Modeling the post-AD 79 Deposits of Somma-Vesuvius to Reconstruct the pre-AD 79 Topography of the Sarno River Plain (Italy)

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Abstract:
During the Plinian eruption of Somma-Vesuvius in AD 79 almost the entire Sarno River Plain (Campania, Italy) was more or less instantly covered by thick volcanic deposits. This contributed to a good preservation of the palaeo-surface and the palaeo-environmental conditions before AD 79. Since the AD 79 volcanic deposits can be clearly distinguished from other stratigraphic layers they can be considered as a chronostratigraphic marker for identifying the pre-AD 79 palaeo-surface in the Sarno River Plain. The objective of this geoarchaeological study was to reconstruct the pre-AD 79 topography and selected palaeo-environmental features of the Sarno River Plain by modelling the thickness of the post-AD 79 deposits. Thus a methodology was developed that is based on an extensive dataset of stratigraphic information, a high-resolution present-day digital elevation model (DEM) and a classification and regression tree approach.

Key Words: *Paleo-Landscape Reconstruction, Classification and Regression Trees, Predictive Modelling, Sarno River Plain, Pompeii*

Introduction

The eruption of Somma-Vesuvius AD 79 is one of the most well known explosive volcanic eruptions in antiquity, above all thanks to the detailed written records of Pliny the Younger. This eruption can be considered a caesura in the existence of an entire landscape since the entire Sarno River Plain besides Pompeii and Herculaneum was buried by pumice fallout and pyroclastic surge deposits. These deposits reached a total thickness of approximately 3.4m (mean and median, determined from 1,236 stratigraphic drillings) ranging from 0.4m to 7.8m (95% confidence interval). Since the deposits of AD 79 are laterally extensive and show a characteristic stratigraphy they can be considered as a chronostratigraphic marker for the identification of the Roman surface before AD 79. Consequently, today, almost 2000 years after, it is still possible to study the Roman surface by means of stratigraphic investigations, which allows us to reconstruct the pre-AD 79 topographic conditions. Furthermore, the character of the Roman stratum provides information about important palaeo-environmental landscape features of the Sarno River Plain before AD 79. The objective of this project is to generate a high-resolution digital elevation model (DEM) of the Sarno River Plain and reconstruct some palaeo-environmental conditions before the eruption of Somma-Vesuvius AD 79. This pre-AD 79 DEM will be the basis for further geoarchaeological research in this area aiming at comprehensively studying the relationship between ancient people and their environment in the hinterland of Pompeii.

Methodology

The methodology applied to reconstruct the pre-AD 79 topography and palaeo-environmental conditions of the Sarno River Plain was described in depth by Vogel and Märker (2010). It is based on an extensive dataset of stratigraphic information, a high-resolution present-day digital elevation model and a classification and regression trees (CARTs) approach. At first we collected a total of 1,840 core drillings from construction works as well as from past archaeological and geological studies to gain a representative network of stratigraphic information of the entire Sarno River Plain. The drillings were localized and digitized using geographic information systems (GIS). Then the stratigraphy was determined from the drilling documentations to identify the volcanic deposits of AD 79, the Roman surface underneath and to characterize the Roman stratum. From figure 1 it can be seen that the stratigraphic drillings are well distributed over the entire Plain. Nevertheless, there are areas

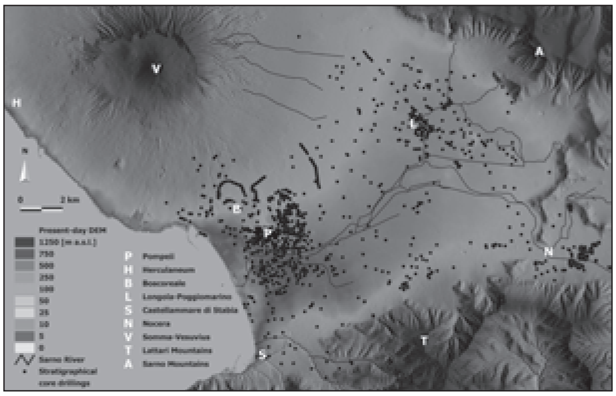

Figure 1. Digital elevation model (DEM) of the Sarno River plain with the location of the stratigraphical drillings and sites of interest (for full colour image please see the online version of this paper)..

showing a high density of stratigraphic data such as Pompeii, Nocera and Longola-Poggiomarino whereas in other areas stratigraphic data are rather scarce.

