Integrated Use of DGPS and the Total Station for the Survey of Archaeological Sites: The Case of Colle Breccioso

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Abstract

A series of topographical surveys carried out during the past years in the Salto Valley (Rieti - Lazio), have provided much interesting data regarding local archaeological sites, particularly along the southern slopes of the Breccioso Hills which rise between the Corvaro and Spedino plain. An interesting site has recently come to our attention at Colle Breccioso. However, the nature of the site was not clear and its structure is hazy, a consequence of the deterioration of the surrounding ground and increased vegetation coverage.

The situation at the site suggested that a detailed survey of the southern incline and the plateau associated with the site would be valuable. The objective of the survey was to highlight topographic variation and to bring to light any traces of human construction or manipulation.

The survey was carried out using a DGPS Leica SR 510, and a total station. The integration of these two instruments (which had both, differing and complementary capacities) produced satisfactory and innovative results. The processing of the Digital Terrain Model (DTM) of the area highlighted several characteristics of the site and the consequent production of thematic maps from this data could be used to guide future excavations at the site.

Key words: Global Positioning System, Total Station, survey technique, Digital Terrain Model, archaeological site, anthropic presence, Cicolano

1. Archaeological picture

The Cicolano area spreads along the Salto - Imele basin, and contains the watersheds of the Velino chain and the Carseolani Mountains. The region is on the eastern extremity of the Sabina area (Lazio, Italy), and owes its name to the historical, Equicoli people. Today, the Cicolano is contained within the administrative boundaries of Fiamignano, Petrella, Pescorocchiano and Borgorose (this more or less covers the Salto Valley from Caprodosso to S. Anatolia) (Almagià 1909:59, Pietrangeli 1976:75).

Settlement in ancient times is generally associated with an Oppida-Vici model; with fortified sites being placed on the heights (*Oppida*) and a myriad of inhabited settlements and necropolises along the valley floor (*Vici*) (Salmon 1985:85-86, Reggiani 1988:67, Alvino 1993:326, Bonocore and Firpo 1998:286). In ancient times, and as material from some Proto - historic necropolises demonsatrates, the Salto Valley must have had a certain importance in connecting the Fucino basin and the Rieti plain, the Sabina Tiberina and the Faliscan plain and, ultimately, Etruria (Alvino 2000:9).

The Roman conquest of the area occurred at the end of the fourth century BC and after bitter fighting over a period of over one hundred years. The annexation of neighbouring Alba Fucens dates to 303 BC and it may be suggested that it was only in c. 290 BC, the final year of campaigning of Manlio Curio Dentato in Sabina, that the whole of the Salto Valley, a marginal area with regards to the Via Valeria, was brought under Roman domination (Bonocore and Firpo 1998:359).

The real outcome of Roman subjugation was the compulsory abandonment of fortified sites and the destruction of sanctuaries along the valley floor which were in outlying positions to the settlements, but well located as regards the road network (Reggiani 1988:67, Alvino 1995:476).

The ancient N.W. - S.E. route was continued during the Roman period by a road which, on more than one occasion, has been identified as the Via Quinzia. An off-shoot of this road, which diverges from the river valley, wound its way over the Corvaro plain and, crossing the Cartore valley, headed off towards the *Ager Albensis* (Liverani 1985:282, Van Wonterghem 1988:423).

Between these two parallel routes, or to be more precise, between the Spedino and Corvaro plains one can find the Breccioso Hill, which climbs to an elevation of 842 metres. This southern slopes of this prominence contain the site which is the subject of this paper. Here a rectangular structure in *opus caementitum* is set, wedged into the slight slope, and high above a series of low terraces breaking towards the valley and outlined by a few square limestone blocks (figure 1).

In amongst the thick, bushy undergrowth are alignments of stone blocks, surrounded by numerous fragments of tiles and *dolia*. This closed rectangular structure may easily be identified as a cistern through traces of *cocciopesto* found on the site, and as suggested by the name of the site itself (Cisterna Vecchia). Despite this, it is

Figure 1: The Colle Breccioso site. The tank on the top of the hill and the terraces delimited from blocks of limestone are clearly visible.

difficult to understand both the structure of the site itself or its larger context.

