CHNT 18 Proceedings

The documentation of archaeological data

Problems in modeling the spatial, temporal, and typological dimensions

Francesco Uliano SCELZA

University of Salerno, Italy

Abstract: This paper describes a proposal for modeling the spatial, temporal and typological dimensions of archaeological data. The proposal is developed on the basis of a formal approach. That is to say with the aim of building a *coherent* system, *complete* and *multi-level*, where the archaeological sources are classified according to stable principles and led back to unifying concepts, able to satisfy the degree of the material evidence. Each source is a testimony of an activity localized in space, time and usage. These dimensions are not unique. They generate a non-linear function of three co-variables. The result of this function is the landscape (urban or rural): an area, anthropized, and historically determined. The problem concerns the need to unify the various available sources, bibliographic, archival, systematic, unsystematic, which are related to each type of discovery. The system consists of a section where the logical and functional constraints of the data are developed in the form of a database, and of an operating GIS environment, made up of 4 coordinates, 3 for space and one for time. The purpose is to analyze the spatial distributions of human activities throughout time, and to document their variabilities. It is a structure that represents and analyzes the chronograph (time, date, etc.), the spatiality (location, size, morphology), and the functionality of archaeological finds. This system was created to manage a wide mutability, since each entity changes in shape, size and location, and has a beginning and an end, a varied role, nature and behaviour. The system was tested during a PhD thesis about the study of population dynamics in the Archaic period in southern Italy.

Keywords: Database; GIS; Spatio-Temporal Modeling

Introduction

The contribution concerns the testing of a space-time model built within a GIS platform. The work starts from a PhD research that has just been completed (fig. 1). The research investigates the spatial organization of the ancient societies between the seventh and third centuries BC settled in Campania and Calabria. This portion of territory is the object of the Greek colonization and the seat of well-organized indigenous communities. According to an established pattern, Poseidonia is an agrarian *polis* (GRECO 1979; GRECO-STAZIO-VALLET 1987; GRECO1992; LONGO 1999; CIPRIANI 2002), Velia is a commercially-oriented city (GRECO 1975; BENCIVENGA TRILLMICH 1990; MADDOLI-STAZIO 1990; GRECO-VECCHIO 1992; DE MAGISTRIS 1995) and we know too little about the oldest settlement of Laos to be able to insert it in one of the two categories (GRECO-GASPARRI 1995; GRECO 1996; LA TORRE 1999). We know however, that Laos was the seat of the sybaritic people after the destruction of their *polis*.

My investigation was able to demonstrate the existence of different settlement systems and to assess their function and evolution.

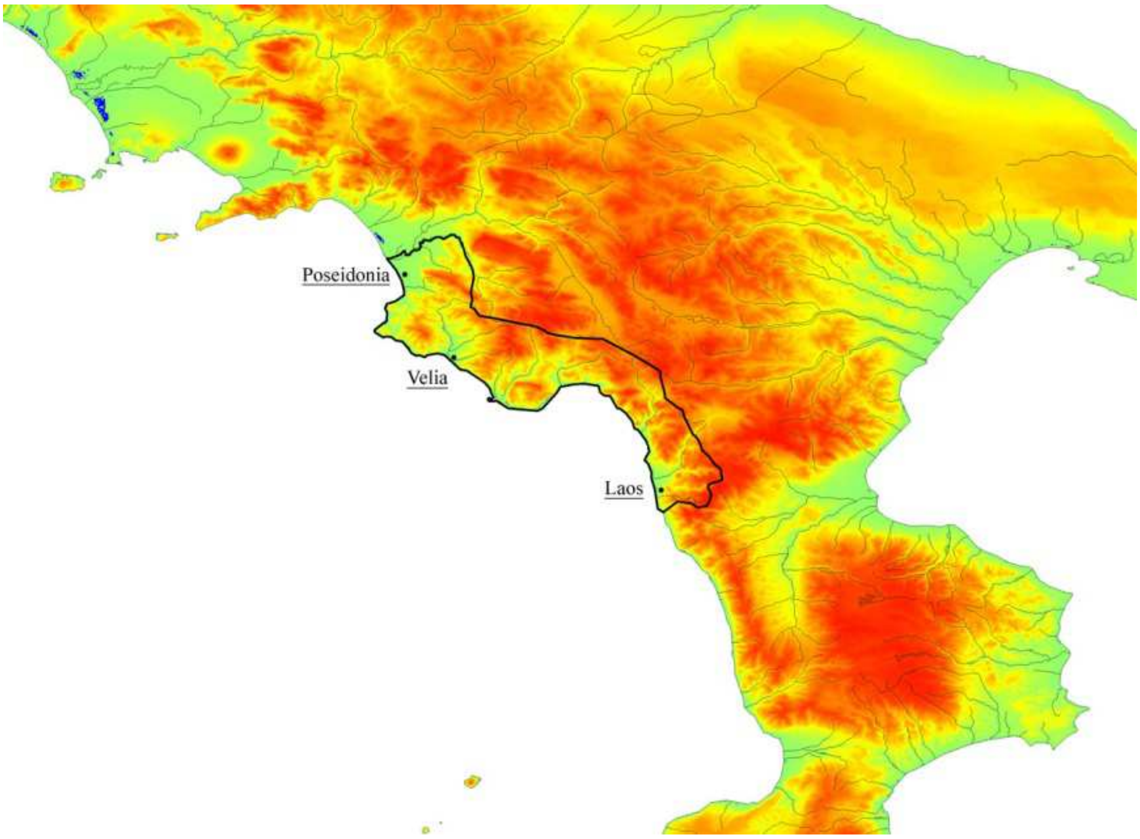

Fig. 1 – The tract of the coastal area of southern Italy included in the study

By adopting GIS software I have built a spatial base including all sources of ancient populations. However, the main problem is the management of archaeological sources that testify activities that take place in a particular space, at a given period and according to a function. These three aspects, space, time and function, are not unique. This means that the data dimensions are a function of three non-linear variables. My intention was to build a multi-dimensional model in which the behaviour of these characters is simulated in order to produce new interpretations. The system goes beyond the constraints of traditional territorial modeling and produces an instrument which controls the archaeological presence in the territory, useful for the protection and management of the heritage.

The work analyzes several different types of sources, which poses a general problem about the possibility of managing a multiple information base. We have to apply and organize the data with the objective of understanding ancient systems of population. Above all we must build a data system.

The scientific and philosophical investigation of the nineteenth and twentieth centuries on the concepts of 'system' and 'structure' has identified several critical points regarding an information system.

They concern:

-the value of the evidence;

-the types of associations;

-the capacity to represent the evolution of reality;

-the consistency and completeness of the information.

In archaeology, the consistency binds the composition of the source and the existence of specific activities; the completeness regards the availability of information and, above all, its entirety.
In the area of our interest, all archaeological studies of the past come from information systems, more or less explicitly expressed. They are built on assumptions or generalizations of the sources and consequently they have limits of consistency and completeness. The main features of the traditional approaches can be summarized in the following scheme:

- Generalization of the relationship between environmental and physical characteristics of the area and archaeological sources
- Lack of quantification
- Generalization of the time variable
- General uncertainty in the definition of the spaces exploited in ancient times
- Proliferation of terminologies that identify the use destination and interpretation of archaeological sources.

