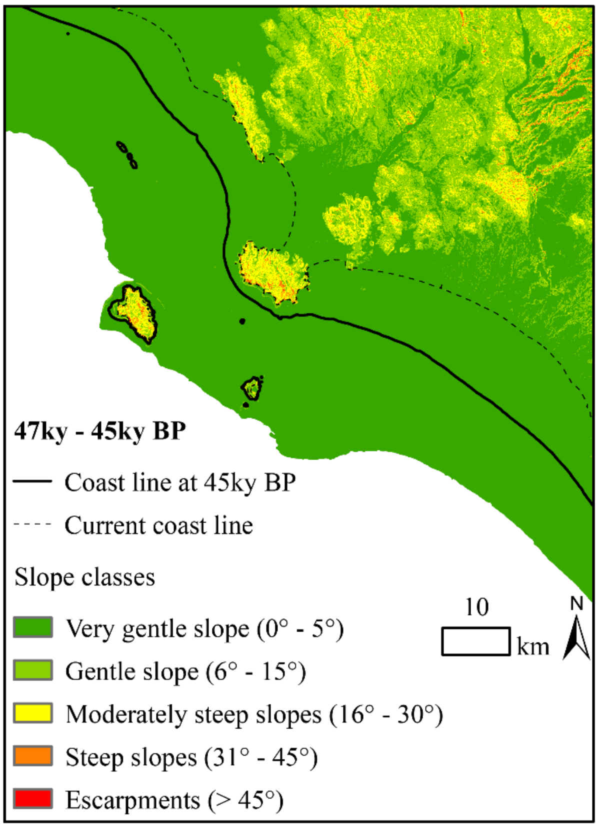

Figure 4. Slope map of the study area (slope classes expressed as degrees).

negligible considering that the sea-level estimate standard error is significantly higher [47], [50].

Finally, the recent contributions of fluvial transport and coastal dynamics have been considered to assess the reliability of each part of the reconstructed model. The Argentario promontory is characterized by a rocky coastline with a null sedimentary apport by fluvial distribution systems (Figure 3, Figure 4). As a result, this area is suitable for paleogeographic reconstructions. More problems affect both the northern and southern coastline sectors. In particular, the Holocene inputs from the Ombrone river significantly changed the assets of the coast, with high sedimentation rates. Sediments transported by the Albegna river in the last 10 ky contributed to the formation of narrow dune belts, connecting the Argentario to the peninsular area (influencing the formation of the Orbetello lagoon). In the south, the area near the Fiora river is affected by the sedimentation rate of fluvial transport and the higher uplift rates (Figure 3).

The paleogeographic analysis, net of the delineation of the margins mentioned above of error, brings out a very different landscape outlook from the present one (Figure 3).

The first evident difference is the large coastal plain extending in front of the cave and along the northern sector of the study area. In particular, the stretch of coastline facing the cave was expected to have an average slope of < 5° and a width of about 8.5 km (directly connecting Grotta dei Santi with part of the coast in front of it). Given the morphology and acclivity of the southwestern face of Punta Avoltore, bordering Grotta dei Santi (mainly ~31°-45°, with some steep escarpments > 45°), we infer that the sea was quite close to this stretch (~2.5 km). In this frame, Mt Argentario was a prominent element of the landscape. Other minor but significant prominent elements on the plain were expected to be what are now the rocks of Isolotto, Argentarola and the Formica di Burano. These morphological features make the Grotta dei Santi an ideal hunter-gatherer' camp, given its potential close access to diversified environments and resources. The cave's position could potentially implement Neandertals' control of the territory.

4.2. Problems for the present and the future

As can be easily understood from this paleogeographic reconstruction, the conformation of the territory around Grotta dei Santi is nowadays totally different from the environmental setting in which the formation of the archaeological deposit took place. From the Late Middle Palaeolithic, the sea level always was significantly lower than today. The rapid sea rising of Holocene produced the destruction of a large part of the original deposit, so that today only the part kept inside the cave is preserved [33], [44], [47], [50]. It goes without saying that the rapid and abrupt climatic changes induced by anthropic activities [31] constitute a serious risk factor for the conservation of the archaeological deposit in the cave. In 2100, according to [30:2], "the sea level could be 500-1,400 mm higher than today due to the melting of continental ice and thermal expansion/steric effects as a consequence of global warming". A similar scenario could compromise the preservation of the archaeological deposit into the cave.

