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A GEOARCHAEOLOGICAL STUDY OF THE METAPONTO COASTAL BELT, SOUTHERN ITALY, BASED ON GEOMORPHOLOGICAL MAPPING AND GIS-SUPPORTED CLASSIFICATION OF LANDFORMS

Abstract: Gioia D., Bavusi M., Di Leo P., Giammatteo T., Schiattarella M., *A geoarchaeological study of the Metaponto coastal belt, Southern Italy, based on geomorphological mapping and GIS-supported classification of landforms.* (IT ISSN 0391-9839, 2016)

In this work we tried to infer the settlement rules and archaeological site patterns in pilot coastal area with high "archaeological potential" through the analysis of the spatial relationships between landform unit maps deriving from a GIS-supported procedure of landform extraction integrated with geomorphological analyses and archaeological evidence. This approach has been tested in the coastal Ionian sector of the Basilicata region, where a detailed geoarchaeological research has been carried out in the frame of the multidisciplinary MeTIBas project (the Italian acronyms for Innovative Methods and Technologies for the Cultural Heritages in the Basilicata region), funded by the European Community. The study area extends on the southernmost part of the Bradano Foredeep, southern Italy, and roughly coincides with the Greek settlement territory of Metaponto and its *Chora* (the area of influence of Greek colonists). Archaeological investigations, regarding about 1400 sites, consisted of a re-examination of literature data and new field surveys. The relationships between landscape elements deriving from the procedure here proposed and archaeological sites have been statistically investigated to derive settlement patterns and rules. Results highlight a preferential distribution of the identified categories of archaeological sites on gently-dipping marine terrace surfaces and near their edges, thus implying that settlement dynamics of the Metaponto territory partially driven by the topographic position.

Key Words: *Geoarchaeology, GIS, Topographic Position Index (TPI), Landform unit, Metaponto (southern Italy), Archaeological site distribution, Settlement rules.*

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Riassunto: Gioia D., Bavusi M., Di Leo P., Giammatteo T., Schiattarella M., *Analisi geoarcheologica della fascia costiera di Metaponto (Italia meridionale) attraverso la cartografia geomorfologica e l'identificazione semi-automatica delle unità di paesaggio.* (IT ISSN 0391-9839, 2016)

Questo lavoro ha come obiettivo l'analisi della distribuzione spaziale delle testimonianze archeologiche e la ricostruzione delle caratteristiche insediative di un'area del settore ionico della Basilicata attraverso l'introduzione di una semplice procedura che prevede l'integrazione di dati cartografici acquisiti con le tradizionali tecniche del rilevamento geomorfologico e quello di terreno e procedure automatiche di estrazione degli elementi del paesaggio. Attraverso tale approccio, è stata ricavata una carta delle unità di paesaggio di un ampio settore di circa 400 kmq coincidente con l'antico territorio della colonia greca di *Metaponto*. L'analisi geoarcheologica di quest'area è stata condotta nell'ambito di un progetto europeo denominato MeTIBas (Metodi e Tecnologie Innovative per i Beni Culturali della Basilicata) ed ha consentito di acquisire, attraverso l'integrazione di dati pregressi e nuovi rilevamenti, un dettagliato database archeologico, che è stato confrontato quantitativamente con le caratteristiche fisiografiche e con gli elementi del paesaggio derivanti dallo studio geomorfologico.

Termini Chiave: Geoarcheologia, GIS, Topographic Position Index (TPI), Unità di paesaggio, Metaponto (Basilicata), Distribuzione dei siti archeologici, dinamiche insediative.

INTRODUCTION

Geoarchaeology is a growing research discipline that takes advantages from the integration of data coming from different research fields such as geology, geomorphology, stratigraphy, mineralogy and geophysics (Butzer, 2008 and references therein). The interplay between man and Italian environment in historical times has been the subject of many scientific works since the '80s and the results from these studies have revealed that the influence of the landscape features on the human activities and choices has often been significant (see for example Schmaltz *& alii*, 2014). Regional and sub-regional archaeological studies of settlement patterns need an integrated methodological approach, in which topographic analyses and DEM-supported or semi-automatic landform classification are frequently fundamental (Silbernagel *&* *alii*, 1997; De Jaeger *&* *alii*, 2000; Turrero *&* *alii*, 2013; Danese *&* *alii*, 2014a, 2014b; among others). On the contrary, detailed geomorphological analysis, landform/landscape mapping and the subsequent definition of landform units are rather rare in geoarchaeological research, although this approach has been proved to be useful for solving geoarchaeological issues (see for example Verhagen & Dragut, 2012).

In this work, we tried to infer the settlement rules and archaeological site patterns through the analysis of the spatial relationships between landform unit maps deriving from a GIS-supported procedure of landform extraction integrated with geomorphological analyses and archaeological evidence. The study area extends on the southernmost sectors of the Bradano Foredeep (fig. 1), and roughly coincides with the ancient territory of the Greek settlement of Metaponto and its *Chora* (the area of influence of Greek colonists). This area has been widely investigated from an archaeological and geoarchaelogical viewpoint since the second half of the 20th century. Pioneer studies of the relationships between geomorphological processes and Greek-Roman occupation are due to Neboit (1980, 1984) whereas the valuable and long-lasting multidisciplinary analysis by Carter (1983, 1990, 2001, 2003, 2008) and Carter & Prieto (2011) highlights a well-developed and widespread rural settlement surrounding the Greek colony of Metaponto.

This paper aims to derive a landform unit map by adopting a GIS procedure based on both a detailed (scale 1:10,000) geomorphological mapping and a DEM-supported landform unit extraction. The usefulness of the landform unit map deriving from such an approach has been tested as a tool for the support of geoarchaeological investigations and the analysis of settlement rules. Then, the relationships between landscape elements and archaeological sites have been statistically investigated to derive settlement patterns and rules.