For these reasons, I adopted a multiple documentary base (organized in a DB and a GIS) capble of acquiring data from different information systems and also able to integrate the actual archaeological works with previous researches.

Data Model

The model is built on a main entity that has the value of connecting and unifying the various available sources. It is called the context. The context manages the resources coming from tradition and leads them to an immediate relationship with the plan of the current investigations. It is a scope of discovery: a bibliographic entry, an unpublished data etc. (fig. 2).

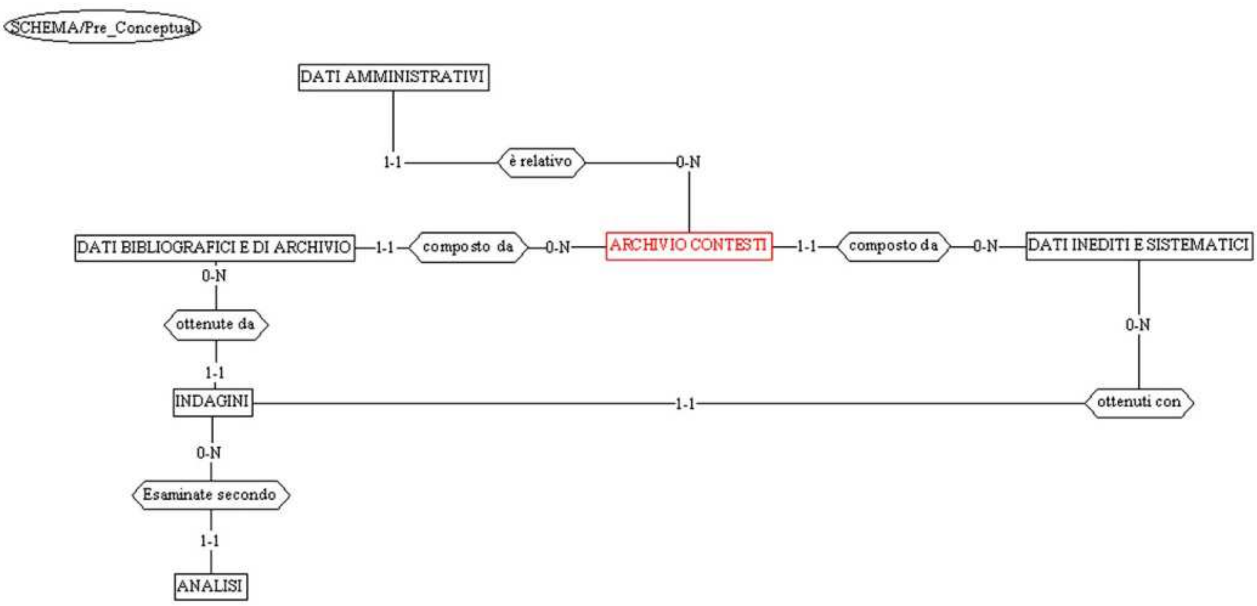

Fig. 2 – Data Model: conceptual scheme

The model has three levels (fig. 3). The first, the most general, collects information related to the context of discovery. The data are synthetic and general. The second, or intermediate, records the investigations that have guided the creation of the data: excavation, survey, remote sensing, and so on. In the third level, the analytical one, we find quantified data relating to each entity found during the investigation. The combination of levels makes up the context. The information structure allows updating without the need to re-modulate the topography. It proposes to compare and to integrate the data, collected at different times with different methods.

Each record corresponds to one or more type of discovery, each of which is linked to specific information on the composition, history and interpretation of the source.

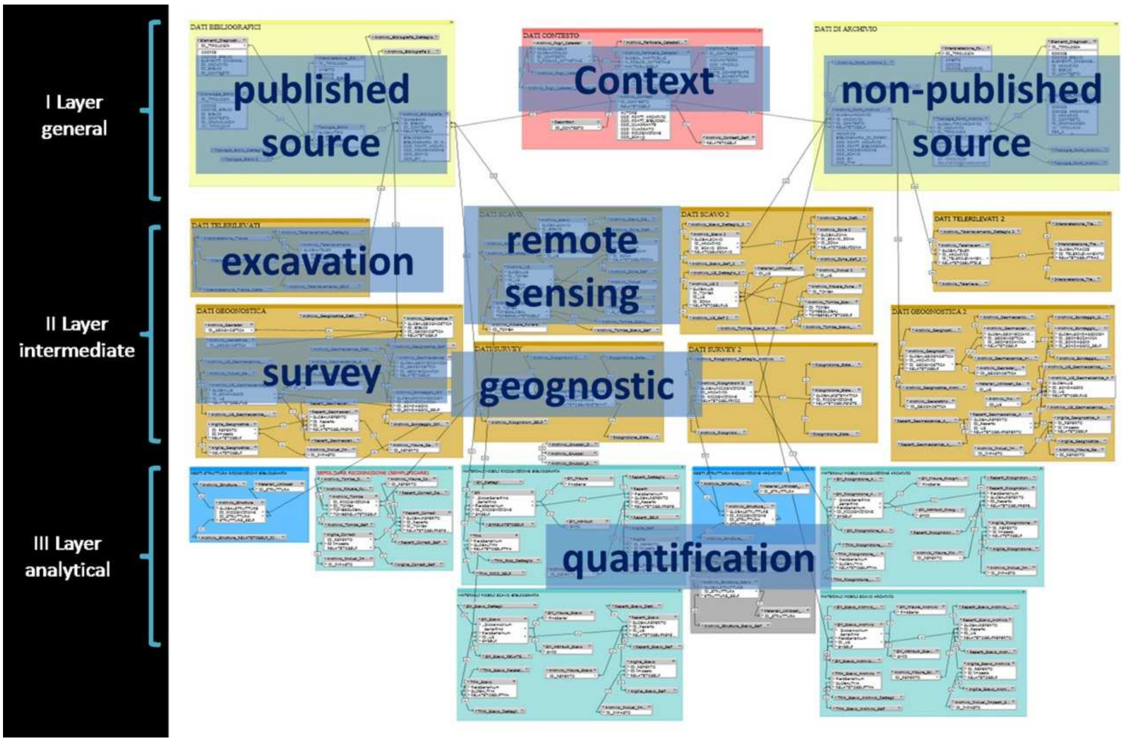

Fig. 3 – Data Model: relational scheme

The chronological and spatial aspects of the data are classified according to different levels of imperfection. I have set up five levels of imperfection:

-the degree of spatial precision;

-the type of spatial configuration;

-the degree of accuracy of the chronology;the type of chronological accuracy;

-type of duration.

The data are a portion of a physical place, the context. They are defined by three co-variables: time, space and function, acting as measurable entities. Any variation in one of the levels, changes the cognitive value of the data and creates the historical entity.

The information, recorded and archived in the documentary base, takes a place in a geographic space, which reproduces the characteristics of the territory. The DB, from this point of view, is the engine that drives the GIS and creates maps.

The three levels of the DB, analytical, intermediate and synthetic, have been translated into three levels of viewing. The union and overlap of the levels create the contexts as a fusion and an integration of different levels of information: general, intermediate, and analytical (Fig. 4). Each spatial plan is related to tabular information. From the point of view of temporality the data are sorted to express duration, periods of time and dynamic relationships.