In turn, this highlights the need of a deep knowledge of the current processes affecting the possible preservation dynamics of this site, to adequately plan the future research and protection interventions.

5. CONCLUSIONS

The major achievements of this work focus on two macro-objectives placed on two different time horizons: the Deep Past and the Near Future.

As far as the Past is concerned, the digital elevation model obtained opens promising windows toward new research about the Grotta dei Santi (a Late Mousterian key site in Central Italy). From the one hand, indeed, the paleogeographic reconstruction will significantly help to understand the relation Humans-Territory. In particular, this work offers a helpful tool to frame Neandertal mobility patterns, the strategies of resources catching and landscape management (e.g., [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29]). From the other hand, the digital elevation model obtained can contribute to visualize the landscape aspect not only during the occupation of Grotta dei Santi by Neandertals, but also in other phases of prehistory (e.g., from the Tyrrhenian Interglacial to the Last Glacial Maximum). It will contribute to reconstruct the evolution of landscape dynamics through the long times of the Late Pleistocene (e.g., [40], [41]). Globally, the latter perspective can contribute for a better focusing of some criticisms for further research, as the contribution of tectonics and Holocene sedimentation rates driven by fluvial dynamics. In turn, this can help also to improve the accuracy of paleogeographic reconstructions (e.g., focusing on specific areas for in-depth geological investigations).

As far as the Future is concerned, this work engages in the hot debate on the rescue knowledge of the archaeological sites. The human-driven climate changes, indeed, also hit the preservation of the cultural and archaeological heritage with catastrophic projections. This issue is particularly relevant in areas interested by high-energy morphological agents, as coastal areas, river valleys, incoherent/instable slopes and other geomorphologically vulnerable contexts (e.g., [32], [61], [62], [63], [64], [65], [66], [67]). The expected scenarios for the end of current century, at least, require careful study of the coastal hazard due to the sea rising as a primary issue in agenda for the management and conservative planning of the archaeological sites located in coastal areas, near to the current sea-level.

ACKNOWLEDGEMENT

For their logistic support we are grateful to the local Heritage Office (SABAP – Siena, Arezzo e Grosseto), the Firemen of Grosseto, the Coast Guard of Porto Ercole, the Red Cross of Porto Ercole, La Venta, AOG Industries di Luciano Chelli, Accademia Mare Ambiente di Porto Santo Stefano and Argentario Divers.

For their financial support we are grateful to the National Geographic Society/Exploration Grant Program (grant NGS-61617R-19 to I. Martini), the Comune di Monte Argentario, the UniCoop Tirreno of Orbetello and the Banca di Credito Cooperativo di Castagneto Carducci.

We extend special thanks to all the people who have made the fieldwork possible, despite the many difficulties.

The fieldwork was carried out under the DG-ABAP|18/03/2021| DECRETO 174 of the Italian Ministry of Culture.

REFERENCES

[1] I. Hodder, A. Mol, Network analysis and entanglement, J. Archaeol. Method Theory 23(1) (2016), pp. 1066-1094. DOI: 10.1007/s10816-015-9259-6.

[2] S. P. Borgatti, M. G. Everett, J. C. Johnson, Analyzing social networks. Second Edition, Sage, London, 2018, ISBN 978- 1-5264-0409-t.

[3] M. B. Schiffer, Archaeological context and systemic context, Am. Antiq. 37 (1972), pp.156-165. DOI: 10.2307/278203.

[4] D. L. Clarke, Spatial Archaeology, Academic Press. Inc., London, 1977, ISBN 0·12·175750·1.

[5] V. Spagnolo, G. Marciani, D. Aureli, F. Berna, G. Toniello, F. Astudillo, F. Boschin, P. Boscato, A. Ronchitelli, Neanderthal activity and resting areas from stratigraphic unit 13 at the Middle Palaeolithic site of Oscurusciuto (Ginosa-Taranto, Southern Italy), Quat. Sci. Rev. 217 (2019), pp. 169-193. DOI: 10.1016/j.quascirev.2018.06.024.