THE GEOARCHAELOGICAL SYSTEM OF THE METAPONTO AREA

Geological and geomorphological setting

The study area is confined between the eastern front of the south-Apennine chain and the western edge of the Apulian Foreland (fig. 1) and represents the southernmost and the youngest outcropping part of the Bradano foredeep (Pieri *&* *alii*, 1996; Lazzari & Pieri, 2002; Tropeano *&* *alii*, 2002; Gioia *&* *alii*, 2014). During early Pleistocene times, this foredeep sector was subject to a stage of subsidence, which resulted in the deposition of marine clays (*Argille subappennine* Formation, Tropeano *&* *alii*, 2002). Lower Pleistocene marine clays are unconformably overlaid by a middle-upper Pleistocene regressive, generally coarsening upward, succession of marine silt, sand, and conglomerate. This succession forms a staircase of marine terraces corresponding to discrete depositional coastal wedges. Since middle Pleistocene, the interplay between a moderate tectonic uplift (< 1 mm/yr, Caputo *&* *alii*, 2010) and eustatic sea-level variations promoted the development of the several orders of marine terraces, which are arranged in a staircase geometry with a systematically decrease of altitude from the oldest to the youngest. The top of the youngest and the lowermost coastal wedge is the present-day Metaponto coastal plain (Brückner, 1980; Caputo *&* *alii*, 2010; Cilumbriello *&* *alii*, 2010; Tropeano *&* *alii*, 2013). Marine clay bedrock and terraced deposits are covered by the most recent, late Pleistocene-Holocene, continental and transitional (marine-continental) deposits. Continental deposits belong to alluvial environments, either located along the channels of the main rivers or on wide flood plains, whereas transitional deposits belong to delta and beach environments, whose depositional systems, during the late Holocene, prograded up to the present-day shoreline (Tropeano *&* *alii*, 2013). Surfaces of marine terraces represent tops of uplifted coastal wedges with an internal complex stratigraphy (Cilumbriello *&* *alii*, 2010). Seismotectonic analysis based on the spatial and vertical arrangement of northern Calabria and Basilicata marine terrace staircase revealed a regional shortening and a contractional tectonic regime during Middle-Upper Pleistocene and possible evidences of Holocene active deformation and seismogenic potential (Caputo *&* *alii*, 2010; Santoro *&* *alii*, 2013). On the other hand, the lack of significant historical and instrumental seismicity in the region could be related to aseismic slip along buried thrust (Caputo *&* *alii*, 2010; Santoro *&* *alii*, 2013) and it suggests a low probability of occurrence of strong historical earthquakes promoting the abandonment of ancient settlement.

From a geomorphological viewpoint, the study area is a medium- to low-relief landscape, featured by the gently-dipping (i.e. slope angles of 3-5° toward the sea) surfaces of the marine terrace staircase repeatedly interrupted by morphological scarps (fig. 2). Marine terraces are deeply cut by a minor drainage network, which shows a well-defined trellis-type pattern and represents the tributary valleys of the three main rivers (i.e. Bradano, Basento, and Cavone rivers). These main streams are meandering-type channels with large alluvial plains, which cross-cut the wide Metaponto coastal plain in their lowest reaches. The flat coastal plain surface represents the top of the sedimentary wedge developed during the Holocene after the last eustatic rise of the sea level that followed the last glacial phase. Until the land reclamation of the last century first decades, the backshore area of the Metaponto coastal plain was characterized by the presence of wide limno-palustrine environments. The plain is now featured by sandy and silty meandering fluvial systems, with some artificial channels. Reclaimed areas, flanking rivers along the plain, are still subject to occasional flooding during major rainfall events.

Historical Outline

The first findings of settlements in the Metaponto area date back to the Neolithic and become numerous in the Bronze and Iron Ages. Archaeological investigations of the Termitito area (near the village of Scanzano Jonico) evidenced many fragments of Mycenaean pottery, dating to

