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The New Archaeology. From remote sensing to archaeological digging in quasi-real time. The case of Monte Prama (Cabras, Sardinia, Italy)

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INTRODUCTION

One of the most important archaeological sites of the western Mediterranean is located in the Sinis peninsula (Cabras, Sardinia, Italy) (Fig. 1). Archaeologists studied this site, which was discovered accidentally in 1974, in 1975, 1977 and 1979 (Bedini *et al*. 2012; Lilliu 1997). A necropolis with monumental sculptures from the early Iron Age characterizes the archaeological area of Monte Prama. Above the graves (8th/9th century BC) a large paved area was built, likely for funeral games, and statues as well as baetyls and nuraghe models were set up there.

After about forty years, new geophysical and archaeological research started in 2013, thanks to a joint project between the Universities of Sassari and Cagliari and the Archaeological Superintendency of Cagliari and Oristano. This research covers both geophysical prospecting and archaeological digs, which are still ongoing. Archaeologists have found 28 statues, measuring up to 2.20 m in height, 16 nuraghe models and 16 baetyls (Fig. 2), including finds from the 1970s.

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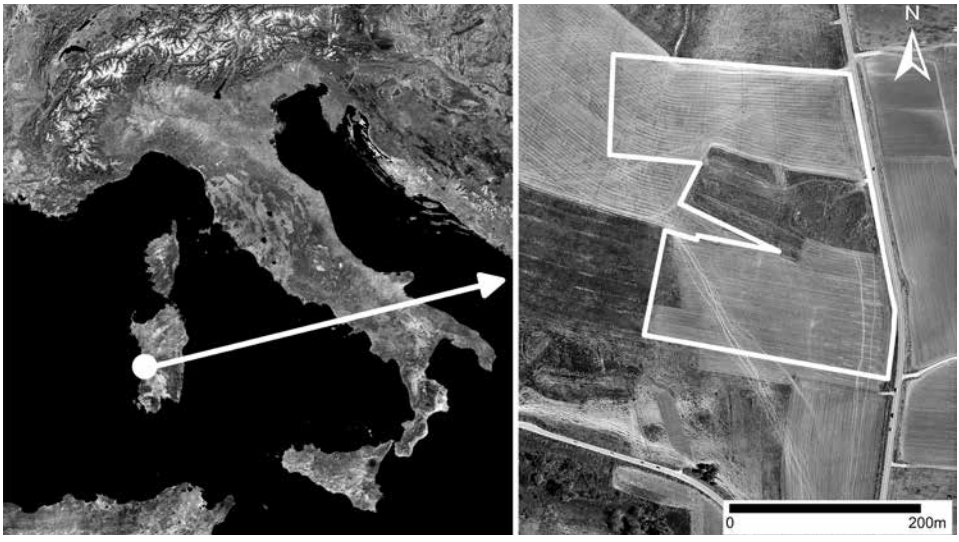

Fig. 1. Studied area. The surveyed area is outlined in white in the picture on the right

The earlier archaeological studies had left unresolved some critical questions regarding the actual extent of the archaeological site (test digs around the site revealed no further evidence of remains) and the presence of a temple and/or village. It was necessary to plan a large-scale survey, covering more than 100 ha, to answer these questions.

Taking into account that in 85% of cases finds are smaller than 25 cm, the common geophysical methods, that is, magnetic (Ciminale and Gallo 2008), electromagnetic (Ranieri *et al.* 2013), electric (Trogu *et al.* 2014; Ranieri *et al.* 2007) and single/dual channel GPR (Piga *et al.* 2014), could not be used, because they are too time-costly and have not enough spatial resolution. The methods used had to meet specific requirements of fast acquisition speed, precise positioning of anomalies, high spatial density of measured points (both vertical and horizontal), target resolution greater than 25 cm and depth of investigation (at least 1.5–2 m).

Therefore, the choice fell on a 16-channel GPR, with 200MHz antenna, that allows for the simultaneous recording of 15 parallel radargrams, spaced 12 cm from one another. Using this device (STREAM-X, by IDS), it was possible to meet all the required conditions:

– fast acquisition speed (about 10–15 km/h);
– differential GPS antenna for positioning measurements with a horizontal shift less than 5 cm;
– spatial density of measurements: horizontal, 12 cm perpendicularly to the moving direction and 9 cm along it; vertical, less than 1 cm;
– horizontal resolution of about 35 cm (due to radar frequency and EM soil velocity);
– depth of sounding, due to the good signal/noise ratio of the instrument, about 1.5–2 m.

With respect to standard single/dual channel GPR, which is frequently used in archaeology, the main advantages of this system include time efficiency, fixed distance between all 15 of the profiles (12 cm), absolute parallelism between all 15 profiles and 3D highlighting of buried targets.