[6] V. Spagnolo, E. A. A. Garcea, From settlement patterns to memory of place among Holocene hunter-gatherers at Sai Island, Middle Nile Valley, Azania, 58(2) (2023), pp. 161-213. DOI: 10.1080/0067270X.2023.2198851.

[7] L. R. Binford, Nunamiut ethnoarchaeology, Academic press, New York, 1978, ISBN 0- 12-100040-0.

[8] L. R. Binford, Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation, Am. Antiq. 45 (1980), pp. 4-20. DOI: 10.2307/279653.

[9] L. R. Binford, The Archaeology of Place, J. Anthropol. Archaeol. 1 (1982), pp. 5-31. DOI: 10.1016/0278-4165(82)90006-X.

[10] L. R. Binford, Constructing frames of reference: An analytical method for archaeological theory building using ethnographic and environmental data sets, University of California Press, Berkeley, 2001, lSBN 0-520-22393-4.

[11] R. L. Kelly, Hunter-gatherer mobility strategies, J. Anthropol. Res. 39 (1983), pp. 277-306.

[12] R. L. Kelly, The lifeways of hunter-gatherers: The foraging spectrum, Cambridge University Press, New York, 2013, ISBN 978-1-107-60761-3.

[13] S. Kent, Studying variability in the archaeological record: an ethnoarchaeological model for distinguishing mobility patterns, Am. Antiq. 54 (1992), pp. 635-660. DOI: 10.2307/280827.

[14] J. E. Yellen, Archaeological approaches to the present. Models for reconstructing the Past, Academic Press Inc., New York, 1977, ISBN 0-12-770350-0.

[15] J. E. Yellen, Optimization and risk in human foraging strategies, J. Hum. Evol. 15 (1986), pp. 733-750. DOI: 10.1016/S0047-2484(86)80007-0.

[16] E. L. Charnov, Optimal foraging, the marginal value theorem, Theor. Popul. Biol. 9(2) (1976), pp. 129-136. DOI: 10.1016/0040-5809(76)90040-X.

[17] V. V. Venkataraman, T. S. Kraft, N. J. Dominy, K. M. Endicott, Hunter-gatherer residential mobility and the marginal value of rainforest patches, PNAS 114 (2017), pp. 3097-3102. DOI: 10.1073/pnas.1617542114.

[18] G. J. Brierley, Landscape memory: the imprint of the past on contemporary landscape forms and processes, Area 42(1) (2010), pp. 76-85.

[19] T. Aubry, L. Luís, J. M. Llach, H. Matias, We will be known by the tracks we leave behind: Exotic lithic raw materials, mobility and social networking among the Côa Valley foragers (Portugal), J. Anthropol. Archaeol. 31(4) (2012), pp. 528-550. DOI: 10.1016/j.jaa.2012.05.003.

[20] B. F. Byrd, A. N. Garrard, P. Brandy, Modeling foraging ranges and spatial organisation of Late Pleistocene hunter–gatherers in the southern Levant – A least-cost GIS approach, Quat. Int. 396 (2016), pp. 62-78. DOI: 10.1016/j.quaint.2015.07.048.

[21] S. Caracausi, G. L. Berruti, S. Daffara, D. Bertè, F. R. Borel, Use of a GIS predictive model for the identification of high altitude prehistoric human frequentations. Results of the Sessera valley project (Piedmont, Italy), Quat. Int. 490 (2018), pp. 10-20. DOI: 10.1016/j.quaint.2018.05.038.

[22] M. de Andrés-Herrero, D. Becker, G. C. Weniger, Reconstruction of LGM faunal patterns using Species Distribution Modelling. The archaeological record of the Solutrean in Iberia, Quat. Int. 485 (2018), pp. 199-208. DOI: 10.1016/j.quaint.2017.10.042.