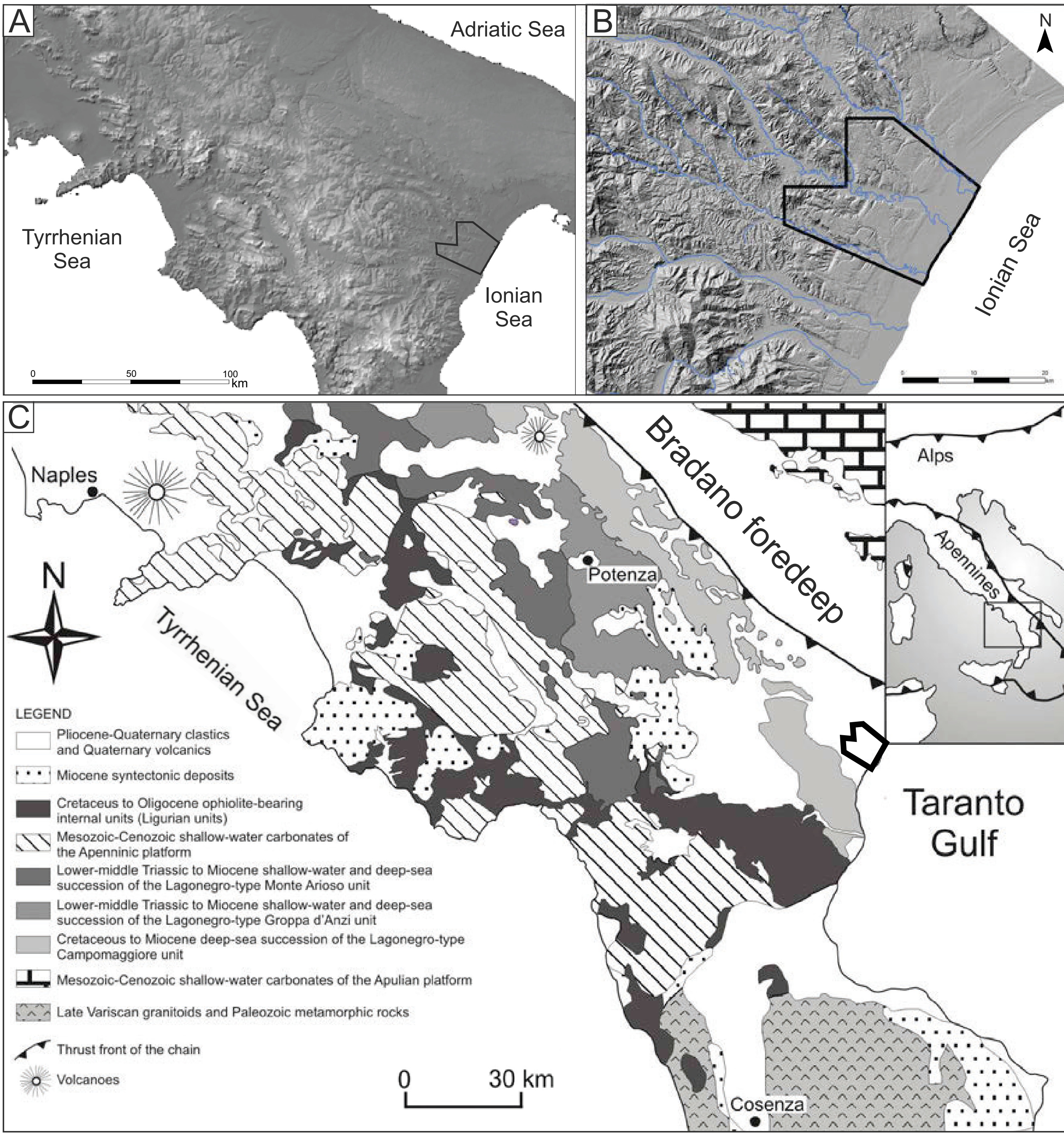

FIG. 1 - Geological map of southern Italy (modified after Martino & *alii*, 2009). In the inset: regional framework (A) and geographical sketch of the Ionian coastal area.

the XII-XIII century B.C., and a few findings of structures (De Siena, 1986b). Then, a flourishing village (characterized by oval-shaped huts) was founded on the Incoronata hill (Pisticci, Matera district) in the VIII century B.C. The village experienced a rapid cultural and economic growth up to the Greek colonization, when it was abandoned (Adamesteanu, 1986; De Siena, 1986a and references therein). In 640 B.C. the Metaponto colony was founded as a consequence of a request by Sybaris, in order to curb the power of the Laconic Taranto. The geographer Strabone (I, 1, 15, C 264-265) recalls Greek hero Nestor, the legendary founder coming back from the Trojan War.

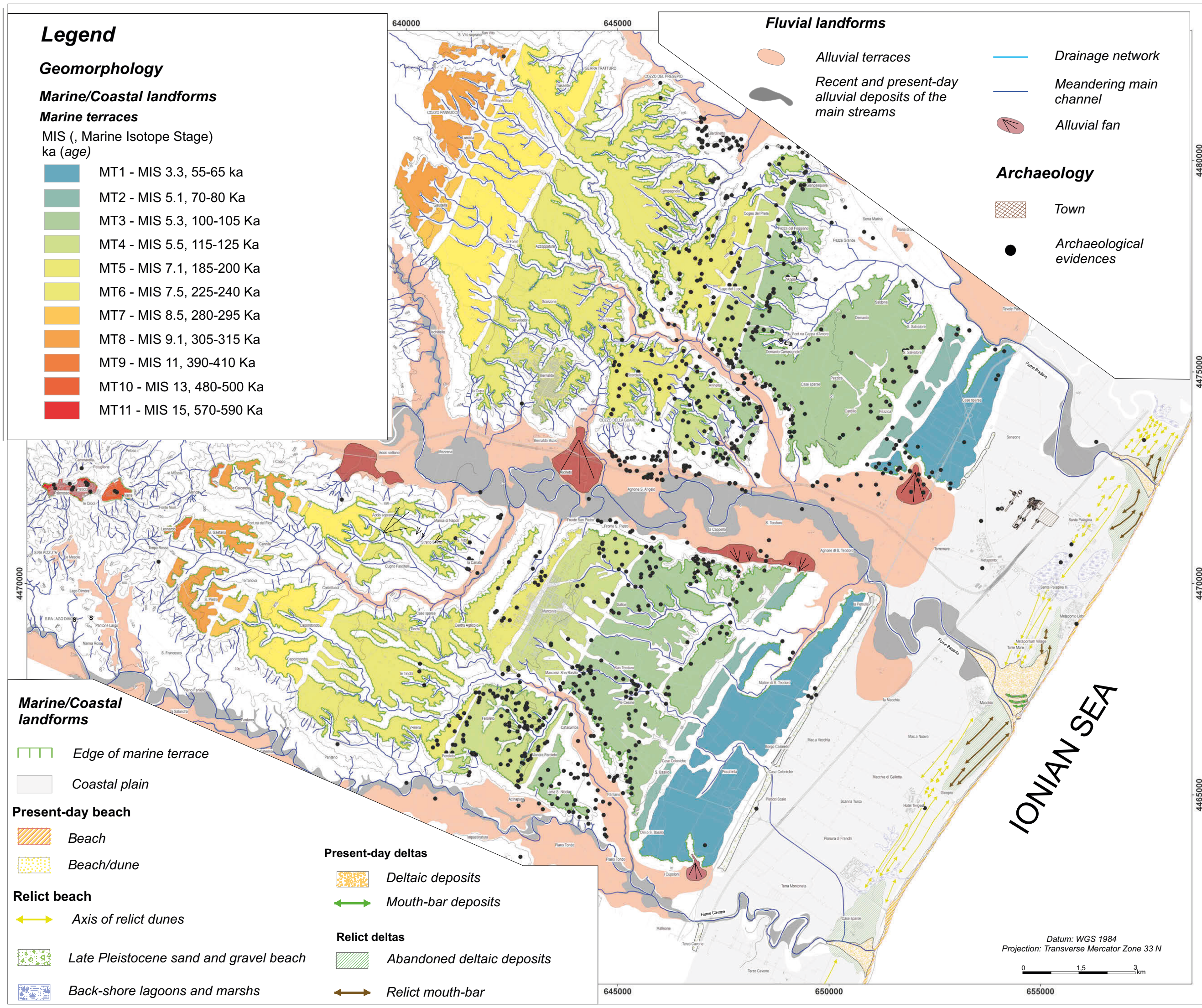

FIG. 2 - Geomorphological map of the study area and spatial distribution of surveyed archaeological sites.