The data structured according to logical constraints of the database must keep significant quality within the geographical information system. The critical point is the ability of GIS to manage the documents without betraying the historical and archaeological value of the data. It is important that the geographical model does not introduce a different orientation than that provided by the formal scheme of the database. In the conceptual scheme the context is a multidimensional entity, formed by an indefinite number of attributes: an informative source that interprets the territory at different scales, both temporal and spatial.

In other words, the transfer of data in a geographic framework changes the archeological documents in spatial data, and the spatial scene assumes the value of the landscape as a result of historical dynamics. In the same way, the diachronic movement of the landscape forms a complex system, difficult to perceive through the analysis of isolated events and elements, which are a-temporal and abstract.

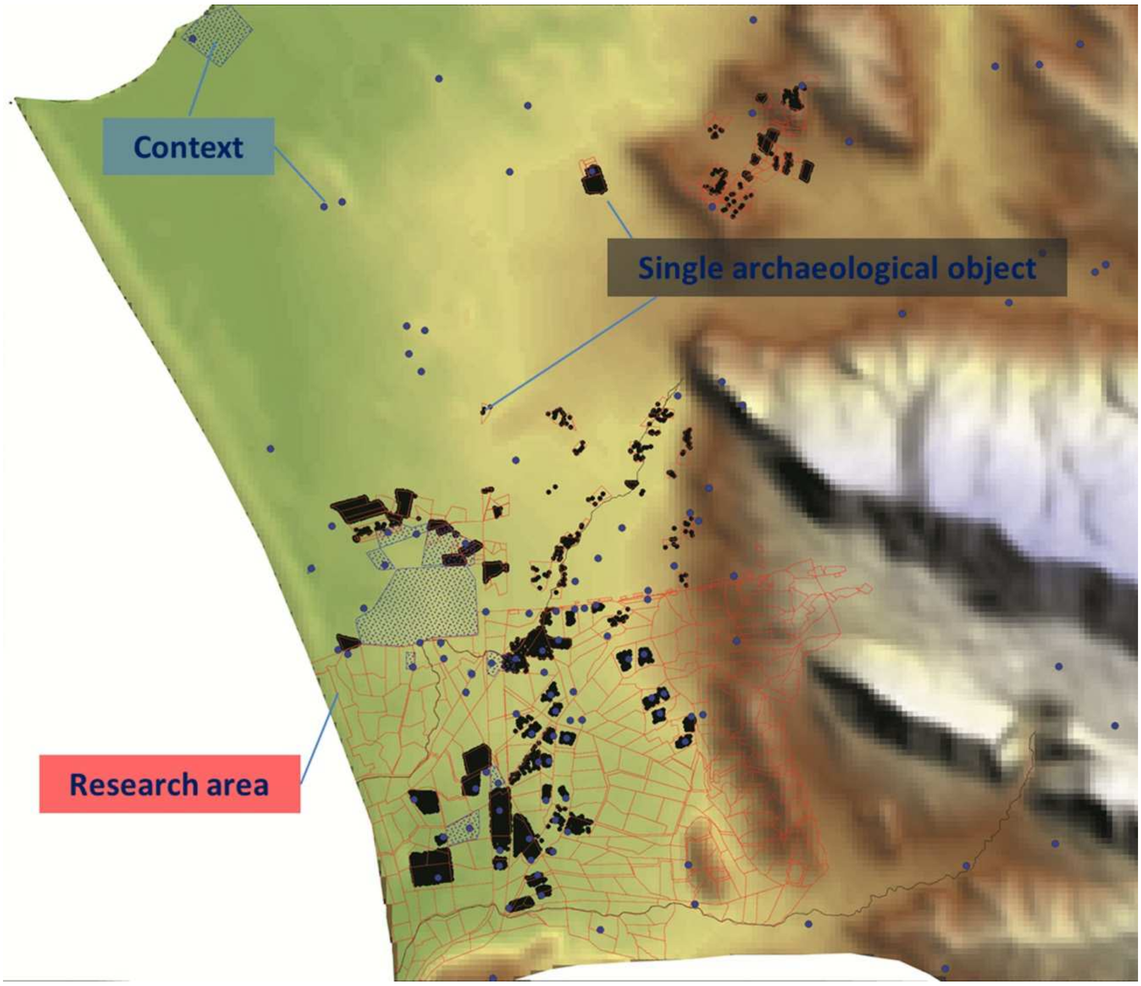

Fig. 4 – Multi-level data distribution

Dealing with time and space

There are no great problems to manage the space. Instead, there are many relating to time. Even more significant when referring to space-time.

Conventional GIS does not always correspond to the needs and to the objectives of archaeological studies. In most cases, temporality can be expressed only as individual fixed states, or as a series of distinct and superimposed stages. In other words, the temporal detail is generally alien to most common conventional GIS.

These limits of a timeless space involve problems of conceptualization and representation. The problem is to give shape to the time as a tool of analysis. The inadequacy of GIS involves at least three main aspects. The first is related to the cartographic origins of the technology that operates with fixed and non-dynamic attributes. Secondly, the inability to represent the reasons of change that exist between different states, because the representations of space overlap only in discrete terms. Finally, its dependence on a table structure where each data item is associated with stable values that prevent exceeding a fixed orientation of the instrument.

Overcoming a space intended as a support means, first of all, the management of interactions both in space and in time. It means addressing fundamental aspects of dating methods and the connections between human activities and the composition of each structure of the landscape.

The geographical research has, for a long time, devised various data models (FREELAN 2003). But in all cases the geographic analysis does not define the difference between the object, the event and the process. Moreover, the geographical models lack an explicit reference to the plurality of time, understood as a unit of measurement and as periodization.

The archaeological dates are inaccurate, expressed through ranges, in constant revision: The events and processes are constructed from the objects, but the latter are arranged in multiple scales, rhythms and directions of time. In the field of archeology there are some experiments that directly address some of the issues of time. Among the most recent and significant, the application TGIS developed by C. Green as an extension of ArcGIS software (GREEN 2009).

The program responds mainly to the following question: what is the probability that a document belongs to a time interval?

In addition, the TGIS allows the formation of periods, based on the management of some parameters of probability and on the definition of degrees of change (fig. 5).

