Abstract

An exploitation system of rock quarries was investigated along a tract of the ancient Appian Way extending between the modern villages of Itri and Fondi (central Italy). Three new quarries carved into carbonatic slopes were discovered through interpretation of aerial photography and photogrammetric restitution (this last still in progress) nearby a few extraction areas already acknowledged in previous works. Later, field surveys confirmed the anthropogenic nature of slope cuts as inferred from squared or rectangular morphological edges and evidence of regular tool-marks. Quarries location and exploitation techniques were analysed in relation to the archaeological requirements for the road construction and maintenance and also considering the geological setting of the area. In particular, it was demonstrated how geometric characteristics of rock masses – such as bedding and joint system spacing or intensity of brittle deformation – played a fundamental role in determining the kind of extracted material and use of different exploitation techniques. Indeed, cubic and pseudo-cubic rock blocks were extracted from quarries A and B during the Roman Age, as evidenced by peculiar tool-marks observed on the rock slope edges and tracing intersecting joint system. Quarry C was instead an open-pit derived from a cataclastic rock volume in the hanging-wall of a main normal fault and from which centimetres-sized debris were derived. The present study set the basis for a further analysis of the local exploitation system which may include other minor quarries used for road maintenance works and construction of other buildings.

Keywords: Landscape Archaeology, Geomorphology, Quarry Exploitation, Ancient Appian Route, Italy

1. Introduction

This work describes the early results of an archaeomorphological analysis on a stretch of the ancient Appian Way at the Aurunci Pass, on the border between the territories of Itri and Fondi in southern Latium (Italy) along the narrow course of the San Andrea Valley (fig. 1a). The study was led in the wider frame of the FIRB (Fondo per gli Investimenti della Ricerca di Base, i.e. Basic Research Funding) project featuring multidisciplinary research aimed at the diachronical reconstruction of landscape modifications and development through the ages, since the Roman Republican period to the nineteenth century AD. Archaeologists from the Literature and Cultural Heritage Department of the second University of Naples and geophysicists, geologists and topographers from the Institute for Technologies Applied to Cultural Heritage of the...
National Research Council (CNR-ITABC) joined the project for a common effort to integrate both the methodologies of analysis and results. The observation of natural and anthropogenic features in the local landscape leads to the definition of interesting and unexpected scenarios. From the interpretation of aerial photographs, original photogrammetric restitution and joined field surveys, an exploitation system of the local calcareous ridges was recognised including several quarries found close to the Appian route track, only partially acknowledged by previous studies (Quilici, 1999; 2011). Moreover, the multidisciplinary approach brought to the assessment the major aspects regarding the siting of ancient mining activities and exploitation techniques for the extraction of raw materials.

2. Archaeological background

The ancient Appian Way crosses the Fondi Plain in a straight line; approaching eastward to the Aurunci mountains, the route track enters the San Andrea Valley and edges hilly carbonate ridges by a gentle turn (figs. 1a, b). This point, also known as the Itri Pass or Gorge, is among the most spectacular and famous tracts of the ancient way, due
to the monumental structures that allowed the transit through the rough landscape.

The route track has been largely preserved in the study area despite natural processes and anthropogenic modifications. The original basalt stone paving can still be observed in several zones, as well as outstanding polygonal worked retaining walls, locally showing sub-parallelepiped elements. These walls, made of calcareous rock blocks, were raised on both route sides at a constant distance of 6.70 m: the lower walls sustained the route terrace towards the San Andrea Valley whereas the upper wall prevented the route track from rock falls and gravity-driven deformations.

The ancient Appian Way gently climbs straight up to the Sant’Andrea stronghold (Bourbon period) then, moving to the south and towards Itri, the slope of the route progressively increases. The ruins of fortifications nowadays occupy an area originally characterised by the presence of an extra-urban sanctuary, probably devoted to Apollo (fig. 1a). The temple was an imposing monumental structure, delimited by high retaining walls on the valley side built in polygonal and squared blocks of limestone and enriched by a system of tanks in concrete faced in uncertain work.

