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GRUPPO NAZIONALE DI GEOFISICA DELLA TERRA SOLIDA

# Atti del 33° Convegno Nazionale

## Tema 3: Geofisica applicata

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# CASE HISTORY: A MAGNETIC AND GPR PROSPECTION ON A ROMAN RURAL VILLA IN WESTERN PIEDMONT (ITALY)

**L. Sambuelli[1], D. Elia[2], V. Meirano[2], C. Colombero[3]**
*[1] Dipartimento di Ingegneria dell'ambiente, del Territorio e delle Infrastrutture – Politecnico di Torino, Italy*
*[2] Dipartimento di Studi Storici – Università di Torino, Italy*
*[3] Dipartimento di Scienze della Terra – Università di Torino, Italy*

**Foreword.** Since the half of the past century the use of geophysical methods for archaeological prospection has been proposed (Segre, 1958; Rees, 1962). However only in the few past decades the evolution of theory, software and instrumentation has allowed for the possibility of adopting multi methods prospection with reasonable execution times and costs. New technologies, such as ERT and GPR, have been added to the traditional ones (Pasquinucci and Trément, 2000; Gaffney and Gater, 2003). On the occasion of exploring an archaeological site in western Piedmont, we then decided to proceed to a multimethod survey using fast methods and taking also into account the information achievable after a 2D or 3D data processing and/or rendering. This choice restricted the methodologies to magnetic and GPR prospecting. The non contact resistance imaging, in our opinion, still gives too smeared results even if indicative of resistivity anomalies. We selected the magnetic prospecting because of the remarkable size of some of the walls actually excavated even if, as we explain in the geological context, the probability of collecting a significant amount of noise was high.

**The geological context.** The village of Costigliole Saluzzo (CN) is located in north-western Italy, at the end of the Varaita Valley, at the edge between north-western Alps and the wide piedmont's plain. The Varaita Valley elongates in WE direction from the Monviso Massif and the administrative border with France (Fig. 1).

From a geological point of view, two main tectono-metamorphic units outcrop in this area: the Dora-Maira Massif, in the lower part of the valley, and the Piedmontese Zone with the Monviso Ophiolitic Massif in the upper part, from the town of Sampeyre to France.

The Dora-Maira Massif is a continental crust unit mainly constituted by ercinic and pre-ercinic methamorphites (mainly gneiss and micascists). On the other hand, the upper part of the valley is characterized by oceanic lithologies (Calcescists with Green Stones, Jurassic-Cretaceous) overthrusted on the Dora-Maira Unit. The Monviso ophiolite complex is a north-trending body, 35 km long and up to 8 km wide, sandwiched structurally between the underlying Dora-Maira thrust units and the tectonically higher, dominantly metasedimentary, units of the Piedmontese Zone (Lombardo *et al.*, 2002).