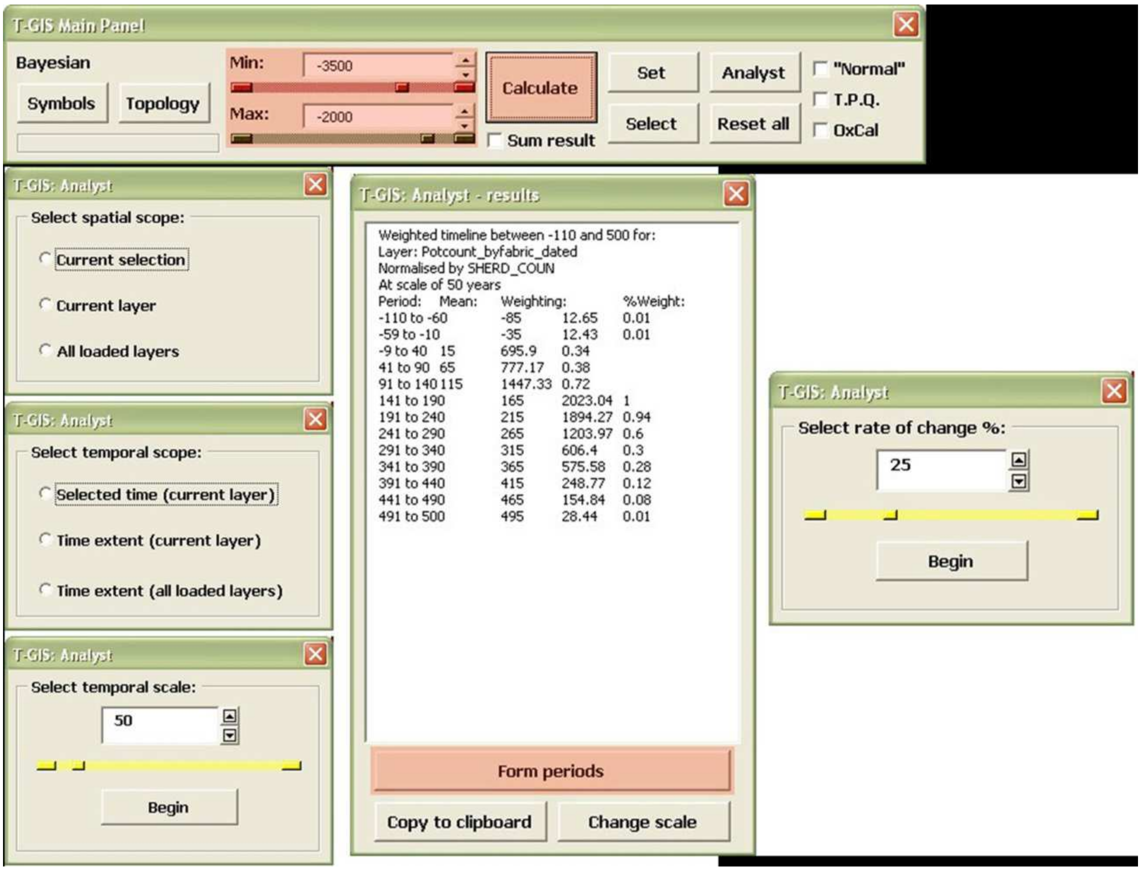

Fig. 5 – Green's TGIS platform

The TGIS does not work on time durations, on extensions in time of the activities or anthropic processes. In my work, the goal is not the mere management of the chronology, but the construction of time periods or phases. Most importantly, how they constitute systems of land use.

The procedure of construction of the phases has a dual path: one empirical, the other statistic. The first method involves the construction of a temporal diagram of all contexts (fig. 6). The chart, made with a spreadsheet, is two-dimensional. It orders the findings on the horizontal axis and a time scale on the ordinate. The time scale has a resolution of 25 years. In this way one can see both the extensions of the findings in time and also the plurality of chronologies. The levels of inaccuracy have been treated with the distribution of different colors. The whole profile was subsequently divided in the direction of the vertical axis of y so as to form aggregations or phases.

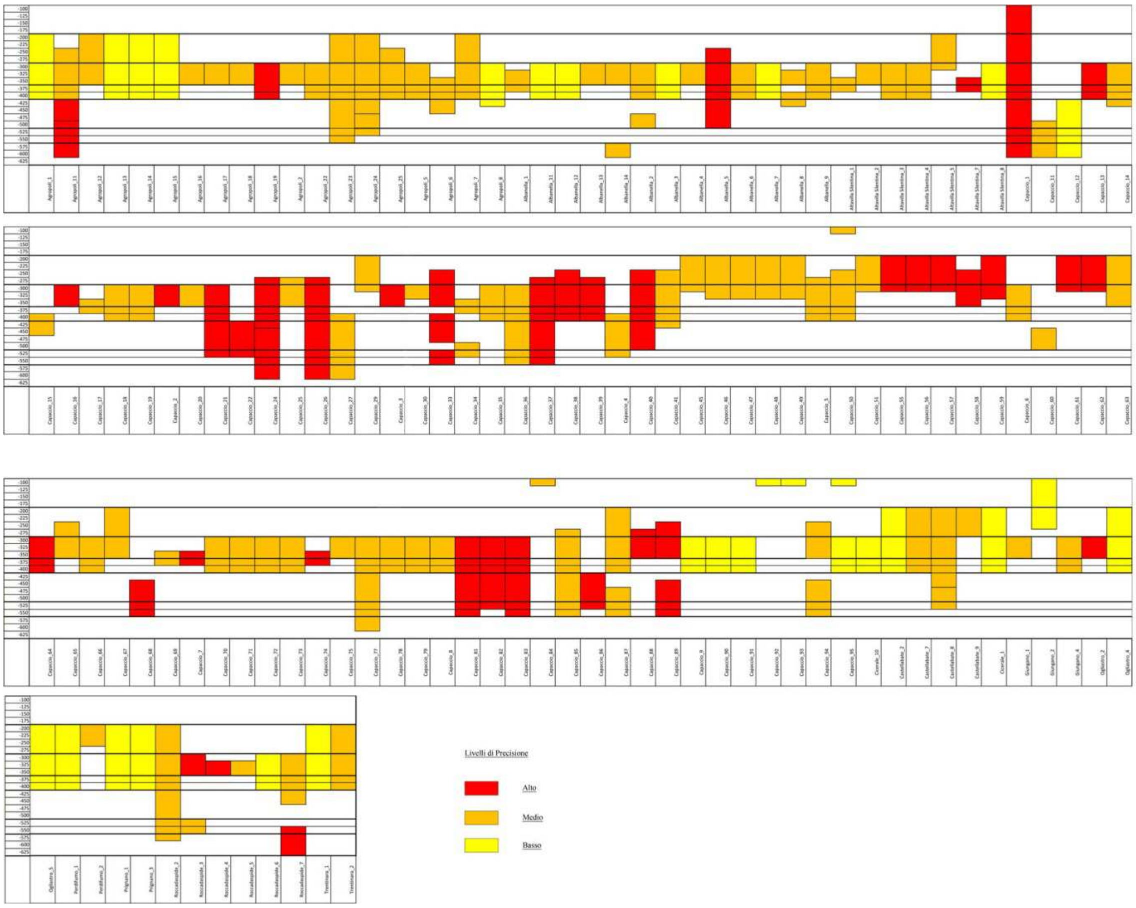

Fig. 6 – Chronographic distribution (intuitive approach)

The second method provides for the adoption of TGIS. The software builds the creations of the phases on the base of the cumulative probabilities of the entire dataset. The critical points are the choice of temporal resolution, or reference scale, and the solution of a degree of change around which aggregate data. Standard and normal distributions have been used for the processing of the data, mainly, the kind of statistical distributions built respectively on a linear and continuous model, and on the bell curve or Gaussian. I tested different types of temporal scales, 25, 50 and 100 years, and different rates of change: 25, 12 and 3%.

Comparing the two profiles, the greatest similarities are found in the rate of change of 12% (fig. 7). The scan of the intuitive dataset tends to enhance the minimal changes and to generalize uniformity. This means that multiple aggregations, estimated as distinct, may contribute to the formation of the same phase, or that between some levels of grouping the changes are minimal. In the statistical method, however, the adoption of a low degree of change almost equates the phases and the time scale, so that each phase corresponds to twenty five years.

