Session 4
Urban Geoarchaeology
Papers

4.1 Geoarchaeological practice applied to archaeological predictive modelling: methodologies and results from MAPPA project

Marta Pappalardo, Giovanni Sarti, Monica Bini, Fabio Fabiani
MAPPAproject - University of Pisa

Veronica Rossi
Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Università di Bologna

Introduction

Late Holocene deposits stored beneath the modern deltaic-alluvial plains are excellent sedimentary archives to explore in detail the succession of landscapes developed, since the Proto-historic period (ca. 3000 yr BC), under the mutual interaction of natural and anthropogenic forcing factors. The recent coring campaign performed in the Pisa plain, in the context of "MAPPA project", has represented a great opportunity to highlight the history of human-environment relationships in a long-settled city area.
Several studies (Bellotti *et alii* 2004; Bruneton *et alii* 2001; Amorosi *et alii* 2004), focused on Holocene coastal sedimentary successions of the western Mediterranean area, have evidenced a characteristic similar depositional trend. During the maximum marine flooding, around 6000-5000 yr BC (Fairbanks *et alii* 1989), the coastal zones were occupied by wide lagoon basins. The following combined effect of sea-level steadying and increasing river sediment supply led to the gradual siltation of the lagoons and the development of modern deltaic-alluvial plains, which experienced a lengthy and intense human land-use history.
These mid-late Holocene fluvio-deltaic successions, accumulated during the last four millennia, recorded the palaeoenvironmental changes occurred at time scales comparable to those involving human civilization and society evolution. Therefore, high-resolution stratigraphic analysis of these deposits, 15-20 m-thick beneath the Pisa urban and periurban area, integrated with multispectral images interpretation constitute a fundamental step toward an accurate and in-depth knowledge of the recent past landscape evolution and to the elaboration of palaeogeographic maps. Matching this objective has required an interdisciplinary approach joining the expertise of Pisa University Earth and Human scientists. This research was performed in the context of the broader project M.A.P.P.A. (Metodologie Applicate alla Predittività del Potenziale Archeologico www. mappaproject.org), funded by the Regional Board of Toscana and carried out by Pisa University in cooperation with the Cultural Heritage Ministry and the Municipality of Pisa. The project is aimed at contributing to the protection, research and governance of the city and of its underground archaeological heritage.

Methods

The reconstruction of ancient landscapes of Pisa plain depends on a detailed understanding of the subsurface stratigraphic architecture, where the relationships between lithofacies and natural or anthropogenically forced depositional environments are recorded. To achieve this objective a cross-disciplinary (sedimentological, geochemical, micropalaeontological, geomorphological, radiometric and archaeological) methodological approach has been followed. Subsurface data coming from different databases were analyzed and reviewed before MAPPA cores execution. The integrated evaluations made by the geologists and archaeologists allowed the identification of 20 highly significant sites for the acquisition of new geoarchaeological information. Each site was measured with a Leica differential GPS in order to acquire the x, y and z coordinates. A geophysical survey was also carried out around each coring point using a GPR-Ground Penetrating Radar IDS system, in order to detect any sub-services in the area of interest and avoid damages.
Nine sedimentary cores, long up to 15 meters (Fig.1), were performed through a continuous perforating system, which ensured an undisturbed core stratigraphy. Other 11 cores (Fig. 1) were drilled using a percussion drilling technique (Vibracorer Atlas Copco, Cobra model, equipped with Elijkamp samplers), which provided smaller diameter cores yet qualitatively similar to those taken during continuous coring. The depth reached with this instrument ranged between 13 and 7 meters depending on the tool's limitations and/or project needs. Archaeologists, geomorphologists and sedimentologists were jointly involved in the field activities, giving rise to a detailed stratigraphic reading of cores in a shared and integrated manner. Overall, 232 samples were collected and then sub-sampled for micropalaeontological, palynological, geochemical and radiocarbon analyses. Around 4-5 samples per metre were taken within fine-grained successions, where the meiofauna (benthic foraminifers and ostracods) and pollen are potentially well preserved and abundant. Instead, in correspondence of sandy deposits or deposits showing evidences of subaerial exposure the sampling interval was reduced to 1-3 samples per metre. Finally, in correspondence of specific anthropic levels, additional samples were taken for palynological analyses to highlight the human impact on the vegetation cover. The chronological framework of the studied succession was based on the integration of 11 radiocarbon ages (performed at the CIRCE Laboratory, University of Naples) with archaeological materials. Core stratigraphic data were integrated with geomorphological and historical investigations, allowing a reliable reconstruction of the middle-late