The new *polis* - surrounded by the coastline, the Bradano and the Basento rivers - was endowed with a regular and well-structured layout. It had a network of orthogonal streets with a main axis (*plateia* A) arranged along SW-NE (about 22 m wide). In addition, it was divided into three major functional areas: i) a public space, *i.e.* an *agorà* with an *ekklesiasterion*-theatre, ii) a sacred area, *i.e.* a sanctuary with monumental temples dedicated to *Hera*, *Apollo*, *Athena* and *Artemis* and iii) a private residential area. Not far from the North Gate, but still inside the city walls, is set the *kerameikos* (artisan area) which consists of a series of rectangular rooms, circular kilns, water channels, pits and numerous drain holes (Carter, 1990; De Siena, 1999, 2012; Giardino & De Siena, 1999). In the *Chora*, i.e. the Metaponto territory, the settlers build up the suburban temple dedicated to *Hera* (the so-called *Tavole Palatine*) in doric style (VI century B.C.). The many farms distributed within the territory (*e.g.* the archaeological sites located in Lago del Lupo, Demanio Campagnolo, Pantanello and Avinella; Carter & Prieto, 2011) represent the economic basis of the colony. Landscape also exhibit several anthropic alignments, likely explained as agrarian division lines or canals to reclaim lands, and burial areas (*e.g.* Ricotta, Crucinia, Casa Teresa and S. Salvatore sites) likely interpreted as *necropolis* (Carter & Prieto, 2011). The Roman conquest, after the defeat of *Pyrrhus* and Taranto (battle of *Heraclea*, 280 B.C.) and the alliance with Hannibal (207 B.C.) led to gradual decline of Metaponto and the narrowing of the urban area within the walls (*Castrum*).

METHODS

The archaeological geodatabase

Geoarchaeological research has been carried out in the frame of the multidisciplinary MeTIBas project (the Italian acronyms for Innovative Methods and Technologies for the Cultural Heritages in the Basilicata region), funded by the European Community. Archaeological investigation has been carried out through a re-examination of literature bibliographic and archive data (Adamesteanu, 1973, 1986; Adamesteanu *& alii*, 1975, 1977; Carter, 1990; 2008; De Siena, 1986a, 1986b; 1999, 2001; Osanna, 1992, 1996, 1999, 2001; among others) and new field surveys, which has permitted to individuate and mapping a total number of about 1480 archaeological sites (fig. 2). A large amount of collected data has been stored in a GIS environment and grouped in the following categories: village, farmhouse, necropolis, productive area, settlement, kiln, public area, sacred area, sanctuary, kiln, fortification, *villas*, votive ditch, channel, and prehistoric site. In order to investigate the settlement dynamics and their possible relationships with environmental and geomorphological factors, the chronology of first evidence and the disappearance of the archaeological sites have been defined according to the following chronological scheme:

– SP: Prehistoric and Protohistoric Ages (Neolithic 10-5,7 Ka BP; Bronze age 4,2-3,1 Ka BP; Iron age 3,1-2,9 Ka BP);
– FC: Age of colony's foundation (625-575 BC = 2,57-2,52 Ka BP);
– EA-EC: from the Archaic to the Classical Age (575-525 B.C. =2,52-2,47 Ka BP - 525-475 B.C. = 2,47-2,42 Ka BP);
– EC-EE: from the Classical to the Hellenistic period (475-275 B.C. = 2,42-2,22 Ka BP);
– EE-ER: from the Hellenistic Age to the Roman period (275-175 B.C. = 2,22-2,12 Ka BP; 150-50 B.C. = 2,1-2,0 Ka BP).

Extraction of the landform unit map and analysis of the relationship between landforms and archaeological evidences

Local topography and landscape features are often described as the most important parameter driving the location of an archaeological site (Tilley, 1994). In order to extract information about the settlement preferences and rules based on topographic and landscape features of the Metaponto area, we firstly carried out an automatic classification of landscape using the Topographic Position Index (TPI, De Reu *& alii*, 2013 and references therein). Among the different methods of automatic extraction of landform units such as the morphometric feature parameterization (Fisher *& alii*, 2004; Ehsani & Quiel, 2008) or SOM (Self Organizing Map, Kohonen, 2001; Ehsani & Quiel, 2009), the TPI method is widely used in geoarchaeological research due to its ability to define the relative topographic position of an area with regard to its surrounding sectors. In fact, TPI estimates the difference between elevation at the central point and the average elevation around it within a predetermined radius (De Reu *& alii*, 2013; Deumlich *& alii*, 2010). Positive TPI values indicate that the point has an altitude higher than the average ones in the surroundings