Consequently, to reconstruct the Roman topography we could not simply interpolate between the drilling points since it would result in a very inhomogeneous spatial resolution and a lot of no-data areas. Hence we applied a geostatistical methodology, based on classification and regression trees, that combines stratigraphic information from the core drillings with present day topographical data. That means that we utilized the present-day topography to draw conclusions on the ancient topography. This is based on the following hypotheses:

1. Past and present-day geomorphic processes are related to terrain characteristics that can be described by topographic indices (elevation, slope, curvature etc.).

2. Thus deposition, erosion and transport processes during the eruption of Somma-Vesuvius in AD 79 were controlled by the pre-AD 79 topography.

Since the present-day topography is the results of the geomorphic process dynamic that was controlled by the pre-AD 79 topography, the present-day topography reflects the ancient topography. Consequently, this topographic memory can be used to reconstruct the ancient conditions. A hydrologically correct present-day digital elevation model of the Sarno River Plain was generated using the Hutchinson algorithm implemented in ArcGIS (Hutchinson 1988; 1989). Afterwards 15 primary and secondary topographic indices were delineated using SAGA GIS. For modelling, the software TreeNet by Salford Systems was applied which is based on the classification and regression tree algorithm. It is used for exploratory data analysis and predictive modelling to discover features and understand structural patterns in large databases. This is done by describing the correlation between a response variable of an incomplete dataset and predictor variables covering the entire study area (Breiman et al. 1984; Myles et al. 2004). As predictor variables we used the present-day DEM and the 15 topographic indices. The response variable which we want to predict is the depth from the present-day surface to the Roman surface (thickness of post-AD 79 deposits) which was taken from the drilling data. TreeNet analyses the correlation between these predictor variables and the response variable for each of the 1,840 drillings and eventually generates a model taking into account the combination of predictor variables having the highest correlation to explain the response variable, i.e. the depth to the Roman surface. Finally, the response variable will be regionalized for the entire Sarno River Plain by means of the predictor variables.

Results and Discussion

The CARTs model achieved a minimum mean absolute error at 2,094 grown trees. It was 0.98m for the training dataset and 1.68m for the test dataset (Vogel et al. 2011). Figure 2 shows the modelled depth to the pre-AD 79 Roman surface (thickness of post-AD 79 deposits) of the Sarno River Plain. From the importance of the predictor variables in the model generation (Table 1) it can be seen that the spatial distribution of volcanic deposits since AD 79 is most notably controlled by the absolute elevation. Of secondary importance are the aspect and hydrological variables. Consequently, the thickness of post-AD 79 deposits is governed by two contrasting sets of processes: 1) the initial deposition of volcanic deposits during the eruption of Somma-Vesuvius, and 2) the subsequent remobilization of that material and redistribution by geomorphic processes of erosion, transport and accumulation (Vogel et al. 2011). The former resulted in an accumulation of deposits along the southeastern foot slopes of Somma-Vesuvius, which is near the source of the eruption. The latter resulted in thinner deposits in the inner plain and thicker deposits along the Tyrrhenian coast. Correspondingly the southern and eastern mountain slopes show thin deposits whereas accumulation can be seen in the adjacent toe slope areas (Fig. 2).

Predictor variable	Importance [%]
Elevation above sea level	100.0
Aspect	93.1
Channel base level	81.6
Altitude above Channel network	59.0
Slope	52.8
Analytical hillshade	50.6
LS-factor	48.6
Curvature classification	46.7
Convergence index	45.9
Profile curvature	44.3
Topographic wetness index	44.1
Stream power	43.8
Curvature	43.2
Plan curvature	41.9
Catchment area	38.5
Channel network	9.8

Table 1. Ranking of importance of the predictor variables used for the model generation. The most important variable was set to 100% whereas the others were calculated relatively thereto.