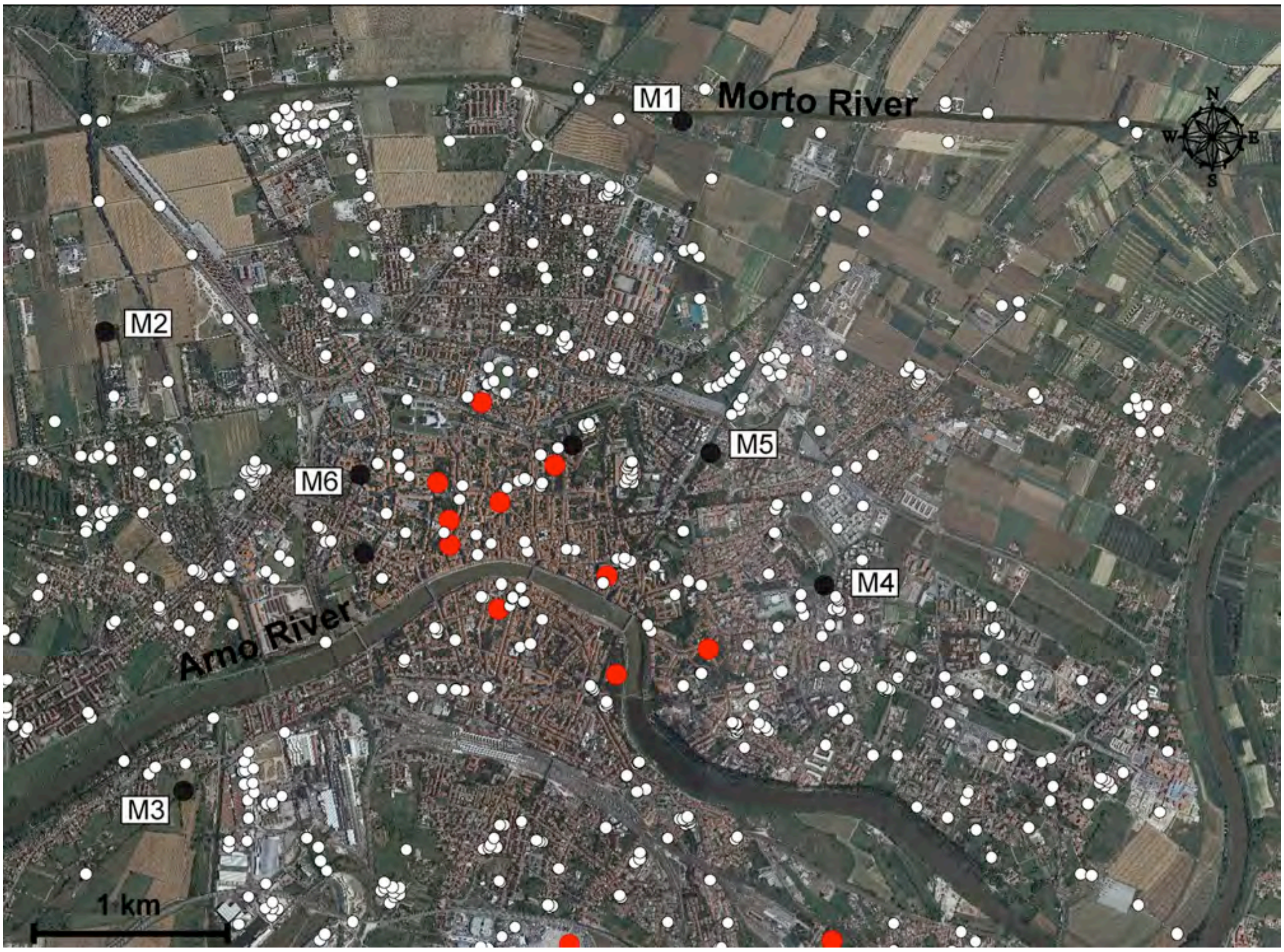

Fig. 1: Location of MAPPA continuous cores (shown as black dots), MAPPA percussion cores (shown as red dots) and high-quality borehole data, selected from the available subsurface dataset (shown as white dots), across the Pisa urban and periurban area.

Holocene environmental evolution in the Pisa old town area. Geomorphological features (palaeochannels and wetlands) were identified by integrated techniques of Remote Sensing and GIS (Bisson and Bini 2012). Specifically, the reconstruction of fluvial network evolution in the Pisa urban area benefited from the analysis of multitemporal aerial photos, dated between 1943 and 2010, together with multispectral images with medium-high resolution acquired from SPOT, ALOS AVNIR-2 and TERRA ASTER satellites. Finally, morphometric elaborations, carried out on a digital elevation model based on Lidar data, were performed in order to detect morphological evidence of past landforms (wetlands) in the Pisa plain.