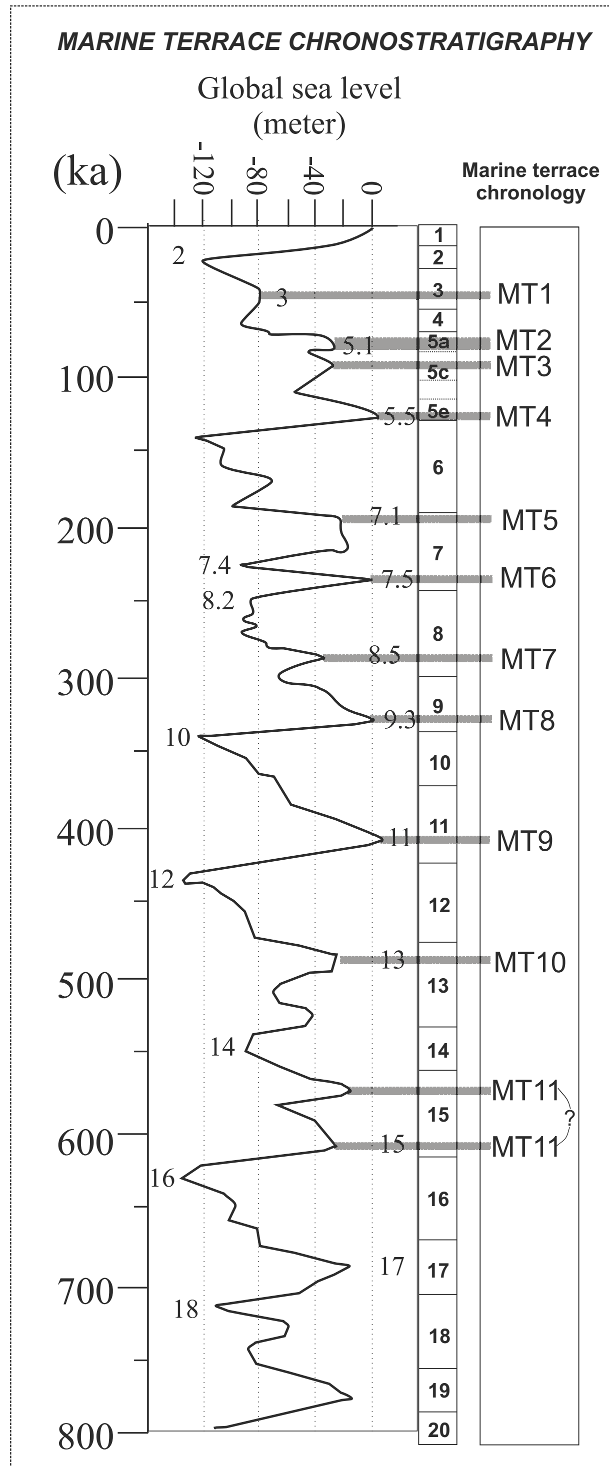

FIG. 3 - Chronostratigraphy of the marine terrace staircase of the study area.

whereas negative values are representative of a pixel with a lower altitude than the average of the search radius. TPI values are strongly influenced by search radius and large search radius highlights major landscape units, whereas detection of minor landforms should be performed by using a small radius. To select the most appropriate parameters in TPI-based automatic classification, we compare TPI values for different search radius with landform detected through geomorphological analysis and we selected a radius of 25 m for the study area.

Results of the semi-automatic classification of landscape based on TPI revealed that this approach is not able to differentiate the gently-dipping or horizontal landforms of different origin (i.e. marine terrace surfaces and alluvial/ coastal plain). Thus, we integrated the information gained by such a DEM-supported landform unit extraction with data coming from classical geomorphological analysis and mapping. Geomorphological analyses have been mainly focused on the definition of the different generations of Quaternary marine and fluvial terraces. After a revision of literature data of all the principal works available in literature which deal with these morphological features (Brückner, 1980; Caputo *& alii*, 2010; Zander *& alii*, 2006; Westaway & Bridgland, 2007; Sauer *& alii*, 2010; Piccarreta *& alii*, 2011; Tropeano *& alii*, 2013; among others), we performed and mapped at scale 1:10,000 an ex-novo study based on the analysis of aerial photos of different ages and on field survey. Although in terms of mapped terraces similarities exist with the previous works, our new mapping and the consequent new numbering (MT1 to MT11 from the youngest to the oldest terrace) should produce misunderstandings in comparing our results with the previous ones. Figure 3 shows the complete sequence of middle-late Pleistocene marine terraces and their inferred absolute ages, which have been defined by a critical revision of the chronological data available in literature.

After a conversion of the geomorphological map in a raster with a resolution of 5 m, we have combined the two raster datasets using the map algebra tool.

Landform unit map deriving by such an approach consists of 17 classes (fig. 4) and allows us to investigate, in a quantitative way, the topographic location and settlement pattern of the archaeological sites of the study area.

RESULTS

The study area is a relatively homogeneous landscape, in which several orders of marine terraces with similar topographic features (i.e. planar surfaces gently-dipping toward the sea) are arranged in a staircase geometry, ranging in elevation from about 400 m a.s.l. to 10-15 m a.s.l. The staircase of terraces is deeply cut by a minor drainage network, which is mainly developed according to a trellis pattern, especially where sand and conglomerate of the marine coastal wedges crop out. The drainage network is more developed and arranged in a dendritic scheme in the south-western sector of the study area, where marine silty clay largely crop out. In this area, badlands are widespread. Other significant morphological elements of the study area (fig. 4) are the coastal plain and the alluvial plains and related terraced areas of the main streams.

The adopted procedure of overlay of the TPI and geomorphological maps (fig. 4) allowed us to define all the above-mentioned geomorphological elements. TPI map with a search radius of 25 m captured well the V-shaped valley related to the entrenchment of the fluvial net and steeper slope areas (fig. 4). On the contrary, gently-dipping morphological elements such as marine terraces, coastal plain and alluvial plains of the landform unit map are defined by the geomorphological mapping. Figure 4A illustrates the amount of area covered by each landform unit: the flat coastal plain area is the largest class, with a total area of about 63 sq. km. Approximately 56 sq. km of the study area falls into the classes of the alluvial plain and the floodplain of the main rivers, whereas V-shaped valleys cover an area of 16 sq. km. Other widespread landforms are MT3 - MT5 marine terraces and steeper (i.e. > 15°) or/ and gentle (< 15°) slope areas covering a surface ranging from 25 to 34 sq. km.

Figure 4B shows the distribution of archaeological sites for category, where one can observe that the most representative class is the farmhouse (42% of the total site). Prehistoric sites and necropolis are the other relevant archaeological evidences, with a percentage of 15% and 25% of the total sites, respectively.