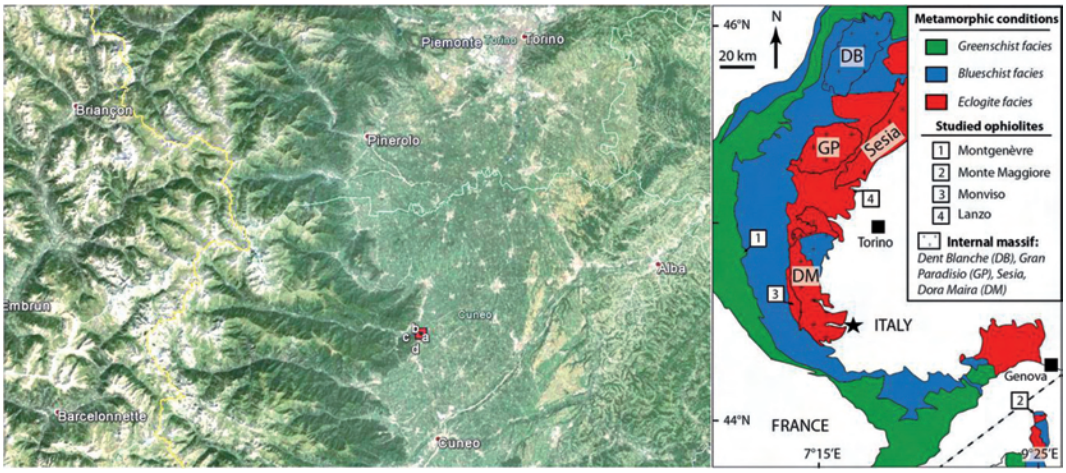



Fig. 1 – On the left the geographical location of the archaeological site: the white letters refer to the surveyed area. On the right the geological map of western Alps; the black star refers to the surveyed area.



001-258 volume 3 191 24-10-2014 16:46:48

The municipal area of Costigliole Saluzzo mainly lies on quaternary deposits mainly consisting of fluvioglacial and fluvial sediments (Pleistocene-Holocene) of the big alluvial fan apparatus of the Varaita River that opens towards the plain with slight slop (about 1%). The deposits are mainly made by medium-to-coarse gravels with a sandy matrix and a wide variety of pebbles and blocks of variable size, resulting from the erosion of the lithologies of the whole valley, can also be found.

The alluvial deposits in the archaeological site show on the surface the presence of centimetric to decimetric pebbles. In the exploratory trenches and excavations, however, the soil seems mainly consisting of silt and clay down to about 3 m. Therefore most of the pebbles are likely due to the destruction of the ancient walls and structures. The Roman remain walls, in fact, are largely made up of these natural pebbles and blocks. From a visual expeditious analysis on the field, the pebble lithology is largely represented by serpentinites and metabasites, probably outcoming from the Monviso Massif. Monviso serpentinites consist of antigorite and magnetite, with subordinate brucite, Mg-chlorite, tremolite, diopside, Ti-clinohumite and haematite (Balestro *et al.,* 2011; Castelli and Compagnoni, 2007). Magnetite grains are generally heterogeneously distributed in the serpentine matrix but locally they appear aligned to form thin bands that cross rocks following preferential directions (Compagnoni and Fiora, 1976). Geochemical analysis of the bulk rock composition shows a very high percentage of iron oxides, variable from 6% to more than 13% (Hattori and Guillot, 2007).

**The archaeological context.** The ruins of a wide *villa rustica* (Fig. 2) belonging to the Roman imperial period (Ist to IIIrd centuries AD) were unearthed by the University of Turin at the southern periphery of modern Costigliole Saluzzo and are still under excavation (Barra Bagnasco, 2003, 2005; Barra Bagnasco and Elia, 2007; Elia and Meirano, 2008, 2008-2009, 2012a, 2012b; Elia, *et al.,* 2013). After the destruction and the abandonment of the settlement, an occupation of the site is attested during the late-antique period (IVth-Vth centuries AD). The area, showing structures and erratic ancient materials, extends over ca 3 hectares. Measuring ca 56 x 85 m in its major phase, the main building reaches an extent of around 5000 $m^2$.

The explorations carried out in the last few years allow for the identification of a "U-shaped" villa characterized by a clearly-defined plan which represents an *unicum* in western *Gallia Cisalpina* so far. The evidence recovered supports the identification of the functions of the different sections of the building, with regard to both the *pars rustica* and the *pars urbana*. The main body is situated in the eastern part and shows an anomalous extent for this kind of buildings. The western part consists in a wide court (more than 1200 $m^2$) delimited by two long wings. These wings were destined to stocking agricultural products and to housing the




Fig. 2 – Plan of the villa (left) and picture of the walls unearthed after earlier excavation campaigns (right).