Up until the end of the 1960s, before the construction of the A24 motorway exit, the Breccioso Hill site was well placed in relation to the neighbouring roads from Corvaro to S. Anatolia and from Corvaro to Torano. As shown by official maps and aerial photographs, these two roads divided right on the lee of the structure. We know that the remains of a roman-imperial building were destroyed at a higher altitude on the hill; perhaps this was a *villa.* The remains of a mosaic in *opus tessellatum* from this site has been incorporated into the war memorial at Spedino. Furthermore, we have some evidence of the existence of the S. Maria de Brizzasecco church, which was already a ruin in the sixteenth century and was probably afterwards substituted by the small chapel of S. Liberatore (Staffa 1987:73). A series of factors together with the probable passing in this zone of a connecting road between the two parts of the ancient road network, its intermediate position between the Corvaro plain, the necropolis of Cau di Cartore and the area of S. Maria del Colle, which is also rich in archaeological remains, creates great interest for study of the settlement.

2. Survey of the site

In order to improve the interpretation of the space layout and to understand the function of the site, we felt that it was essential to investigate the situation of the site, as well as its physical and geomorphological condition. In fact, the nature of the construction itself appears to be clearly linked to the territory within which it is located.

With the aim of highlighting topographic variation of the slope, which was probably subject to terracing in the past, as the limestone blocks show, a detailed survey of the Breccioso Hill was carried out using an experimental Differential Global Positioning System (DGPS) Leica SR510 with a single frequency and differential mode. This instrument guarantees a level of precision to one centimetre when calculating point co-ordinates.

At first, the DGPS was calibrated to measure the level of reliability of the Z coordinate, that is, the value of the height of a topographical point. In fact, as regards research aims, it was important

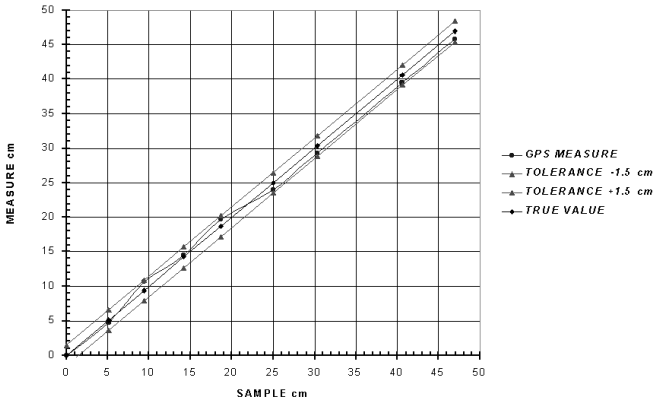

Figure 2: The graph shows the instrument's variable vertical range. The measured value falls into the instrument's tolerance range according to that declared by the producer.

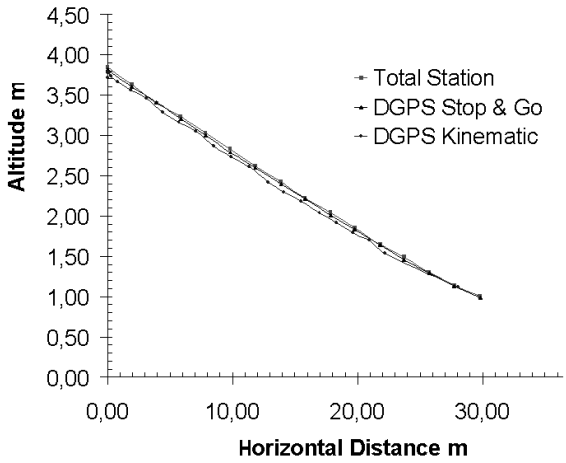

Figure 3: The graph shows the degree of shifting of the Z co-ordinate according to the method used for the acquisition. The values are included in the expected trend of 2-3 cm.

to be able to pick out even minimal height variations in the terrain that are potentially associated with buried structures.

In order to establish the instrument's level of precision in reading relative Z co-ordinates two tests were carried out. First the rod onto which the DGPS aerial was screwed was raised through a series of differing sample heights. Then, a series of measurements were taken using the receiver in the «stop and go» mode, that is, according to a very rapid static procedure where the device is held stationary for 60 seconds to take the reading. In this way, the height of the samples was taken in order to verify the instrument's variable vertical range. The data shown by the chart (figure 2) indicates that the measured values falls within the instrument's claimed tolerance range, i.e. 1 or 2 cm.