Statistical analysis of the spatial relationships between archaeological site location and landform units has been carried out in order to determine whether there is a significant correlation between site location and specific geomorphic elements. Simple frequency analysis (fig. 5) demonstrated that there is a non-random distribution of archaeological sites, which are preferentially located on mid-altitude marine terraces (MT3, MT4, MT5 terraces, fig. 5). Gentle slope areas and alluvial terraces of the main streams and their main tributaries are other preferential locations of the archaeological evidence. Frequency distribution of archaeological sites for chronological period (fig. 6) provided some additional results about the initial territory occupation and the dynamics of settlement rules during the Greek colonization. We can in fact observe a significant occupation of the coastal plain areas during the foundation of colony (FC period) and a gradual and significant increase of the number of archaeological sites (mainly farmhouses) on the top of MT3, MT4 and MT5 marine terraces from the spreading of the Metaponto colony up to the Classical-Hellenistic ages (FC and EC-EE in fig. 6, respectively), when human presence becomes dramatically strong. The preferential occupation of the marine terraces MT3 and MT4 MT5 suggests that on these landform units better conditions for a massive development of agricultural practices can be found, likely due to well-developed soil profiles. Farmhouses in the Metaponto territory indeed increased from 39% of total sites during FC age to 63% during the EA-EC period (about 2520-2420 yr before BP) and, according to literary sources and archaeological researches (Carter & Prieto, 2011; De Siena, 2012), Metaponto was affected by economic growth and a massive increased in population from Archaic to Classical ages (De Siena, 2012). The migration of settlements from low-altitude areas towards marine

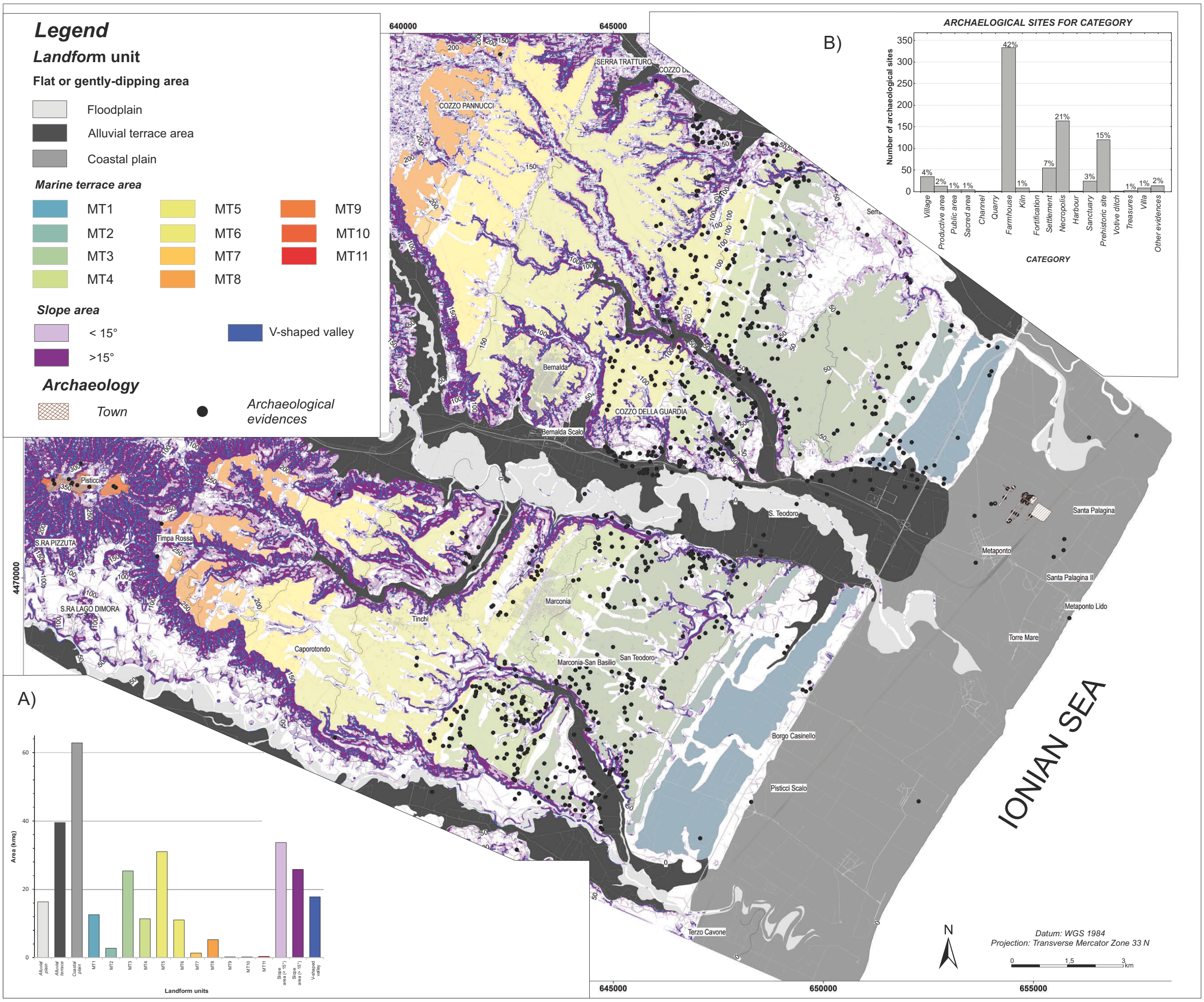

FIG. 4 - Landform unit map obtained by the integration of geomorphological analysis and by the supervised classification of landforms based on TPI method. Spatial distribution of archaeological sites is also shown. Graphs showing the surface area of the different landform units (A) and the number of archaeological sites for category (B).

terraces during the EA-EC period can therefore be related to the spreading of agriculture.

During the Classical and Hellenistic ages, a relevant increase of sites located in the alluvial terrace areas has also been observed. Although further studies are required, this trend of site dynamics and changing of settlement rules could be related to a landscape evolution coupled with historical causes. The latest stage of Metaponto hystory is in fact featured by a significant decrease of human occupation and the arrival of the Romans in this area marks the final decline of the ancient town and its *Chora*: Metaponto suffered a significant contraction (only the *Castrum* area is inhabited) and the territory is progressively depopulated.

Neboit (1980; 1984) recognized the occurrence/acceleration of alluvial deposition in the main rivers from the study area during the Greek–Roman period, suggesting a possible increase of erosion processes within tributary catchments due to changes in land use and extensive agricultural practises. Recent work based on a detailed morphostratigraphic analysis of the Basento river lower reach (supported by tephrochronology and radiometric dating) demonstrated that filling and downcutting episodes were predominantly climate-driven, with a minor role of anthropogenic impact (Boenzi & *alii,* 2008). The Authors reconstructed a phase of alluvial deposition starting at about 2800 cal. yr. BP interrupted by a period of deposition stasis at about 2500 cal. yr BP. This period - which roughly corresponds to the transition from FC to EA-EC period (fig. 6) - was followed by an alluvial sedimentation continued at higher rates until 1620 cal. yr BP (Boenzi & *alii*, 2008).