001-258 volume 3 192 24-10-2014 16:46:49

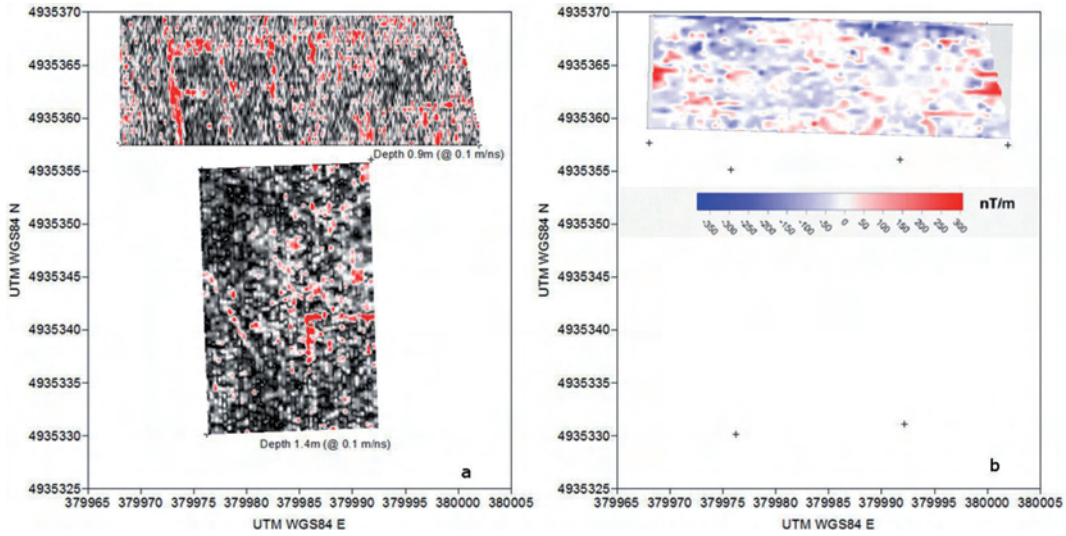



Fig. 3 – a) GPR timeslices on the south and north areas. b) Map of the vertical gradient of the TMF. Near the northern side of the area a metallic fence, that could not be removed, strongly influenced the measurements.

productive units (namely, a wine press room), while the central body had a residential function. The villa also shows a southern area including a small paved court which probably acted as a *taberna deversoria* for housing merchants and voyagers travelling on the way to ancient Gallia. The building had a water supply line and a sewer system.

The walls of the *villa* show socles in *opus caementicium* or dry rubble with pebbles and fragmentary tiles and bricks, while the elevations were basically in perishable materials, like sun-dried bricks, pisé or *opus craticium*. The roofs, sometimes covering wide surfaces, were made of large rectangular tiles and cover-tiles.

The building complex described is the result of a long series of enlargements and modifications, starting during the Augustan period.

Near the main construction, other contemporary buildings are known, probable dependencies to the *villa*. The characteristics and destination of these partially explored evidences are still under evaluation. The geophysical investigation programme started from the immediate surroundings of some of these structures, south of the ”trincea F” (north area). Moreover, to test the effectiveness of the methods in the given geological context, another area was selected for a blind test (south area) where some structures were already unearthed and later covered .

**Data acquisition and processing.** We made the survey on two areas within the archaeological site: the North area and the south area (Fig. 3). In the north area, on May 2014, we made both a magnetic and GPR survey while in the south area only a GPR survey was performed on July 2014, after the processing of North area data which lead us to exclude the magnetic method.

In the North area we used a Radar K2 from IDS with a 500 MHz IDS antenna. On the whole we made 31 profiles, each one about 32 m long. The profile interval was 0.4m while the trace interval was 0.035 m. The trace’s length was 50 ns and they were digitized with 512 samples. All the profiles show, on average, a quite broad band spectrum with a -3dB band ranging from 200 to 700 MHz. Raw radargrams showed a lot of clutters and there were no evidences of clear coherent reflections in the x-twt domain. The processing flow was very reduced and it consisted of: move start time, to set properly the zero time; dewow to remove low frequency effects and a non linear manual gain, increasing with time, to recover energy in the deeper radar section. Time slices, on the envelope of the Hilbert transform of the radargrams, have then been made summing up the samples over 1 ns window length.