[23] R. Ekshtain, C. A. Tryon, Lithic raw material acquisition and use by early Homo sapiens at Skhul, Israel, J. Hum. Evol. 127 (2019), pp. 149-170. DOI: 10.1016/j.jhevol.2018.10.005.

[24] R. Ekshtain, A. Malinsky-Buller, S. Ilani, I. Segal, E. Hovers, Raw material exploitation around the Middle Paleolithic site of 'Ein Qashish, Quat. Int. 331 (2014), pp. 248-266. DOI: 10.1016/j.quaint.2013.07.025.

[25] M. García-Rojas, E. Dominguez-Ballesteros, A. Prieto, A. Calvo, A. Sánchez, A. Tarriño, A. Arrizabalaga, A great step forward. Lithic raw material procurement and management among Palaeolithic hunter-gatherers in the Basque crossroads, J. Lithic Technol. 7(2) (2020), pp. 1-19. DOI: 10.2218/jls.5434.

[26] A. B. Marín-Arroyo, A. Sanz-Royo, What Neanderthals and AMH ate: reassessment of the subsistence across the Middle–Upper Palaeolithic transition in the Vasco-Cantabrian region of SW Europe, J. Quat. Sci. 37(2) (2022), pp. 320-334. DOI: 10.1002/jqs.3291.

[27] H. Parow-Souchon, C. Purschwitz, Variability in chert raw material procurement and use during the Upper Paleolithic and Early Neolithic of the southern Levant: A regional perspective from the Greater Petra area, J. Archaeol. Sci. Rep. 29 (2020), 102087. DOI: 10.1016/j.jasrep.2019.102087.

[28] A. Prieto, M. García-Rojas, A. Sánchez, A. Calvo, E. Domínguez-Ballesteros, J. Ordoño, M. I. García-Collado, Stones in Motion: Cost units to understand flint procurement strategies during the Upper Palaeolithic in the south-western Pyrenees using GIS, J. Lithic Technol. 3(1) (2016), pp. 133-160. DOI: 10.2218/jls.v3i1.1310.