The second test allowed us to verify the validity of the height measurements on an incline. A set of equidistant points was fixed with the total station and the distances and relative heights were determined for each point relative to the origin point 0. Using the DGPS to calculate these points, we noticed that in the «stop and go» mode, the reproduction of data in respect to the total station is constant, whilst in the kinematic mode there is a slight divergence. However, each method of measurement was contained within the expected variation of 2-3 cm (figure 3).

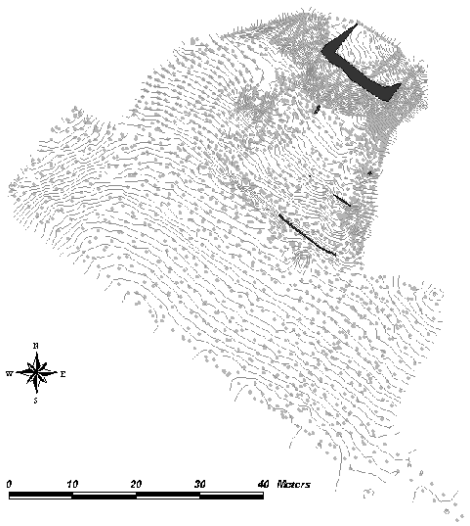

Figure 4: Colle Breccioso. Digital Terrain Model (DTM) of the hill. The surface structures are represented in black.

Having tested the instrumentation the whole of the Colle Breccioso site was then surveyed using the available instruments.

In order to carry out the survey, we chose to use the DGPS instrumentation in full kinematic mode. The operator carried a rucksack to which the aerial was attached on his back, and he then walked slowly over the entire area of coverage, including rugged areas and ensuring coverage of any localised height variation. During this operation the DGPS receiver recorded a point every 2 seconds. In this way it was possible to acquire a large number of points in a relatively short time and with limited energy loss. The operator also has the choice to decide on the density level of the points in relation to the morphology of the ground or any visible anomalies encountered during survey. Obviously, kinematic recording has a level of precision which is lower than that of a static reading, above all in respect of the x and y values, because the recording time of each point is shorter and because the aerial is not fixed but is affected by involuntary movements of the operator.

As the experimental tests showed, the margin of error may vary between 2 and 3 cm: this is quite acceptable for the reconstruction of contour lines or for morphological aspects of the ground. However, the error is too high for specific features, for example the edges of surface structures which may require a pinpoint position.

When the survey required a high level of precision, the aerial was positioned on a rod and the «stop-go» method was used. In these cases, the instrument was fixed upon a point for about 60 seconds thus reducing the possible error to 1.5 - 2 cm.

As part of the terraced zone was not easily accessible, a consequence of vegetation cover, it was necessary to use the total station in areas where vegetation prevented satellite connection. Standing structures including, for example, the tank on the top of the hill, were also surveyed using standard instrumentation (figure 1).

The integration of GPS acquisition methods which are both quick and easy to use, and the co-ordinated use of various instruments such as the DGPS and the total station, made it possible for as few as three people to survey the whole Breccioso Hill in a single day. This result in itself is significant, if one thinks about the time and effort that would usually be necessary for such a survey.