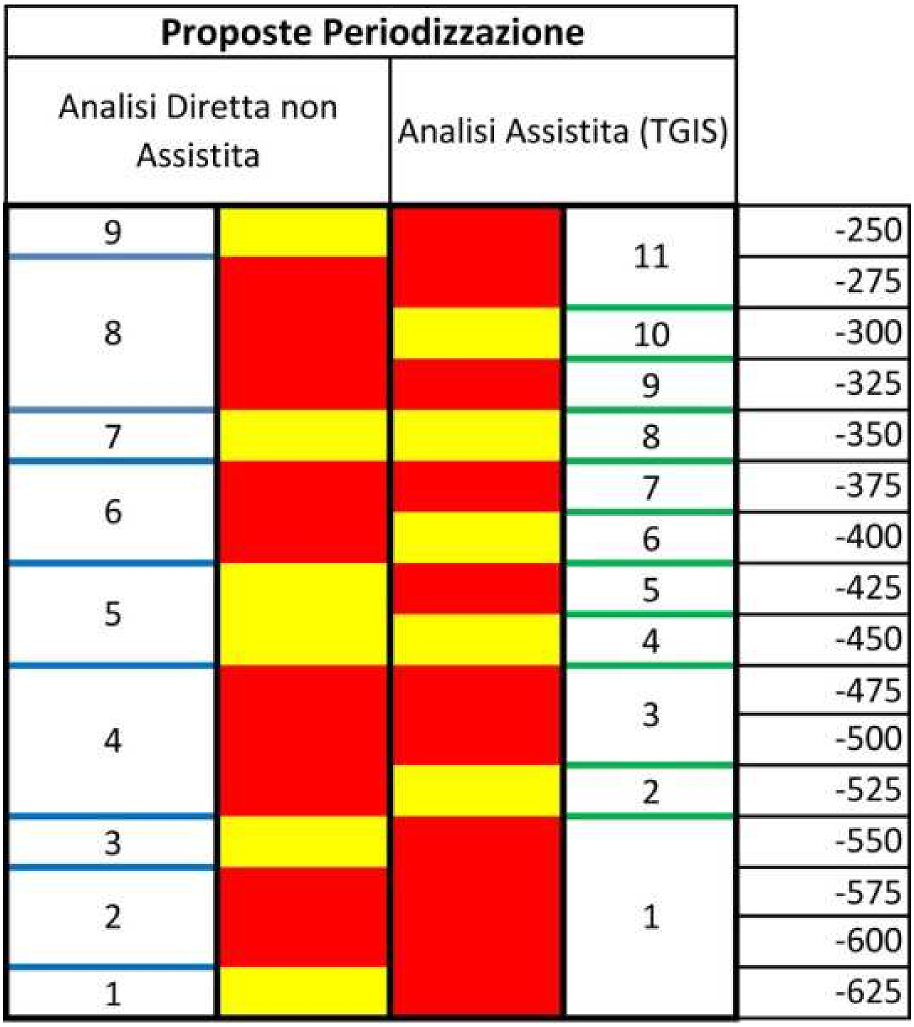

Fig. 7 – Comparison of TGIS (on the right) and the intuitive (on the left) distributions

By distributing all the data in the corresponding phases we obtain new GIS layers. The temporal range of the phases has been incorporated into the engine of TGIS in order to process all the data with respect to the limits of each period. In this way, it is possible to analyze the relationship between all the evidence and each phase. The result is a new map which contains a topological index which expresses the degree of belonging. (fig. 8). In addition, every period, processed by both methods, is subjected to the analysis of trends (fig. 9). Each level so formed is subsequently thematised according to interpretative and typological values.

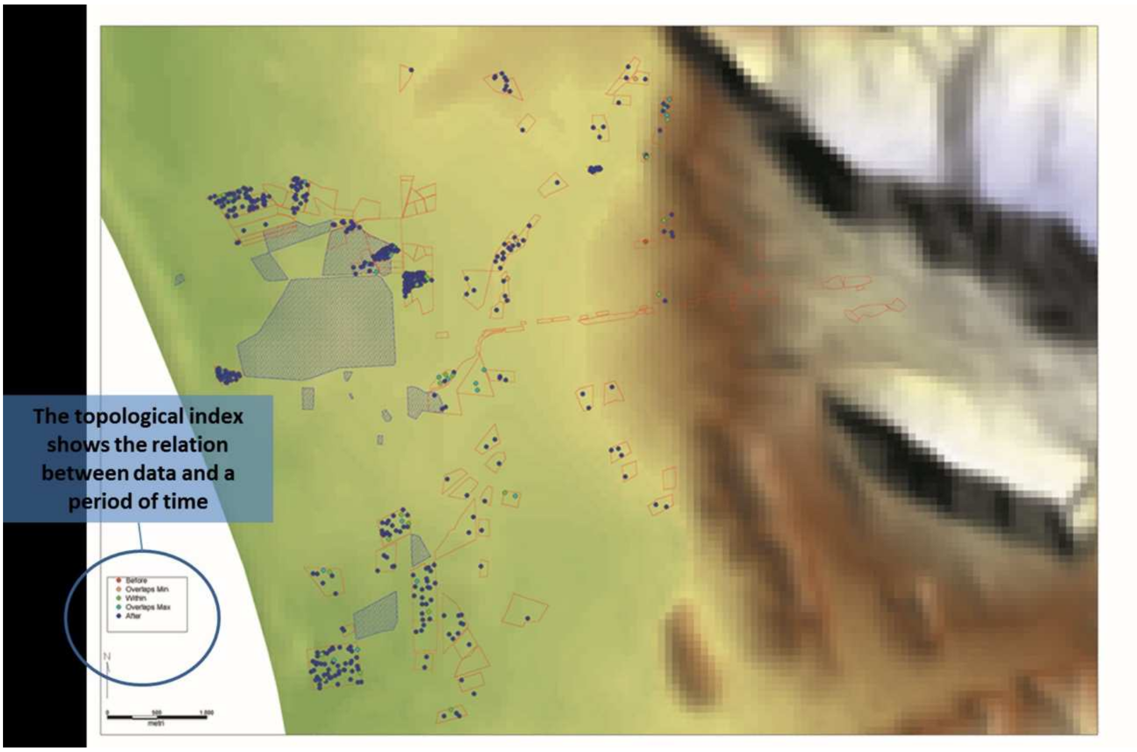

Fig. 8 – Statistical processing of time series data with the application TGIS. The colors indicate the topological relationship of the data with respect to a temporal range