In such an archaeological context, some rock quarries were already documented flanking the entire route track and carved within the carbonate slope featuring the SW side of the San Andrea Valley (fig. 1b). Quarry types include both wide, sub-vertical cuts nearby the tanks and stronghold area and smaller rock caves. Rock material from quarries exploitation was surely used for walls construction; however, caves location was also partly influenced by space need for building (Quilici, 1999).
3. Geological and geomorphological setting

3.1. General features

In the study area, the ancient Appian Way crosses a hilly landscape which features calcareous mountain ridges made by Mesozoic, shallow-water carbonates spanning in age between the late Jurassic and the Late Cretaceous. The Mesozoic sequence is characterised, from the bottom to the top, by Upper Jurassic oolitic and biodetric limestone (and dolomites) which outcrop in the southern sectors towards the Itri side, Middle Cretaceous biodetric limestone with thin intercalations of red or grey clays and breccias levels, and by Upper Cretaceous biodetric limestone and dolomitic levels, these last outcropping on the northern side of the area, towards the town of Fondi (fig. 1b).

The carbonate sequence features a NE-SW oriented, gently NW-dipping monocline which is locally deformed by recumbent folds representing remnants of the Neogene Apennine tectonics. The landscape morphogenesis was also driven by the enucleating of NE-SW oriented normal faults (such as faults F1 and F2 in fig. 3a) with subordinate NW-SE oriented elements. As it will be further discussed, these last tectonic features influenced the location of quarries and determined the kind of material extracted.
The geological setting of the area is completed by Quaternary deposits which lie uncomfortably on the Mesozoic sequence. Talus slope and paleo-landslide, clastic deposits fill the San Andreas Valley in its southernmost part at greater elevations, around 250 m asl, while debris fan and alluvial deposits are present in the northern sector, at a lower average elevation of 150 m.

3.2 Structural control on cave location and rock material characteristics

Some rock quarries along the southern sector of the study area had been already documented (Quilici, 1999); in this study we acknowledged the presence of three previously undiscovered caves (named A-C in figs. 2a, b, 3a and tab. 1) which were detected almost at the same time by means of aerial photograph interpretation and photogrammetric restitution.

By comparing quarries locations to the trend of main tectonic features in the area it turns out that carbonate slopes were exploited along the traces of main normal faults affecting the Upper Cretaceous limestones featuring the hilly slopes and bounding the Appian route track on the Fondi side (figs. 1b and 3a). This strict correspondence can be explained considering that brittle deformation due to fault activity disarticulated the original rock masses into isolated blocks delimited by joint surfaces (fractures). This clearly helped extraction of stony material from cave A and B, where intersecting joint systems formed rock blocks with different shape and dimensions, depending on bedding \( S_0 \) and joint systems spacing \( S_1, S_2 \) (tab. 1). In particular, intersecting discontinuities within cave A give origin to cubic blocks with a maximum volume of about 0.064 m\(^3\), whereas in cave C pseudo-cubic rock blocks reach volumes of much greater an order of magnitude, i.e. up to 0.42 m\(^3\).

Brittle deformation was much more intense into rock material around quarry C because the original rock mass was in the hanging-wall of a main NE-SW oriented normal faults (faults F1 in fig. 3a). Severe fracturing generated a cataclastic rock ("cataclasite"), which can be defined as a cohesive tectonic breccias (fig. 3b) consisting in angular clasts dispersed in a fine-grained matrix. Even today, centimetres-sized octahedral blocks are largely available from this quarry and were probably used for different purposes than the larger rock blocks from caves B and C.

4. Characteristics of quarries and exploitation techniques

As aforementioned, landscape analysis evidenced an exploitation system of the calcareous rock slopes on the SW side of the ancient Appian Way; quarries are located, prevalently, along the slopes edges while only in a few cases were carved into middle slope zones. Apart from acknowledged caves, three others extraction areas were discovered (namely caves A-C) and are presently undergoing detailed studies including high-resolution photogrammetry (which will allow an estimation of missing rock volumes).

Quarries were carved into limestone and dolomitic rock slopes with different shape and dimensions depending on brittle deformation persistence, bedding and joint systems spacing and extraction techniques that changed through the ages. Caves exploitation in the whole area is undoubtedly documented for the Roman Age when it was developed to provide stony rough material needed for the construction of retaining walls along the route track and other structures; nevertheless, extraction activities from the same rock slopes can also be hypothesised during the main phases of route track recovery and paving restoration in the sixteenth and nineteenth centuries AD.

Indeed, field surveys were focused on the detection of distinctive features compatible with different technologies; therefore, we assign to an Ancient Age quarries showing dimensions and characteristics similar to those produced by extraction techniques acknowledged for the Roman age (fig. 2a).