[29] A. Prieto, A. Arrizabalaga, I. Yusta, Lithic raw material in the Cantabrian region: Dialectical relationship between flint and quartzite in the Palaeolithic record, J. Lithic Technol. 8(1) (2021), pp. 1-31.
DOI: 10.2218/jls.4334.
[30] F. Antonioli, G. De Falco, V. Lo Presti, L. Moretti, G. Scardino, M. Anzidei, D. Bonaldo, S. Carniel, G. Leoni, S. Furlani, A. Marsico, M. Petitta, G. Randazzo, G. Scicchitano, G. Mastronuzzi, Relative sea-level rise and potential submersion risk for 2100 on 16 coastal plains of the Mediterranean Sea, Water 12 (8) (2020), 2173.
DOI: 10.3390/w12082173.
[31] J. Rockström, J. Gupta, D. Qin, S. J. Lade, J. F. Abrams, L. S. Andersen, D. I. Armstrong McKay, X. Bai, G. Bala, S. E. Bunn, D. Ciobanu, F. DeClerck, K. Ebi, L. Gifford, Ch. Gordon, S. Hasan, N. Kanie, T. M. Lenton, S. Loriani, D. M. Liverman, A. Mohamed, N. Nakicenovic, D. Obura, D. Ospina, K. Prodani, C. Rammelt, B. Sakschewski, J. Scholtens, B. Stewart-Koster, Th. Tharammal, D. van Vuuren, P. H. Verburg, R. Winkelmann, C. Zimm, E. M. Bennett, S. Bringezu, W. Broadgate, P. A. Green, L. Huang, L. Jacobson, Ch. Ndehedehe, S. Pedde, J. Rocha, M. Scheffer, L. Schulte-Uebbing, W. de Vries, C. Xiao, C. Xu, X. Xu, No. Zafra-Calvo, X. Zhang, Safe and just Earth system boundaries, Nature 619 (2023), pp. 102-111.
DOI: 10.1038/s41586-023-06083-8.
[32] F. Zaina, T. Deodato, Satellite-Based Methodology for Purposes of Rescue Archaeology of Cultural Heritage Threatened by Dam Construction. Remote Sensing 14(4) (2022), 1009.
[33] A. G. Segre, Giacimenti pleistocenici con fauna e industria litica a Monte Argentario (Grosseto), Riv. Sci. Preist. XIV (1959), pp. 1-18.
[34] J. Crezzini, A. Moroni, Archeozoologia. La ricostruzione del comportamento umano dall'esame dei resti faunistici recuperati nei siti archeologici, Etruria Natura IX (2012), pp. 36-43.
[35] M. Freguglia, P. Gambogi, L. Milani, A. Moroni Lanfredini, S. Ricci, Monte Argentario (GR). Cala dei Santi: Grotta dei Santi, Notiziario della Soprintendenza per i Beni Archeologici della Toscana (2007), pp. 488-491, ISBN 9788878143852.
[36] M. Freguglia, F. Bernardini, G. Boschian, C. Capanna, J. Crezzini, P. Gambogi, L. Longo, L. Milani, A. Moroni Lanfredini, F. Parenti, S. Ricci, Monte Argentario (GR). Cala dei Santi: Grotta dei Santi, Notiziario della Soprintendenza per i Beni Archeologici della Toscana 4 (2008), pp. 377-380, ISBN 9788878144477.
[37] A. Moroni Lanfredini, M. Freguglia, F. Bernardini, G. Boschian, C. Cavanna, J. Crezzini, P. Gambogi, L. Longo, L. Milani, F. Parenti, S. Ricci, Nuove ricerche alla Grotta dei Santi (Monte Argentario, Grosseto), In: N. Negroni Catacchio (ed.), L'alba dell'Etruria Fenomeni di continuità e trasformazione nei secoli XII-VIII a.C. Ricerche e scavi, Atti del IX Incontro del Centro Studi di Preistoria e Archeologia, (2010), pp. 649-662, ISBN 8863990387.
[38] A. Moroni, F. Parenti, A. Araujo, G. Boschian, F. Boschin, G. Capecchi, J. Crezzini, J. J. Hublin, G. Marciani, V. Spagnolo, S. Talamo, P. Gambogi, Monte Argentario (GR). Grotta di Cala dei Santi (Concessione di Scavo), Notiziario della Soprintendenza per i Beni Archeologici della Toscana 10/2014 (2015), pp. 364-366, ISBN 9788878146532.
[39] V. Spagnolo, G. Boschian, A. Araujo, F. Boschin, G. Capecchi, J. Crezzini, J. J. Hublin, G. Marciani, G. Montanari-Canini, F. Parenti, S. Talamo, A. Moroni, Monte Argentario (GR). Cala dei Santi: Grotta dei Santi (concessione di scavo), Notiziario della Soprintendenza per i Beni Archeologici della Toscana 11/2015 (2016), pp.555-558, ISBN 9788878147027.
[40] E. Conti, Ricostruzione paleo-geografica della costa grossetana nell'intervallo M.I.S. 2 - M.I.S. 5e, BA Thesis, Università degli Studi di Siena, Siena, Italy, 2022.