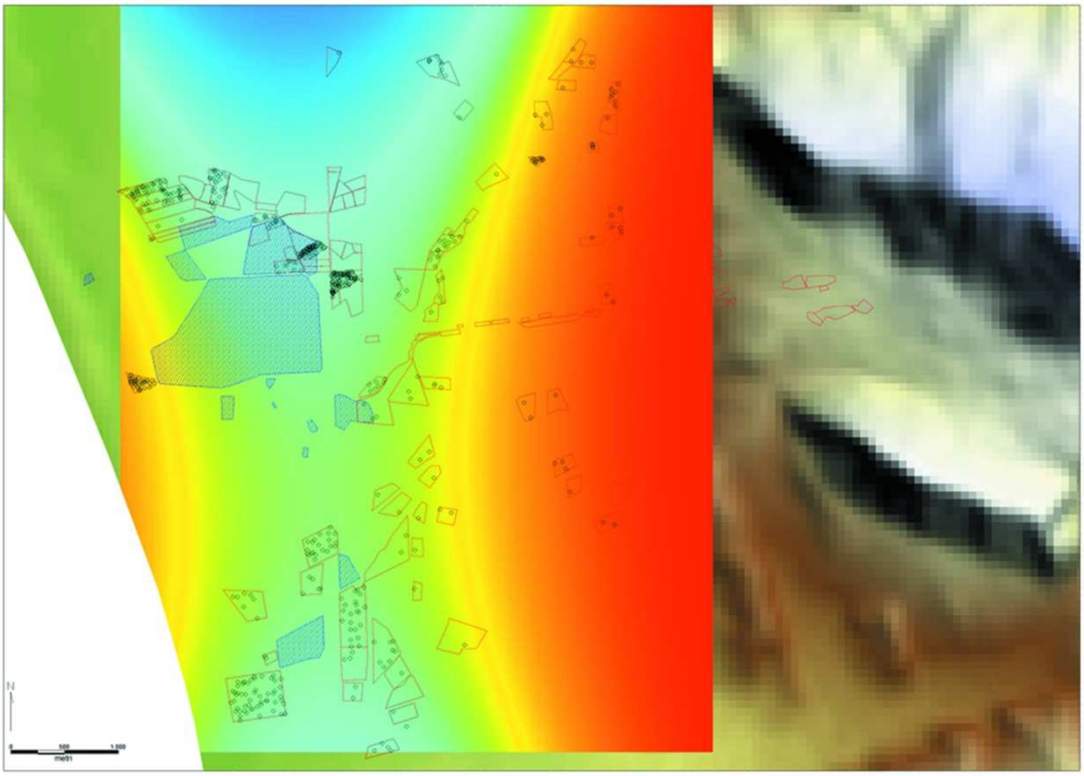

Fig. 9 – Statistical processing of time series data: trend analysis

Multidimensional Model

Up to now, we have discussed the creation of two-dimensional GIS layers. The further stage of development of the system takes into account the development of a multi-dimensional space-time scheme. The module was built with the intention of giving shape to various characterizations of time, while maintaining the relationship with spatial entities, and with the territory (fig. 10).

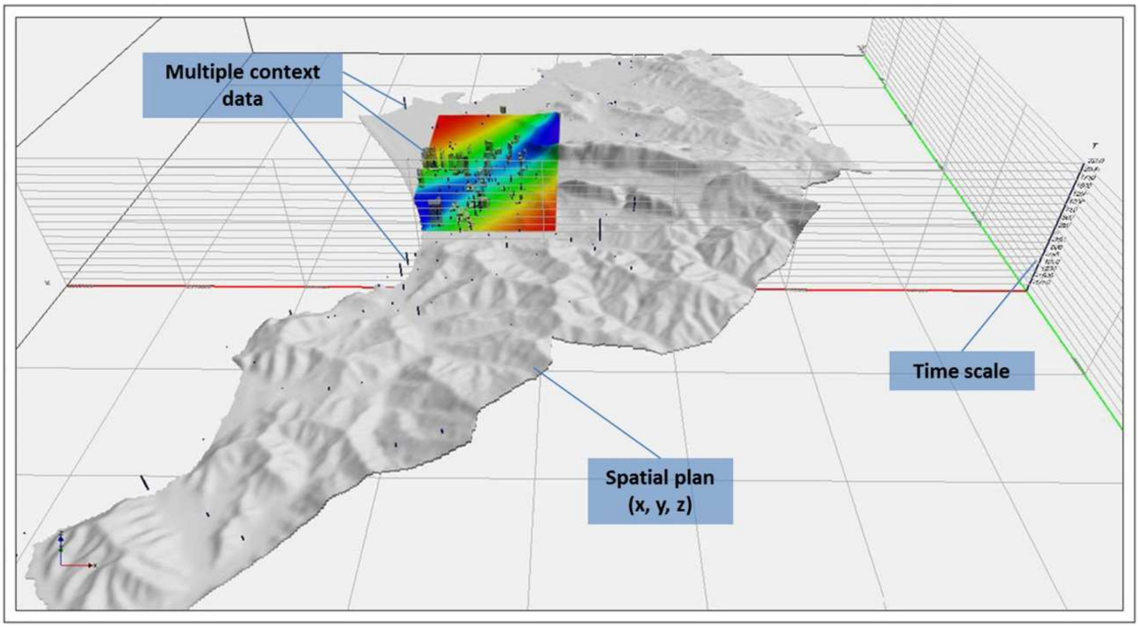

Fig. 10 – Space-time model. General view

It is a three dimensional space in which the z axis is intended to accommodate the dimension of time. It is made up of the same levels of information included in the GIS base. The difference is that each record of each layer has been developed according to the time line, by a process of extrusion. Each data receives a single or multiple temporal determination depending on the number of time intervals that covers it. For example, a sherd's area, divided into three chronological intervals, will be solved in as many line segments to specific spatial coordinates (fig. 11).

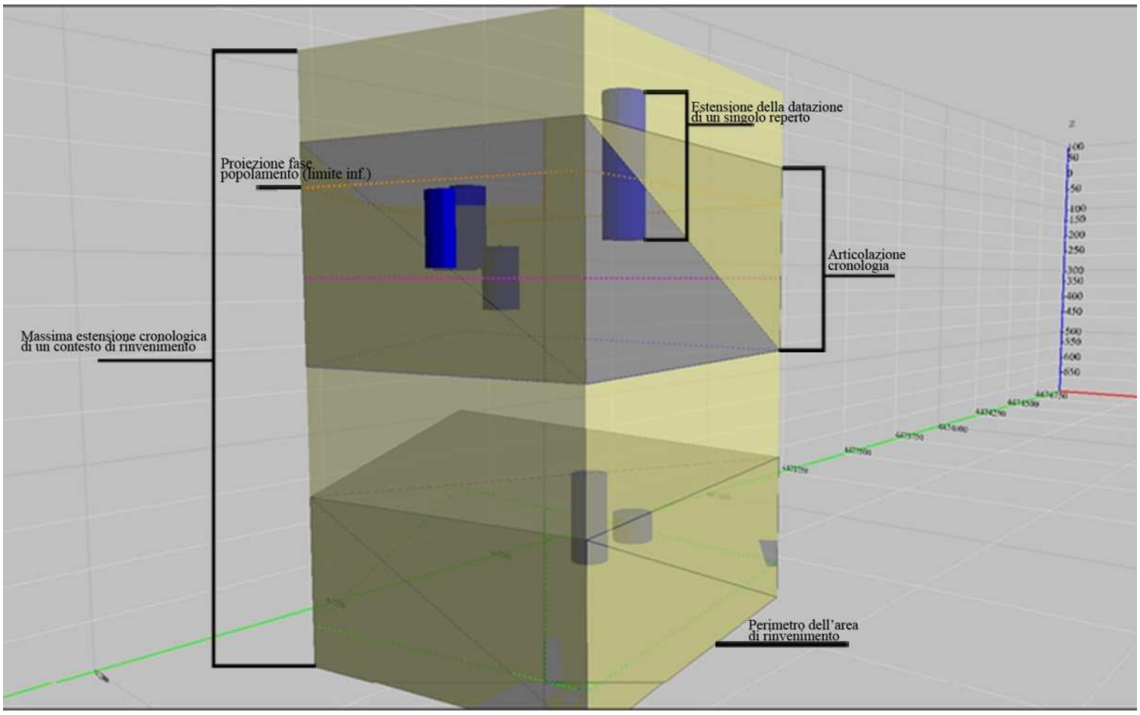

Fig. 11 – Space-time model. Example on a single sherd's area

At the same time, each fragment which composes the area of fragments is represented on the basis of its chronological extension. Once the scene geometry is obtained, each temporal profile receives the theme of the material class and the degree of reliability.