A singular case is represented by cave B which is located a few tens of metres from the road track,
where the Mesozoic rock slope is bounded by Qua-
ternary debris fan deposits (fig. 1b); this cave pre-
sents a terraced structure and has a larger dimen-
sion. Field observation on the present, sub-vertical
edge (fig. 4a) evidenced some regular marks (figs.
4b, c) which indicate lines of extraction with an av-
erage distance of 60-65 cm. This measure indicates
a precise choice during extraction workings for the
production of two-roman feet dimensioned rock
blocks; the success of this technique was favoured
by the similar bedding and joint systems spacing
(tab. 1). The quarry edge traces the outer (northern)
boundary of the cataclastic rock volume (fig. 3a)
this suggesting that extraction could not proceed
further due to reduced mechanical rock properties
and size of rock blocks.

Despite the dense arboreal and shrub-like
vegetation, which partly hide the quarry area, a
squared rock block was observed on the upper ter-
trace that shows dimensions compatible with cuts
on the sub-vertical edge (fig. 5d). The block was
probably discarded or abandoned during trans-
port; its presence gives an idea of the cave at its
full activity. The uppermost terrace on which it lies
– right at the foot of the cave front – was probably
used for preliminary shaping, storage and moving
of extracted rock blocks. Then, slipway systems
and machinery helped to move rock blocks first
from the cave terraces to the road track and finally
to the construction sites.

Finally, a few metres above cave B, in the
hanging-wall of fault F1, the smallest cave C was
detected (figs. 3a, b). This cave was exploited as an
open-pit, directly within the cataclastic rock vol-
ume. Centimetres-sized and wedge-shaped rock
blocks were produced from this quarry and were
used for concrete and wall facing operas.

### 5. Discussion and conclusion

The comparison between geological features, such
as joint systems spacing within rock masses or
cataclastic fragmentation nearby fault traces, and
evidence of exploitation techniques in analysed
quarries is leading in the archaeological area of
the ancient Appian Way to the definition of inter-
esting working hypotheses. As a preliminary con-
sideration, it can be concluded that quarries were
located and first exploited taking into account the
closeness to construction sites for the realisation
of the route track and subordinate operas, includ-
ing engineered modifications of bounding rock
slopes. The wise planning of volumes excavations
and fillings had to be managed considering the pe-
cular characteristics needed for the construction
of a Roman road, by guaranteeing, for instance,
the straight trend and a constant dip. As a further
factor for the development of the exploitation
system, the geological and tectonic setting directly
controlled:

<table>
<thead>
<tr>
<th>cave n°</th>
<th>bedding attitude [S0]</th>
<th>joint systems</th>
<th>rock blocks characteristics</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>orientation spacing [m]</td>
<td>J1 spacing</td>
<td>J1</td>
</tr>
<tr>
<td>A</td>
<td>N318°;28° 0.3-0.4</td>
<td>N358; 88 0.3-0.4</td>
<td>N300;78 0.3-0.4</td>
</tr>
<tr>
<td>B</td>
<td>N310°;25° 0.4-0.6</td>
<td>N120; 21 0.8-1.0</td>
<td>N290;84 0.6-0.7</td>
</tr>
</tbody>
</table>

Tab. 1. Geometric characteristics of discontinuities with-
in rock mass in caves A and B.
1) the kind of extracted material in terms of rock block volumes; and
2) the exploitation techniques.
In particular, the regularly spaced bedding and joint discontinuities observed in caves B and A favoured the extraction of cubic or pseudo-cubic rock blocks; evidence from cave B witnessed for the production of 2 Roman-feet cubic blocks. Blocks with volume ranging from 0.0064 and 0.56 m\(^3\) from quarries A and B, respectively, were probably used for construction of polygonal work retaining walls (figs. 5b-c).

More pervasive brittle deformation in the proximity of fault traces, such as in the case of cave C, provided finer rock material suitable for concrete production or walls facing (fig. 5a).

Further analyses are planned in the study area in the next months and will be mainly focussed on the assessment of quarried rock volumes. In particular, this issue will make necessary the processing of digital photogrammetric aerial surveys with scales and equidistance metrics appropriate to define the trend of morphological surfaces bounding rock cave areas. A renewed attention will be dedicated also to small, new pits sited along the route track close to the remains of the Roman temple which were probably cultivated during maintenance works of the road and for the edification of new buildings such as the Bourbon stronghold.
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References

Quilici L, 1999: La via Appia attraverso la gola di Itri, Atlante Tematico di Topografia Antica, 8, 51-94.