[41] E. Conti, S. Arrighi, N. Bigliazzi, F. Boschin, A. Brindisi, K. Brogi, A. Burgassi, J. Crezzini, C. Dominici, L. Latragna, T. Luzzetti, G. Marciani, I. Martini, A. Moroni, S. Pitzianti, S. Ricci, M. Rossini, A. Salvi, S. Scaramucci, V. Spagnolo, Paleogeographic reconstruction of the Tuscan coastal area nearby Grotta dei Santi (Monte Argentario, Italy) during the Neandertal occupation, 2022 IMEKO TC4 Int. Conf. on Metrology for Archaeology and Cultural Heritage University of Calabria, Italy, October 19-21, 2022, 46-51.
DOI: 10.21014/tc4-ARC-2022.010
[42] A. Burgassi, Analisi ad alta risoluzione della suscettività magnetica della Grotta di Cala dei Santi (Monte Argentario, Grosseto), BA Thesis, Università degli Studi di Siena, Siena, Italy, 2021. [in Italian]
[43] G. Montanari, Grotta dei Santi, Monte Argentario (GR): i piccoli mammiferi dei livelli musteriani, MA Thesis, Università degli Studi di Ferrara, Ferrara, Italy, 2014. [in Italian]
[44] A. Moroni, G. Boschian, J. Crezzini, G. Montanari-Canini, G. Marciani, G. Capecchi, S. Arrighi, D. Aureli, C. Berto, M. Freguglia, A. Araujo, S. Scaramucci, J. J. Hublin, T. Lauer, S. Benazzi, F. Parenti, M. Bonato, S. Ricci, S. Talamo, A. G. Segre, F. Boschin, V. Spagnolo, Late Neandertals in Central Italy. High-resolution chronicles from Grotta Dei Santi (Monte Argentario - Tuscany), Quat. Sci. Rev. 217 (2019), pp.130-151.
DOI: 10.1016/j.quascirev.2018.11.021.
[45] V. Spagnolo, Studio delle strategie insediative del Paleolitico medio in Italia centro-meridionale, PhD Dissertation, Università degli Studi di Siena Siena, Italy, 2017. [in Italian]
[46] V. Spagnolo, J. Crezzini, G. Marciani, G. Capecchi, S. Arrighi, D. Aureli, I. Ekberg, S. Scaramucci, L. Tassoni, F. Boschin, A. Moroni, Neandertal camps and hyena dens. Living floor 150A at Grotta dei Santi (Monte Argentario, Tuscany, Italy), J. Archaeol. Sci. Rep. 30 (2020), 102249.
DOI: 10.1016/j.jasrep.2020.102249.
[47] F. Antonioli, Sea level change in Western-Central Mediterranean since 300 kyr: comparing global sea level curves with observed data, Alp. Mediterr. Quat. 25 (2012), pp. 15-23.
[48] L. Ferranti, F. Antonioli, B. Mauz, A. Amorosi, G. Dai Pra, G. Mastronuzzi, C. Monaco, P. Orrù, M. Pappalardo, U. Radtke, P. Renda, P. Romano, P. Sansò, V. Verrubbi, Markers of the last interglacial sea-level high stand along the coast of Italy: Tectonic implications, Quat. Int. 145-146 (2006), pp. 19-29.
DOI: 10.1016/j.quaint.2005.07.009.
[49] L. Ferranti, F. Antonioli, M. Anzidei, C. Monaco, P. Stocchi, The timescale and spatial extent of vertical tectonic motions in Italy: insights from relative sea-level changes studies, J. Virtual Explor. 36 (2010), pp. 1-34.
DOI: 10.3809/jvirtex.2010.00255.
[50] C. Waelbroeck, L. Labeyrie, E. Michel, J. C. Duplessy, K. Lambeck, J. F. Mcmanus, E. Balbon, M. Labracherie, Sea-level and deep water temperature changes derived from benthic foraminifera isotopic records, Quat. Sci. Rev. 21 (2002), pp. 295-305.
DOI: 10.1016/S0277-3791(01)00101-9.
[51] European Commission, EMODnet Bathymetry. Online [Accessed 12 July 2021]
https://www.emodnet-bathymetry.eu
[52] Garmin Italy Technologies, Navionics Online [Accessed 12 July 2021]
https://navionics.com/ita
[53] S. Arrighi, E. Bortolini, L. Tassoni, A. Benocci, G. Manganelli, V. Spagnolo, L. M. Foresi, A. M. Bambini, F. Lugli, F. Badino, D. Aureli, F. Boschin, C. Figus, G. Marciani, G. Oxilia, S. Silvestrini, A. Cipriani, M. Romandini, M. Peresani, A. Ronchitelli, A. Moroni, S. Benazzi, Backdating systematic shell ornament making in Europe to 45,000 years ago, Archaeol. Anthropol. Sci. 12(2) (2020), pp. 1-22.
DOI: 10.1007/s12520-019-00985-3.
[54] J. Conolly, M. Lake, Geographical Information Systems in Archaeology, Cambridge University Press, Cambridge, 2006, ISBN 978-0-521-79330-8.
[55] INGV, TINITALY. Online [Accessed 12 July 2021]
https://tinitaly.pi.ingv.it/
[56] S. Tarquini, l. Nannipieri, The 10 m-resolution TINITALY DEM as a trans-disciplinary basis for the analysis of the Italian territory:

Current trends and new perspectives, Geomorphology 281 (2017), pp. 108-115.
DOI: 10.1016/j.geomorph.2016.12.022.
[57] Regione Toscana. Online [Accessed 12 July 2021] http://www502.regione.toscana.it/geoscopio/
[58] Regione Lazio, Lazio Region Geoportal. Online [Accessed 12 July 2021] https://geoportale.regione.lazio.it/documents/272/metadata_detail
[59] P. J. Reimer, W. E. N. Austin, E. Bard, A. Bayliss, P. G. Blackwell, C. B. Ramsey, M. Butzin, H. Cheng, R. L. Edwards, M. Friedrich, P. M. Grootes, T. P. Guilderson, I. Hajdas, K. A. Hughen, T. J. Heaton, A. G. Hogg, B. Kromer, S. W. Manning, R. Muscheler, J. G. Palmer, C. Pearson, J. van der Plicht, R. W. Reimer, D. A. Richards, E. M. Scott, J. R. Southon, C. S. M. Turney, L. Wacker, F. Adolphi, U. Büntgen, M. Capano, S. M. Fahrni, A. Fogtmann-Schulz, R. Friedrich, P. Köhler, S. Kudsk, F. Miyake, J. Olsen, F. Reinig, M. Sakamoto, A. Sookdeo, S. Talamo, The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP), Radiocarbonn 62(4) (2020), pp. 725-757.
DOI: 10.1017/RDC.2020.41.
[60] S. O. Rasmussen, M. Bigler, S. P. Blockley, T. Blunier, S. L. Buchardt, H. B. Clausen, M. Winstrup, A stratigraphic framework for abrupt climatic changes during the Last Glacial period based on three synchronized Greenland ice-core records: refining and extending the INTIMATE event stratigraphy, Quat. Sci. Rev. 106 (2014), pp. 14-28.
DOI: 10.1016/j.quascirev.2014.09.007.
[61] I. Cook, R. Johnston, K Selby, Climate change and cultural heritage: A landscape vulnerability framework, J. Island Coast. Archaeol. 16(2-4) (2021), pp. 553-571.
DOI: 10.1080/15564894.2019.1605430.
[62] P. Ezcurra, I. C. Rivera-Collazo, An assessment of the impacts of climate change on Puerto Rico's cultural heritage with a case study on sea-level rise, J. Cult. Herit. 32 (2018), pp. 198-209.
DOI: 10.1016/j.culher.2018.01.016.
[63] G. Hambrecht, M. Rockman, International approaches to climate change and cultural heritage, Am. Antiq. 82(4) (2017), pp. 627-641.
DOI: 10.1017/aaq.2017.30.
[64] D. V. Harkin, M. Davies, E. Hyslop, H. Fluck, M. Wiggins, O. Merritt, L. Barker, M. Deery, R. McNeary, K. Westley, Impacts of climate change on cultural heritage, MCCIP Sci. Rev. (2020), pp. 616-641.
DOI: 10.14465/2020.arc26.che.
[65] S. A. Orr, J. Richards, S. Fatorić, Climate change and cultural heritage: A systematic literature review (2016–2020), Hist. Environ.: Policy Pract. 12(3-4) (2021), pp. 434-477.
DOI: 10.1080/17567505.2021.1957264.
[66] E. Perez-Alvaro, Climate change and underwater cultural heritage: Impacts and challenges, J. Cult. Herit. 21 (2016), pp. 842-848.
DOI: 10.1016/j.culher.2016.03.006.
[67] J. Wright, Maritime archaeology and climate change: An invitation, J. Marit. Archaeol. 11(3) (2016), pp. 255-270.
DOI: 10.1007/s11457-016-9164-5.
[68] C. Bronk Ramsey, Bayesian analysis of radiocarbon dates, Radiocarbon 51(1) (2009), pp. 337-360.
DOI: 10.1017/S0033822200033865.