In the model every place has a location in time and space. It follows that the distances are measures of space and time and that the changes of the forms describe transformations of the attitudes of exploitation.

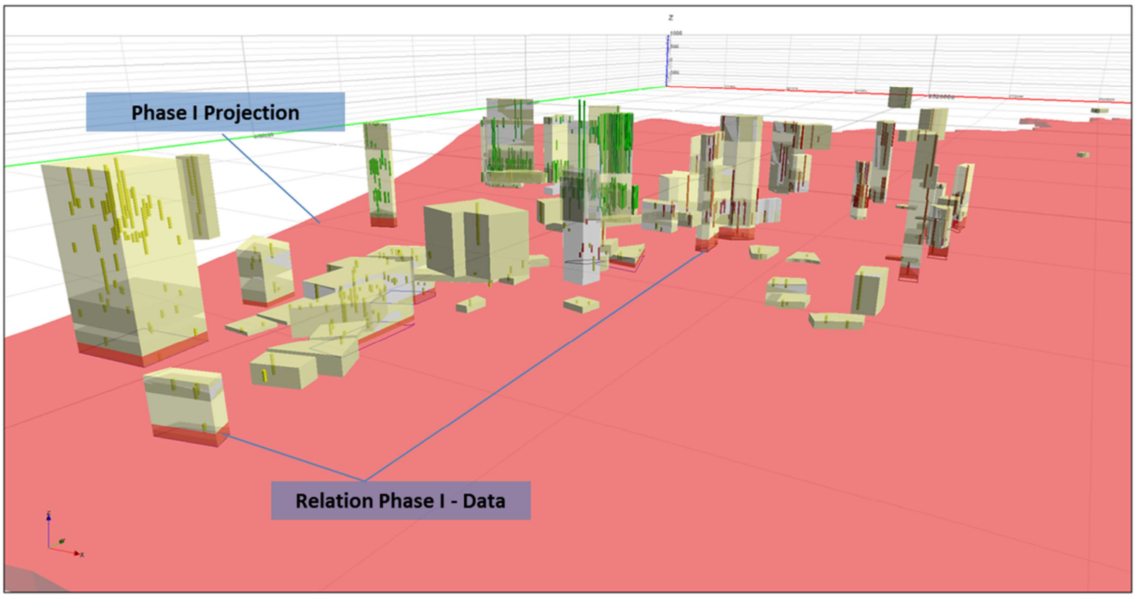

Fig.12 – Space-time model. General representation of the pestan area. The red plane is a single phase of occupation

The comparison between the three-dimensional development of the area of discovery and the individual elements shows the temporal dynamics of the environment and encourages the analysis of the evolutionary reasons regarding the exploitation of space.
The module allows the projections and the representation of data in chronological phases (fig. 12). The insertion point is specified by an offset function that controls the axis of z. In this way a phase, a period, a twenty-five year data plan, is placed in a precise location of the space and in an equally precise position of the time.
This allows one to compare and analyze in more detail the individual values of the contexts, the individual findings and the chronological associations. The raster layers derived from the statistical processing of the TGIS and inherent to the trend of the chronological data are handled in the same way (fig. 13).

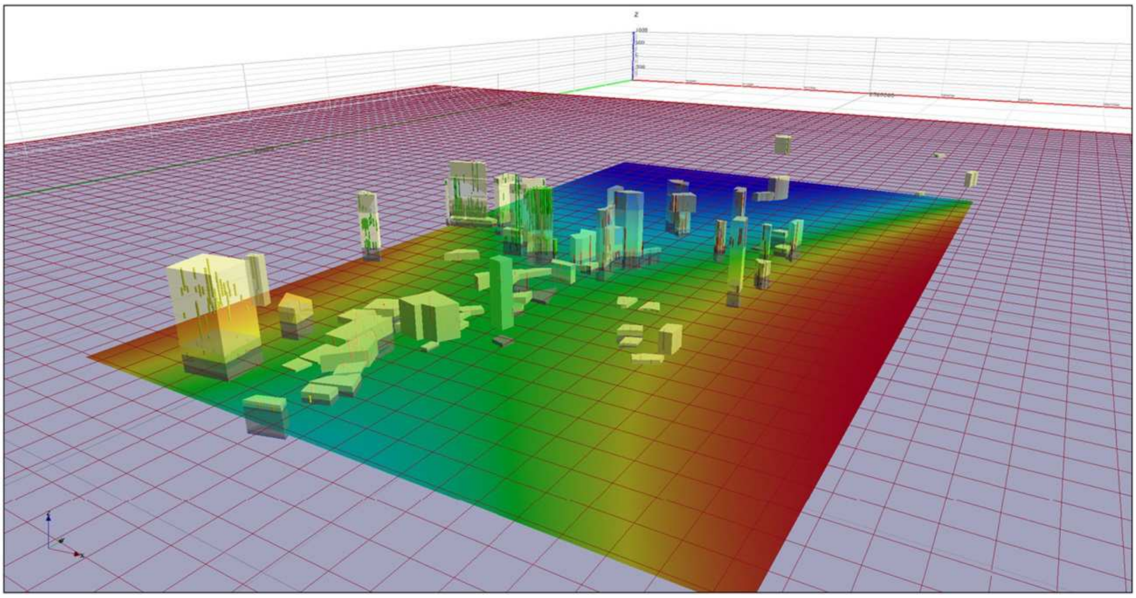

Fig. 13 – Space-time model. General representation of the pestan area with the plane of the trend analysis

The structural representations of the territory are added and arranged at a specific time (fig. 14). These maps are distributed over the digital terrain model in order to create a simulation of the plan elevation. The territory is represented in its evolution as it is placed, together with the other levels, in specific portions of time. The development of natural framework, valid for certain periods, is the environmental context. The proposition is to manage spatial, temporal and thematic data simultaneously in a specific natural context, characterized with particular aspects, contextual to the ancient period. The distinction between the temporal and the spatial coordinate validates the hypothesis that the model defines a space of four dimensions. In fact, the three spatial dimensions are intimately related to the individual entities represented, while the temporal dimension is developed on the z axis. In this way each point in the model has three spatial coordinates and a temporal one. However, the lack of a volumetric development limits the spatial aspects and reduces the characteristics of the model to a 3.5 d space. Nevertheless, the creation of a real volumetric space, where volume means space-time depth, is possible through the construction of voxels entities.