Results

The acquired data set allowed the reconstruction of the main landscape changes occurred in the surrounding of Pisa from the proto-historic period to the present day. These changes are illustrated in seven palaeogeographic maps each one representing a specific historical time-interval (Proto-historic, Etruscan, Roman, Early Medieval, Late Medieval, Modern and Contemporary).
The Proto-historic period (3300-721 yr BC) saw the progressive evolution of the ancient lagoon into a more confined paludal area, evolving in turn into a poorly drained floodplain. This depositional trend reflects the first stages of the deltaic-alluvial plain formation. Concerning the palaeohydrographic network, two main distributary channels flowed in the surrounding of Pisa city area during the Eneolithic age (3300-1900 yr BC). Specifically, a N-S fluvial course corresponding to the palaeo-Auser, a former branch of the Serchio River, merged into the palaeo-Arno River about two hundred metres west of the Ponte di Mezzo. A more articulated palaeohydrographic network occurred during the Bronze-Iron ages (ca. 1900-700 yr BC). Four main branches were identified: two N-S oriented and an E-W oriented paleo-Serchio River courses, the latter flowing few hundred metres north of the Ponte di Mezzo, and a palaeo-Arno River course.
Around 700 yr BC, corresponding to the Etruscan transition, an extensive development of swamps occurred in wide sectors of Pisa old town. Wetlands formation took place at the confluence of Arno and Serchio river palaeochannels, in low-lying areas bounded by higher levees, and had a profound impact on the Etruscan settlements. Unfortunately, the available data didn't allow an accurate reconstruction of the coeval palaeohydrographic network.
At the Etruscan/Roman transition (around 90 yr BC) swamps were drained and the modern alluvial plain began to form, documenting the first strong human control on the