001-258 volume 3 193 24-10-2014 16:46:51

In the north area we also made a magnetic survey with a GSM-19GF Overhauser magnetometer in walk-grad mode, setting an acquisition frequency of 2 readings/s. Both the total magnetic field (TMF) and the vertical gradient of the TMF were acquired with lower and upper sensors at 0.2m and 0.8 m above the ground respectively. On the whole we acquired 5093 raw readings along 51 profiles with a profile interval of 0.2 m. A further interpolation showed that, along any profile, on average, we had a 0.3 m reading interval. After outliers rejection and bad quality data removal we worked on 4647 readings. Data were then destriped and the gradient and TMF maps were obtained with a triangular interpolation.

In the south area we used a Radar K2 from IDS with a 200 MHz GSSI antenna. On the whole we made 41 profiles, each one about 25 m long. The profile interval was 0.25 m while the trace interval was 0.075 m. The trace's length was 100 ns and they were digitized with 512 samples. All the profiles show, on average, a spectrum with a -3dB band ranging from 100 to 250 MHz. Raw radargrams showed again a lot of clutters and there were no or little evidences of clear coherent reflections in the x-twt domain. The processing was reduced and it consisted of: move start time, to set properly the zero time; dewow to remove low frequency effects; a Butterworth 4 poles bandpass filter (100-500 MHz); a non linear manual gain, increasing with time, to recover energy in the deeper radar section and a time cut to 50 ns. The choice of the filter bandwidth, larger than the -3dB band, has been done to preserve shorter wavelets. Indeed in the average spectrum there is still a platform of energy at -9dB up to about 600 MHz, Time slices, on the envelope of the Hilbert transform of the radargrams, have then been made summing up the samples over 2 ns window length.

**Results.** Results are shown in Figs. 3a and 3b.

The vertical gradient map, as the total field one, is noisy and it is likely pervasively influenced by the serpentine pebbles and blocks. A simulation run with the software POTENSOFT (Ozgu Arısoy and Dikmen, 2011) showed that a cube having 0.2 m side with a magnetic susceptibility of 0.05 (SI), 0.2 m below the lower sensor, gives a total field and an vertical gradient anomaly compatible, both in amplitude and wavelength, with some of the high spots found in the field. Such a spread noise hinder the recognition of any alignment. The magnetic map does not seem to have any relation with the underlying structures revealed by the GPR despite the noticeable size of the structures themselves. It should however be observed that the walls are built randomly assembling blocks of serpentine and other lithologies in such a way that they might also give a magnetic signal similar to an incoherent noise. In every GPR time slice clutters are thoroughly in evidence. All the top of the walls are very irregular and there are not flat surfaces in agreement with the ones already dug up. Clutters concentration between and aside the walls let us suppose that there could be a remarkable amount of ruined material. The tops of reflecting walls in the North area are more shallow than the one in the South area. A long diagonal reflecting body, with an incoherent direction with respect to the others, appears in the western part of the South area. Looking at raw data both magnetic and GPR surveys failed to find any structure. Only time slice processing of GPR data revealed a frame of buried walls limiting rooms with dimensions comparable to the ones already dug up.

**Comments and conclusions.** Once again this case history pointed out the importance of the information on the target and surrounding environment materials in the early stage of the design of a geophysical prospection (Sambuelli and Strobbia, 2002). The results of the prospection allow for important preliminary evaluations concerning an unexplored area and are crucial in order to plan further excavations. In this area, anomalies showing straight lines have emerged, which confidently belong to two different buildings. The North area, in particular, shows the south continuation of two parallel structures already unearthed in trench F for a very short part. They respectively correspond to the outer west wall and to a inner wall of the same building and they both can be traced for more than 12 m. Other structures, approximately perpendicular to these ones, apparently delimitate two rows of quadrangular rooms showing recurrent dimensions (4-5 m). Further anomalies in the south-east corner of the North area and



001-258 volume 3 194 24-10-2014 16:46:51

in north-east corner of the South area are probably related to a second building. Short parts of east-west orientated walls belonging to this construction had already emerged in a limited sounding made in the modern irrigation canal crossing the archaeological area. In this case, the presence of a rectangular building (11 x 7 m) can be inferred.