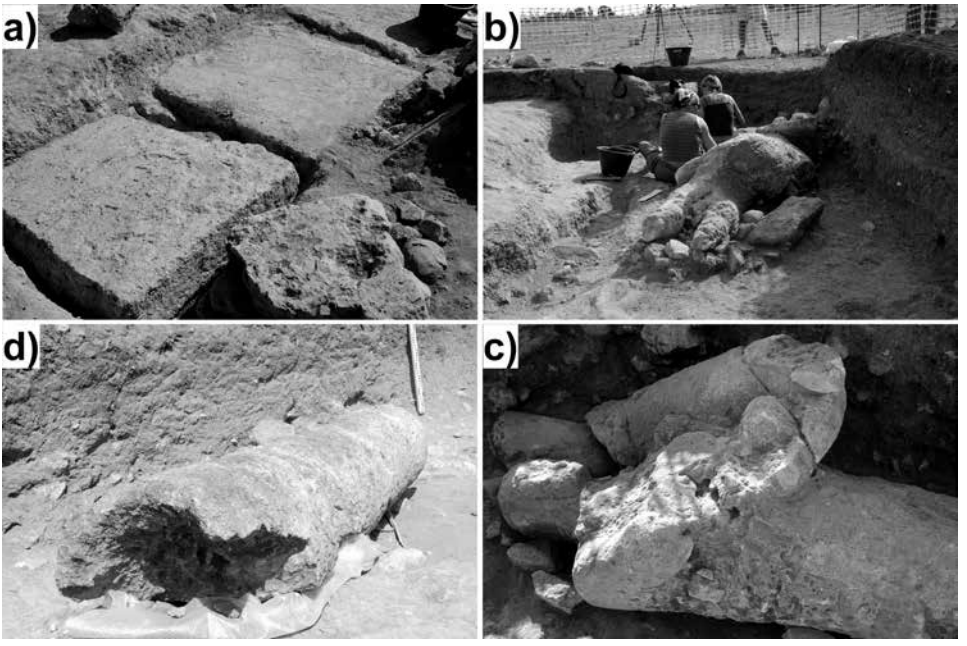

Fig. 2. Selected finds from current excavations: a) slabs; b) statues; c) the only statue to be found with the head attached; d) baetyl

At the site of Monte Prama, we also used some other unconventional methods like Three dimensional electric resistivity tomography (3DERT), continuous automated resistivity prospection (ARP), aerial thermography and aerial multispectral survey.

DISCUSSION

Data show the widespread presence of anomalies probably related to archaeological targets at a depth range between 30 cm and 160 cm. Surveys have clearly demonstrated the presence of extended anomalies far beyond the limits of the earlier excavations. Many anomalies revealed well-aligned patterns that sometimes corresponded well with finds from the 1970s archaeological excavations. The most relevant data was acquired immediately south of the area excavated in the 1970s (along a NNE–SSW direction, about 15 m long and 3 m wide) where, until now, no further extension of the necropolis had been expected.

To verify some of the anomalies, archaeologists have excavated five trenches based on the results of the GPR prospecting. The major anomalies have been clearly correlated with two statues (almost intact), three baetyls, eight square slabs overlying graves and several circular tombs. Feedback from the excavations permitted some types of anomalies clearly distinguishable in the radargrams to be classified as specific features: massive objects, slabs and fragments (Fig. 3). Other types of anomalies were linked to channels and roads on the grounds of current knowledge of the site. Thanks to the

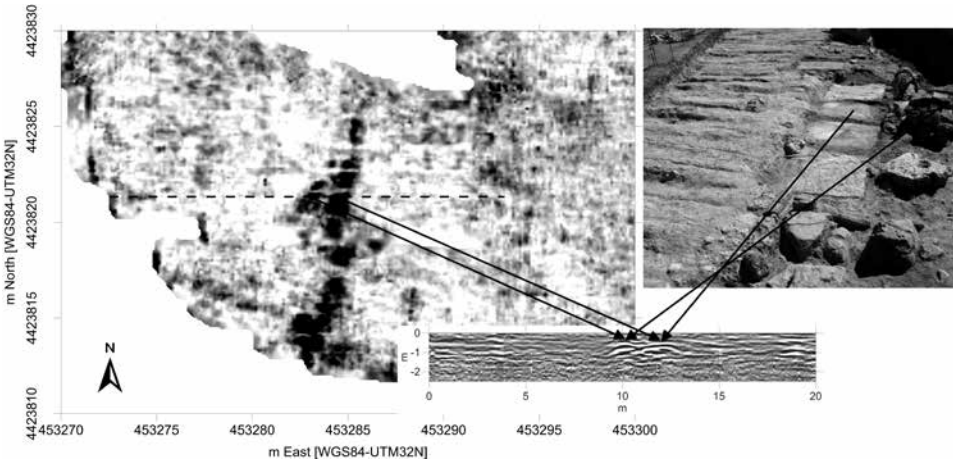

Fig. 3. Example of excavation results. The baetyl and grave were well marked by anomalies pointed out by the arrows. The dashed line corresponds to the radargram

interpretation of the digging results, we have interpreted some anomalies in the surrounding areas, like probable tombs, roads, landfills and statues or baetyls.

CONCLUSIONS

The results of geophysical surveys and excavations carried out so far have made conclusions possible regarding the unsolved questions related to the extent of the site.

1. The area of the necropolis is certainly larger than previously assumed.
2. The results of excavations in selected areas, based on GPR data, confirm the continuation of the necropolis in a southward direction.
3. Digs carried out based on geophysical results have demonstrated a strong link between location and depth of GPR anomalies and archaeological finds. In particular, two statues, almost completely intact, two baetyls and one nuraghe model, which were clearly identified and positioned by the GPR survey, were found by archaeologist in just a few days after the geophysical survey.
4. A comparison of archaeological finds and GPR anomalies made it possible to recognize at least three types of anomalies: massive objects of medium to large size, slabs and accumulations of fragments.
5. The use of fast, reliable and of high-resolution devices, like the Stream-X, open new scenarios in archaeological science. In fact, without the use of these types of tools it would not be possible to run a geophysical prospection over an area of more than 6 ha in just eight working days, obtaining raw radargrams spaced a constant 12 cm apart, giving a very accurate coverage of the area and time-slices of excellent quality. Moreover, the accurate positioning obtained by the use of differential GPS allows quick and precise location of the anomalies on the ground, permitting a careful selection of dig sites with considerable saving of time and expenditures.

Therefore, Stream-X has proved to be a very useful tool, particularly for the assessment of archaeological risk.

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