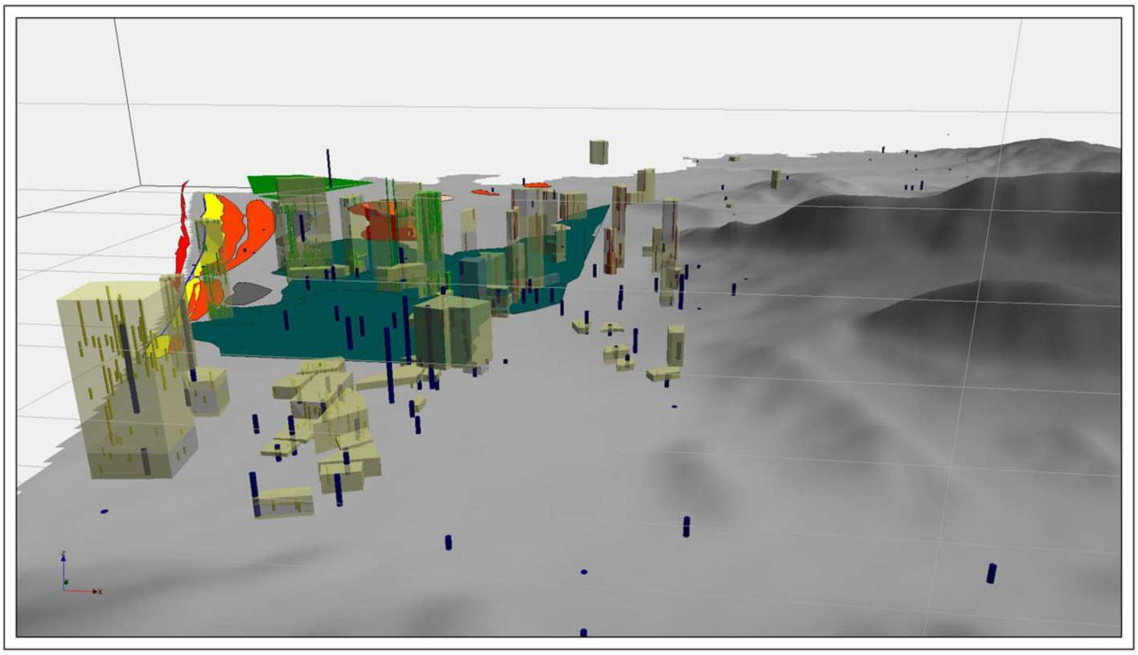

Fig. 14 – Space-time model. General representation of the pestan area with paleogeography

Conclusions

To summarize we can conclude that the model addresses the following questions: how do the activities or events constitute a process of structuring of the territory? And how many activities remain even in a varied area? Which activities are the signal of a different way of interpreting the territorial occupation? And so on.
In fact, the analysis of a dataset is not reduced to the comparison of individual distribution maps, almost isolated diagrams stuck in time; almost like instant photos. The introduction of a plural perspective, based on the integrated management of the three variables, space, time and function avoids the danger of compressing archaeological information into abstract images. It does not limit the archaeological documents to unique points in space and unique moments of time.

Conversely, in the multidimensional module the archaeological data are distributed according to a unified timescale that measures the time continuously. This does not mean that the space-time is built on a linear and uniform model of time, rather that the module integrates different timescales and encourages a diachronic analysis. At the base there is not the question of how time functions but how the archaeological data function over time and which are their variations. Thereby, it is possible to examine the development and consistency of a system of data, even if it is heterogeneous, with different degrees of accuracy and reliability, resulting from circumstantial investigations.

The management of the time, plural and non-continuous, integrated with spatial and functional aspects of material culture, gives movement to archaeological evidence and represents them as dynamic and changing entities. Briefly, the management of time allows the representation of historical processes. Over time the dimensions of the space are determined. They change or persist according to the archaeological indicators. Time moves with the space as a result of specific activities and behaviors. Time moves and creates the landscape. In this way, the functionality and the direction of the information system determine the availability of a real space for the construction of landscapes.

References

GRECO, E. (1975). “Velia e Palinuro. Problemi di topografia antica”, *MEFRA* 87: 81-142.

GRECO, E. (1979). “Ricerche sulla chora poseidoniate: il "paesaggio agrario" dalla fondazione della città alla fine del sec. IV a.C.”, *Dialoghi di Archeologia* 2: 7-26.

GRECO, E., STAZIO, A. and VALLET, G. (1987) (eds.). *Città e territorio nelle colonie greche d'occidente I*, Taranto: ISAMG.

BENCIVENGA TRILLMICH, C. (1990). “Elea: problems of the relationship between City and Territory, and of Urban Organization in the Archaic Period”, in: J. P. Descoeudres (eds.), *Greek Colonists and Native Populations*, Proceedings of the First Australian Congress of Classical Archaeology held in honour of Emeritus Professore A. D. Trendall (Sydney, 9-4 July 1989), Oxford: Clarendon Press: 365-371.

MADDOLI, G., STAZIO A. (1990) (eds.), *A sud di Velia - Ricognizioni e ricerche 1982-1988*, Taranto: ISAMG

GRECO, E. (1992). “La città e il territorio: problemi di storia topografica”, in *Posedonia Paestum*, Atti del XXVII Convegno di Studi sulla Magna Grecia, (Taranto - Paestum 1987), Napoli: ISAMG: 471-499.

GRECO, G., VECCHIO L. (1992). *Archeologia e territorio. Ricognizioni, scavi e ricerche nel Cilento*, Agropoli: Edizioni dell'Alento: 153-166.

DE MAGISTRIS, E. (1995). “Il mare di Elea”, in *Tra Lazio e Campania. Contributi di Storia e Topografia Antica*, Quaderni del Dipartimento di Scienze dell'Antichità 16: 7-77.

GRECO, E. (1996).” Laos, colonia di Sibari”, in: F. D'Andria, K. Mannino (eds.), *Ricerche sulla casa in Magna Grecia e in Sicilia*, Galatina (LE): Congedo Editore: 127-132.

GRECO, E., GASPARRI, D. (1995) (eds.). *Laos. Città e territorio nelle colonie greche d'Occidente 2*, Taranto: ISAMG.

LA TORRE , G. F. (1999). “Blanda, Lavinium, Clampetia, Cerillae, Tempsa”, *Forma Italiae* 38.

LONGO, F. (1999). “Poseidonia” in E. Greco (eds.), *La città greca antica. Istituzioni, società e forme urbane*, Roma: Progetti Donzelli: 365-384.

CIPRIANI, M. (2002).”Poseidonia”, in E. Greco (a cura di), *Gli Achei e l'identità etnica degli Achei d'Occidente*, Atti del Convegno Internazionale di Studi (Paestum 23-25 febbraio 2001), Paestum 2002, pp.363-388.

FREELAN, S. (2003). “Developing a Quasi-Temporal GIS for Archival Map Data”, *http://proceedings.esri.com/library/.*

GREEN, C. (2009) *Winding Dali's clock: the construction of a fuzzy temporal-GIS for archaeology*, Thesis submitted for the degree of Doctor of Philosophy at the University of Leicester, 2009.

Imprint:

Proceedings of the 18th International Conference on Cultural Heritage and New Technologies 2013 (CHNT 18, 2013)

Vienna 2014

http://www.chnt.at/proceedings-chnt-18/

ISBN 978-3-200-03676-5

Editor/Publisher**:** Museen der Stadt Wien – Stadtarchäologie

Editorial Team: Wolfgang Börner, Susanne Uhlirz