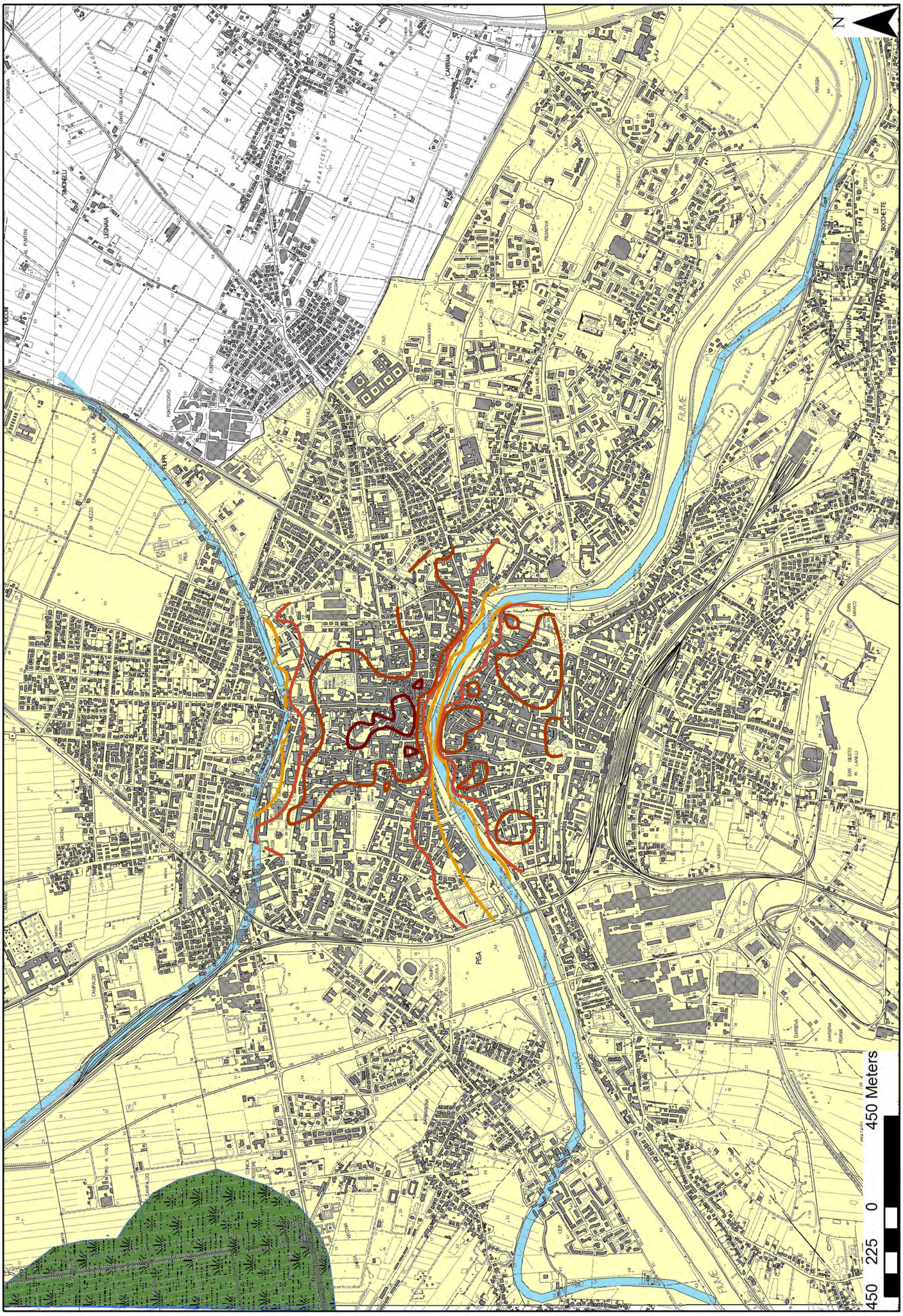

Fig.2: Palaeogeographic map of Pisa historical town and surrandings during the Late Meddle Ages. Legend: In Yellow, well drained alluvial plain; in green: wetlands; in blue, palaeorivers; brown line, palaeoisoipse with an equidistance of 2 m (max elevation 6m).

environment. Indeed, during the Roman period the natural evolution of the alluvial plain together with increasing water works led to the establishment of a well-drained floodplain locally subject to overbank processes. Palaeo-Arno and Auser rivers still characterized the hydrological pattern in the neighboring of Pisa. The palaeo-Arno flowed roughly like its present-day position crossing Pisa from E to W, while the Auser was probably split in two branches. One of the branches flowed along the north side of the Piazza del Duomo, while the other probably flowed more to south. So far, clear geological evidences of the fluvial course described by Strabo have not been found.

The transition to the Early Middle Ages saw a renewed rapid wetland expansion due to the bad maintenance of drainage channels. From the Late Middle Ages these wetlands gradually disappeared leading to the formation of a wide well-drained floodplain area, characterized by high aggrading rates supported by an intense human-land use. Between the Late Middle Ages and the beginning of Modern Age, two river courses were identified (Figure 2). The former corresponds to the Arno River, that reached its present position, and the latter is interpreted as the Auser flowing north of the city walls (Figure 2).

During the Modern Age the Arno River maintains its position, while the Auser was forced to flow northward (Bruni and Cosci 2003). In the time-interval between the Late Middle Ages and the beginning of Contemporary Age the topographic data show a considerable thickness of artificial ground (ca. 2 m) in correspondence of the Pisa historical centre.

Bibliography

Amorosi A., Colalongo M.L., Fiorini F., Fusco F., Pasini G., Vaiani S.C., Sarti G. 2004, *Palaeogeographic and palaeoclimatic evolution of the Po Plain from 150-ky core records*, in «Global and Planetary Change», 40, pp. 55-78

Bellotti P., Caputo C., Davoli L., Evangelista S., Garzanti E., Pugliese F., Valeri P. 2004, *Morpho-sedimentary characteristics and Holocene evolution of the emergent part of the Ombrone River delta (southern Tuscany)*, in «Geomorphology», 61, pp. 71-90

Bisson A., Bini M. 2012, *A multidisciplinary approach to reveal palaeo-hydrographic features: The case study of Luna archaeological site surroundings*, in: International Journal of Geographical Information Science, 26 (2), pp. 327-343

Bruneton H., Arnaud-Fassetta G., Provansal M., Sistach D. 2001, *Geomorphological evidence for fluvial change during the Roman period in the lower Rhone valley (Southern France)*, in: «Catena», 45, pp. 287-312

Bruni S., Cosci M. 2003, *Alpheae veterem contemptlor originis urbem, quam cingunt geminis Arnus et Ausur aquis. Il paesaggio di Pisa etrusca e romana: materiali e problemi* , in Bruni S. (Ed.), *Il porto urbano di Pisa. La fase etrusca. Il contesto e il relitto ellenistico*, pp. 29-43

Fairbanks R.G. 1989, *A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation*, in: «Nature», 342, pp. 637-642