To get the absolute elevation above sea level of the Roman surface the predicted depth

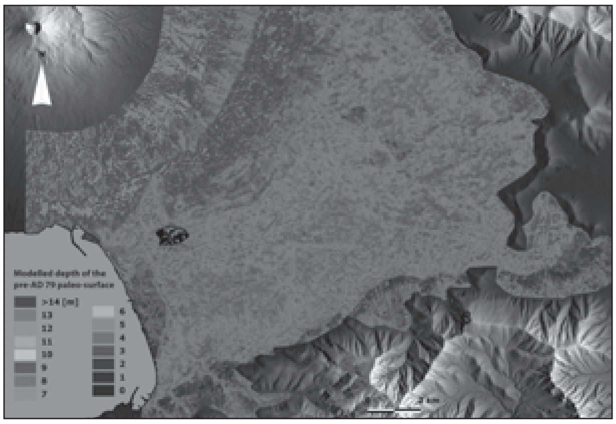

Figure 2. Modelled depth of the pre-AD 79 surface (thickness of post-AD 79 deposits) in the Sarno River plain.

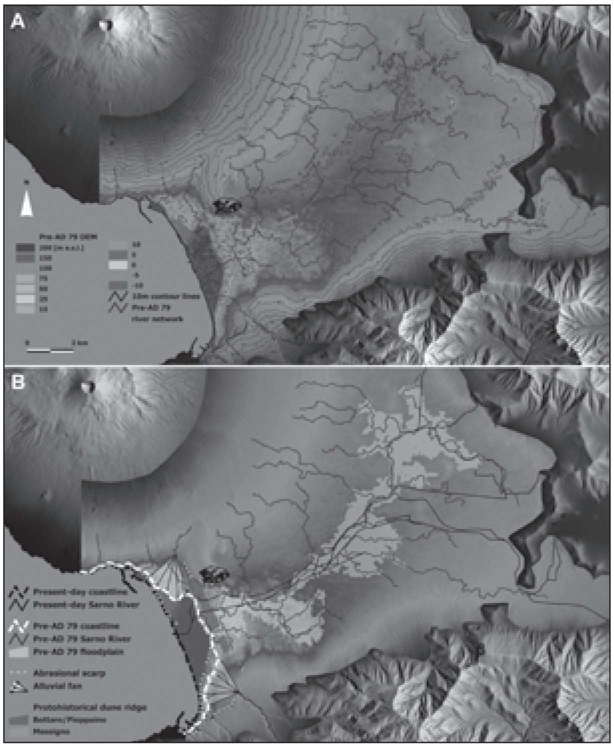

Figure 3. Top: Pre-AD 79 digital elevation model (DEM) of the Sarno River plain. Bottom: pre-AD 79 paleo-environmental and paleo-geomorphological features.

was subtracted from the present-day digital elevation model (Fig. 3a). The Roman surface is approximately 5.8m deeper than the present-day surface resulting in the entire coastal area lying below the present-day sea level. Using SAGA GIS the palaeo-river network was modelled along the natural depth contours of the pre-AD 79 topography. To reconstruct some environmental conditions before AD 79 especially the ancient coastline and the floodplain of the palaeo-Sarno the pre-AD 79 topography was compared with the character of the Roman stratum that was taken from the drilling data (Fig. 3b). The approximate location of the Roman coastline was already predefined by the littoral deposits that are distributed nearly parallel to the present-day coastline in a distance between 1,100m and 1,300m. The floodplain of the palaeo-Sarno on the other hand is represented by fluvial/palustrine deposits that are almost perfectly linked to the modelled palaeo-river network. They are characterized by the 1m to 2m isolines of the 'vertical distance to channel network' index (SAGA GIS) (Olaya and Conrad 2008). Consequently, this area can be determined as the flood area in which the palaeo-Sarno most likely had its ancient riverbed (Vogel and Märker 2010; Vogel et al. 2011).

Conclusions and Outlook

For the first time the pre-AD 79 topography and some palaeo-environmental conditions of the entire Sarno River Plain were reconstructed using sophisticated geostatistical methods. Nevertheless it is important to emphasise that this reconstruction is only a model of the Roman conditions based on the hypotheses stated above. In the future further stratigraphic drillings and additional geophysical prospections will be carried out to validate the results. Through the combination of the pre-AD 79 DEM with archaeological findings the palaeo-environmental reconstruction of the Sarno River Plain can be refined. This pre-AD 79 DEM can now be used to identify zones of particular interest to carry out further stratigraphic or geomorphological investigations. In the future the Roman DEM can be of great importance for detailed geoarchaeological investigations of the Roman conditions in the Sarno River Plain.

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