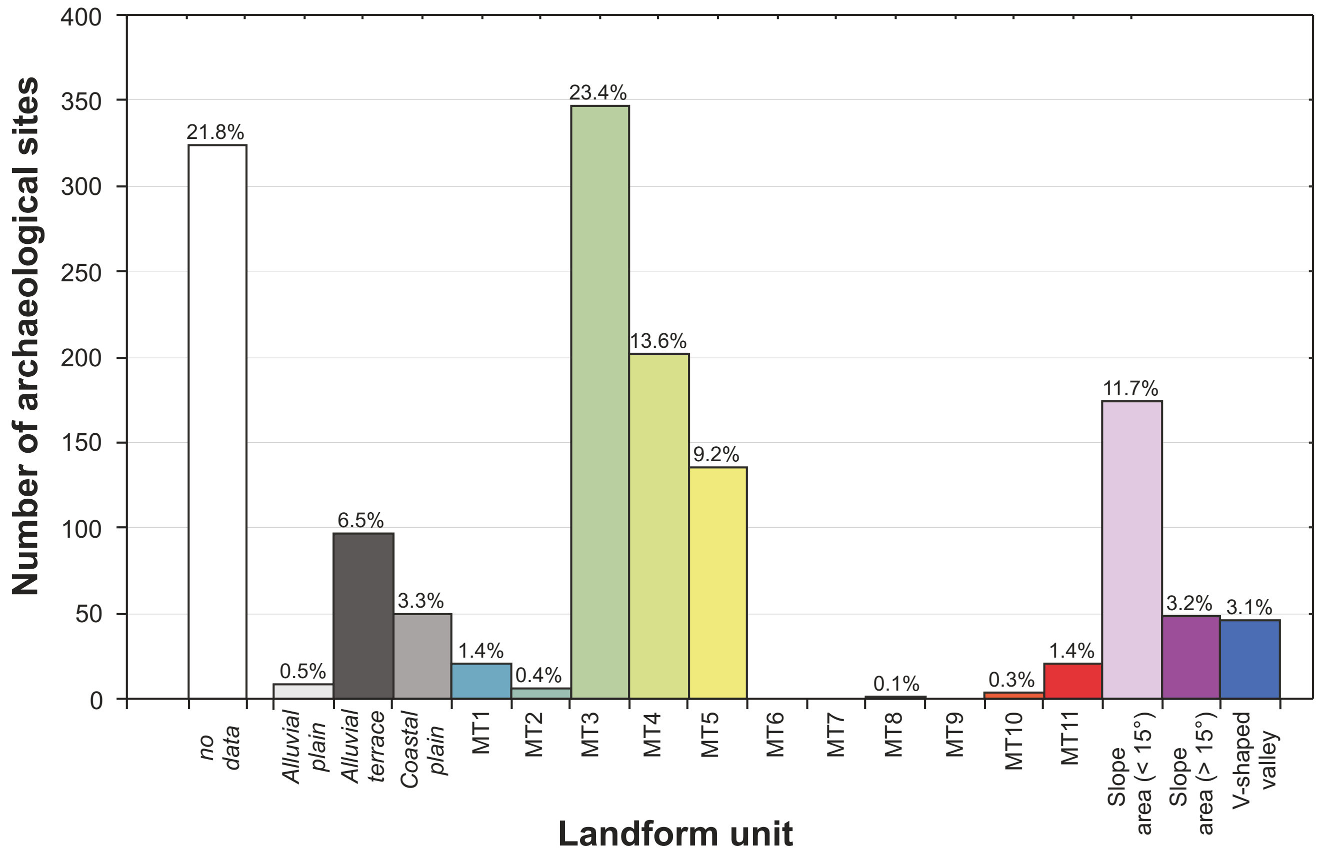

FIG. 5 - Frequency distribution of archaelogical sites for the different landform units.

On this basis, our results indicating an increase in farmhouses on the top of marine terraces from the FC up to EC-EE periods and modifications of settlement distribution in the Metaponto area could be therefore related to the acceleration of alluvial processes. On the other hand, the progressive decrease of human occupation during the Hellenistic up to the Roman Age is clearly consequence of the beginning of the decadent phases coupled to the Roman conquest, but a role played by the increase in flooding occurrence in the coastal plain/floodplains of the main rivers (Boenzi *& alii*, 2008; Piccarreta *& alii*, 2011) should not be neglected.

Finally, archaeological sites located on the top of marine terraces are preferentially distributed near the terrace edges. As a matter of fact, the graph of Figure 7 shows the minimum distance between archaeological sites and marine edges and highlights that about the half of the archaeological sites is located at a distance lower than 150 m to terrace edges, whereas the 85% of the total sites located on the marine terraces are within a distance from terrace edge of 380 m. This preferential distribution could be related to a defence or visibility exigencies.

CONCLUDING REMARKS

The study area is a relatively «simple» landscape, since it is featured by a regular staircase of gently-dipping marine terraces deeply cut by three main meandering-type rivers and their minor tributaries. The automatic classification of landforms based on TPI index suffers some limitations such as the influence of the search radius, the difficulty to capture small and large landforms together and the impossibility to differentiate the several generations of similar landforms. The approach here adopted is based on a GIS-supported procedure consisting of data overlay coming from DEM analysis and traditional geomorphological mapping and it overcame the above-mentioned limitations. The landform unit map deriving from such an approach has been used i) to investigate the complex interactions between man and environment through time and ii) to infer settlement rules and factors driving the site selection, iii) to understand the influence of Holocene geomorphological evolution on archaeological site modifications in the Metaponto area.

Our analyses highlight that archaeological sites are preferentially distributed on gently-dipping marine terrace surfaces and near their edges, and it can be assumed that the site selection was at least partially driven by this topographic position.