At this stage of research, prospection allows for a better knowledge of the dependencies of the villa in the area north to the main building, and offers new data about the extent and inner plan of these constructions, which will be verified by means of further archaeological investigations.

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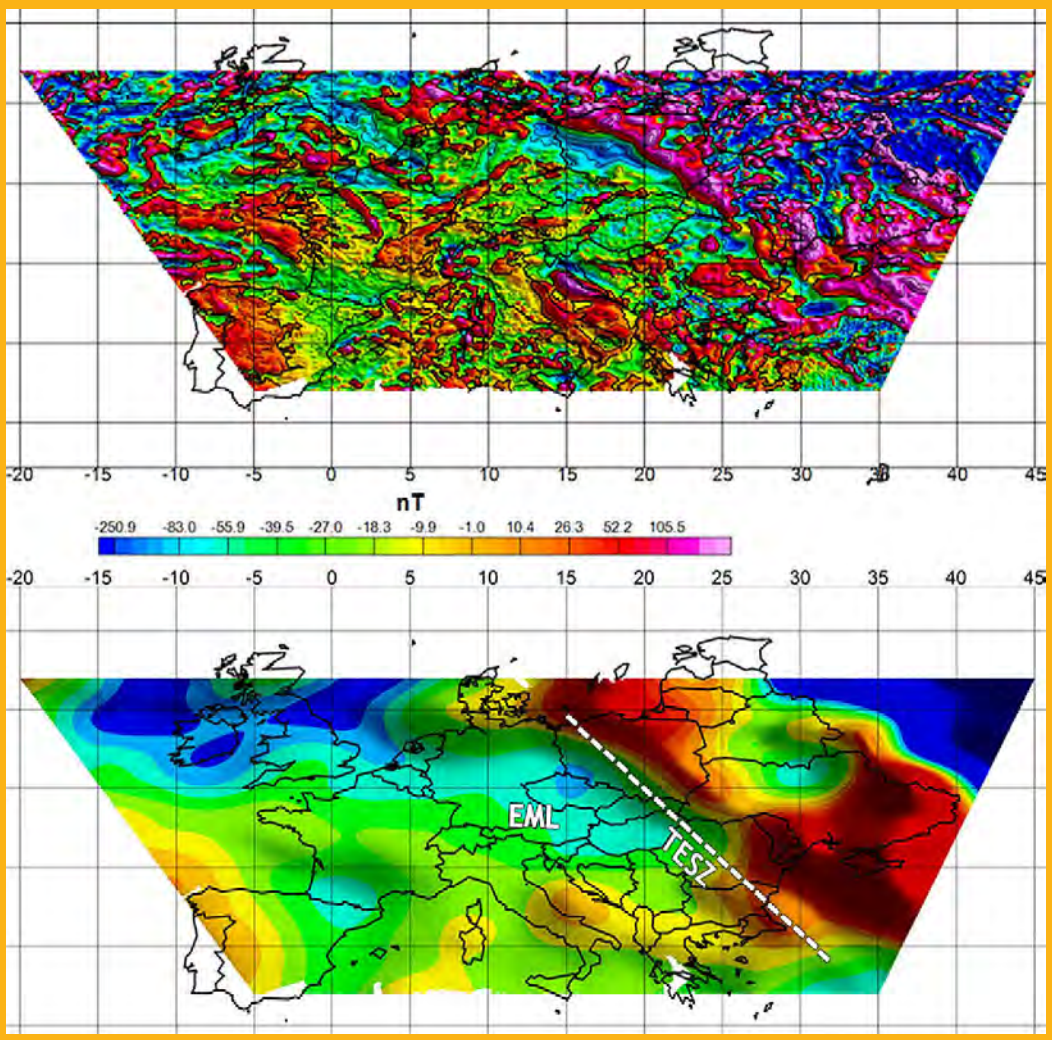
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001-258 volume 3 195 24-10-2014 16:46:51




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