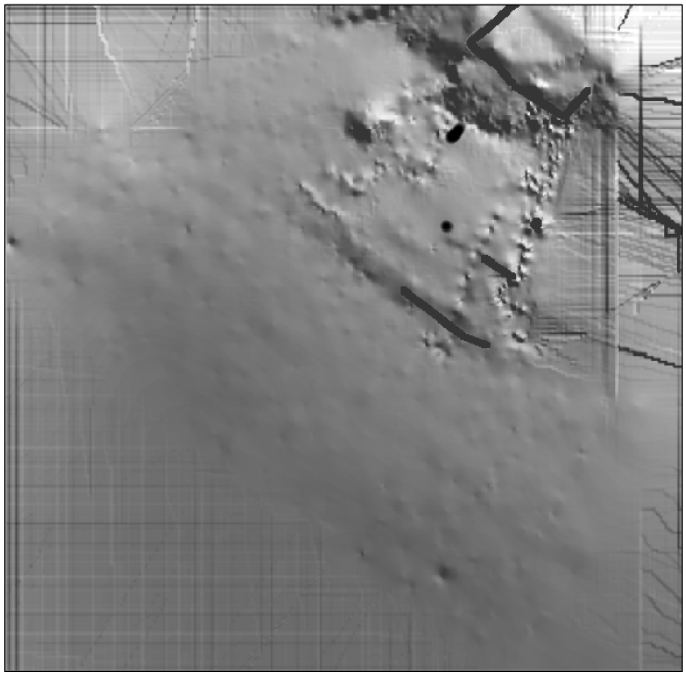

Figure 5: Colle Breccioso. DTM of the studied area overlaid with the shaded elaboration. Four terrace levels are clearly visible.

3. Elaboration of the data

Following survey, the relative system of co-ordinates of the total station was calibrated to the absolute grid of the DGPS, using a simple translation and rotation matrix. In this way, we obtained complete homogeneity within the collected data and could proceed to final interpretation. Data was manipulated within ER Mapper software and, in order to create a digital model of the hill, an interpolation of the height data set was implemented using a Triangular Irregular Network (TIN). In figure 4, the contour lines and all the captured points are given; in those areas where a higher density of measurements is shown, the total station system was used. The surface structures, surveyed using the total station system and then geo-referenced, are represented in black. The cistern on the top of the hill, which is a closed, rectangular form, does not appear as such on the survey, but is open at the northern end where it was impossible to take measurements.

Within the survey area some parallel contour lines appear very close to one another. This confirms the presence of abrupt, non-natural variations in the topography. The southern side of the hill is subject to a succession of low, wide terraces. These structures were demarcated by stone walls located on the ground surface (figure 1).

Figure 5 shows the Digital Elevation Model (DEM) of the area in hill-shaded form. Four levels appear on the map that can be interpreted as artificial terraces. They slope towards the bottom of the valley from which a large plain extends. The succession of minor terraces along the gradual slope suggests an absence of significant ground movement, thus eliminating the need for major buttressing. The whole character of the site is discernible from the map. The terracing was probably associated with a project to ex-

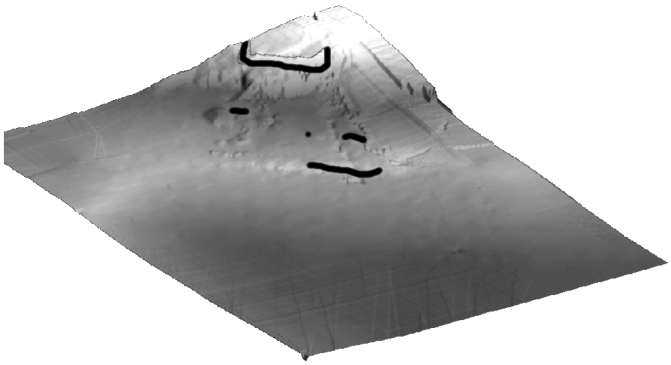

Figure 6: Colle Breccioso. On the map, overlaid with a mesh in pseudo - colour, the Z value was increased in order to highlight even the minimum variations in height.

ploit the hill, and the cistern must have been associated with this endeavour. In figure 6 the Z value was increased in order to highlight minor variations in height. The map emphasises some anomalies that are probably associated with buried structures. On the map one may pick out the position of the complex, carefully placed on the side of the hill and in front of the plain below. Today the site, which has fallen into a state of abandonment, hides the plotted position which is closely connected to the morphology of the slope.

4. Conclusion

In conclusion, the achievement of the micro-survey of the Breccioso Hill was the discovery and analysis of a series of archaeological structures. The maps that were produced from this survey could act as a guide to future excavation and direct the planning of further archaeological investigation.

The integrated use of the DGPS and the total station produced precise and satisfactory results, significantly reduced the registration time of survey points and resolved problems of field data collection. The co-ordinated, integrated survey of the micro-morphology of the terrain and visible structures has provided something extra, not only in respect of the position and nature of the remains, but also as regards its close relationship with the local topography. The use of space on the Breccioso Hill site is now clearer and we are able to provide some suggestions regarding a possible interpretation of the surviving structures. The terraces and the presence of the cistern might perhaps suggest a public or holy building but obviously only further research and excavation at the site will provide such concrete answers.

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