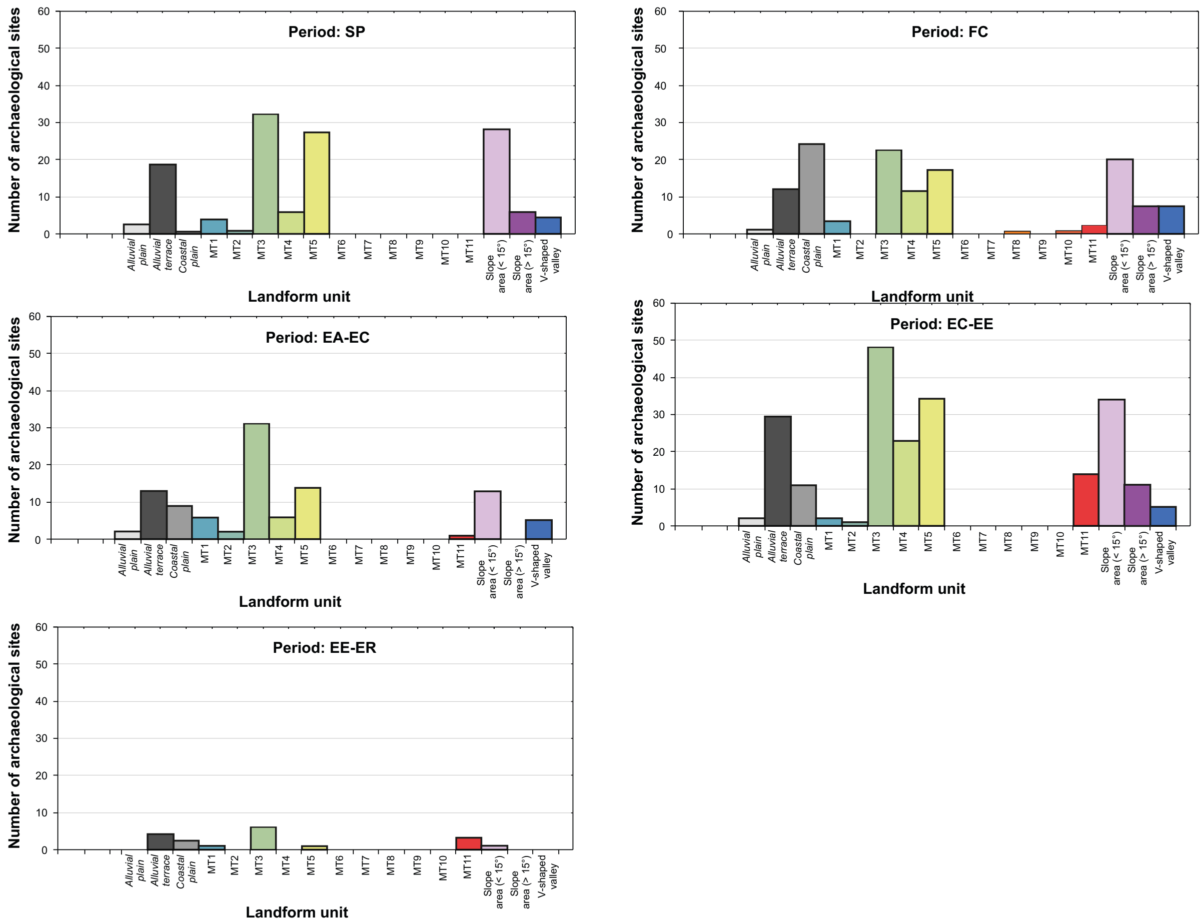

FIG. 6 - Statistical relationships between archaelogical sites and landform elements for the different chronological periods of the Greek and Roman occupation.

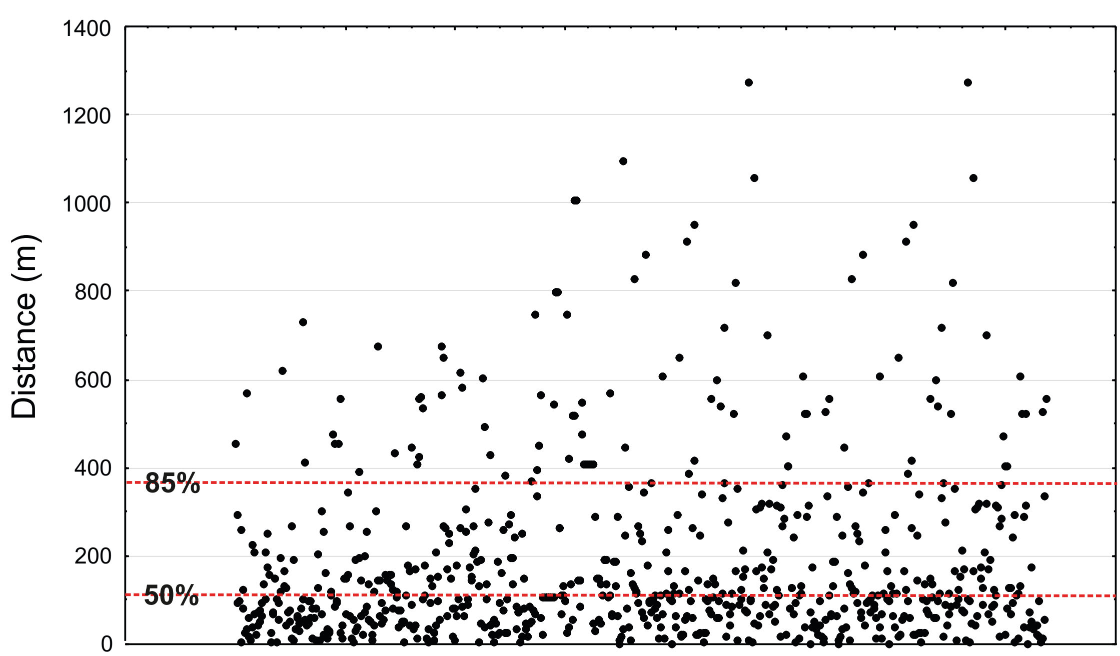

FIG. 7 - Graph showing the minimum linear distance between archaeological sites located on the top of marine terraces and terrace edge.

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