Geogr. Fis. Dinam. Quat.
36 (2013), 241-257, 10 figg., 1 tab.

DOI 10.4461/GFDQ.2013.36.20

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GEOSITES WITHIN ROME CITY CENTER (ITALY): A MIXTURE OF CULTURAL AND GEOMORPHOLOGICAL HERITAGE

ABSTRACT: DEL MONTE M., FREDI P., PICA A. & VERGARI F., *Geosites within Rome City center (Italy): a mixture of cultural and geomorphological heritage*. (IT ISSN 0391-9838, 2013).

Rome has been an international destination for thousands of years. Visitors that are attracted by well-known historical and cultural sites can also find a wealth of natural and geomorphological features in the city. These characteristics, which are some of the main contributors to the success of *Aeterna Urbs*, are often hidden or have been modified by millennia of urbanization. This «man-made layering» is unique from other cities around the world, but the features are still recognizable among the usual tourist attractions.

In this work, we present the results of a geomorphological analysis conducted within Rome that led to the production of a geomorphological sketch of Rome and an inventory of the geosites in the city center. We identified two new geosites that are essentially geomorphosites because they are of geologic interest and are also typical expressions of the evolution of the relief. In the first case, Isola Tiberina (Tiber Island), the geomorphosite is evidence of the paleogeographical conditions present when Rome was founded, while the second, Testaccio Mount, is a geomorphosite that today represents a significant man-made hill built by landfill activity by an advanced society two thousand years ago.

The results of the investigations led to the proposal of an urban geotourist trail that shows the geomorphological evolution of the area and the geologic and climatic framework that has contributed to the historical development of the city. Moreover, the itinerary demonstrates how the history, urban planning and geomorphological characteristics of the area are connected; thus, it is intended to popularize geo-knowledge of Rome, whose main attractions have been traditionally related only to its historical heritage.

KEY WORDS: Urban Geomorphology, Geomorphosites, Geotourist itinerary, Rome.

RIASSUNTO: DEL MONTE M., FREDI P., PICA A. & VERGARI F., *I geositi del centro storico di Roma: connubio di patrimonio culturale e geomorfologico*. (IT ISSN 0391-9838, 2013).

La città di Roma è da sempre meta turistica internazionale di primaria importanza. I visitatori sono attratti dai ben noti siti di interesse storico e culturale, ma potrebbero scoprire in Roma una stupefacente ricchezza di aspetti naturali e geomorfologici. La morfologia, che ha notevolmente contribuito al successo della *Aeterna Urbs* nel corso dei secoli, è spesso nascosta o è stata modificata da millenni di urbanizzazione. La stratificazione antropica che caratterizza Roma è unica tra tutte le città del mondo, ma, nonostante le trasformazioni apportate dall'uomo, sono ancora riconoscibili numerose forme del rilievo nel paesaggio attuale, punteggiato di attrazioni storico archeologiche.

In questo lavoro presentiamo i risultati di un pluriennale rilevamento geomorfologico condotto nella città di Roma, che ha portato alla produzione di uno schema geomorfologico del centro storico. L'indagine ha permesso inoltre di evidenziare alcuni siti di interesse geologico (geositi), di cui si propone la valorizzazione. In particolare, si segnalano due geomorfositi, che sono tipica espressione dell' evoluzione del rilievo dell'area: l'Isola Tiberina, testimonianza delle condizioni paleogeografiche presenti all'epoca della fondazione di Roma; il Monte Testaccio, che rappresenta oggi una particolarissima collina di origine antropica, nata dalle attività di discarica di una società assai avanzata di duemila anni fa.

La valorizzazione del patrimonio geomorfologico così individuato si esplica nella proposta di un itinerario geoturistico urbano, che mostra l'evoluzione geomorfologica del territorio e il quadro geologico e climatico che hanno contribuito allo sviluppo storico della città. Inoltre, il percorso mostra come la storia, l'urbanizzazione e le caratteristiche geomorfologiche dell'area sono in stretta relazione. Lo scopo della proposta di valorizzazione è dunque divulgare le geo-conoscenze acquisite su Roma, affiancandole alle attrazioni della città, tradizionalmente legate solo al suo patrimonio storico culturale.

TERMINI CHIAVE: Geomorfologia urbana, Geomorfositi, Itinerari turistici, Roma.

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The research was funded by the Ministry of Instruction, University and Research (MIUR), PRIN Project 2010-2011 «Dinamica dei sistemi morfoclimatici in risposta ai cambiamenti globali e rischi geomorfologici indotti» (National coordinator C. Baroni, Research Unit coordinator M. Del Monte).

INTRODUCTION

Rome is one of the most popular tourist destination all over the world. Visitors that are interested in Rome's well-known historical and cultural sites can be often surprised to find a wealth of scenery and landscapes. Among the reasons for the success of the *Aeterna Urbs* are its natural and geomorphological features. These features, which have been hidden or modified by millennia of urbanization but which are still recognizable among the usual tourist attractions, form a unique «man-made layering» that is rare in other cities around the world.

The geological and the natural heritage represents, itself, an attraction for people (Reynard, 2008). Explanations and interpretations of natural features of the Roman landscape are not generally available in tourist guidebooks. The traditional descriptions of cultural and historical features should be augmented by a simplified scientific presentation of the region's geomorphological evolution, with a focus on how it has influenced the architectural development and the history of the city.

In this work, we present the results of a geomorphological analysis that was conducted within Rome. The analysis led to an inventory of geosites in the city center that includes two new geosites of geomorphological interest (defined as «geomorphosites» by Panizza, 2001, 2003) and allowed to propose the enhancement of the geological heritage of Rome, through an urban-environment geotourist trail. It shows the geomorphological evolution of the area and describes how the geological and climatic framework of the region has contributed to the historical development of the city. The main attractions of Rome have been traditionally related to its historical heritage, the itinerary is intended to popularize the geo-knowledge and the link between nature and culture.

MATERIAL AND METHODS

The analysis of the landforms in the study area was performed by means of a geomorphological survey. We obtained information on the action of surface processes over time to show how the area has been subjected to rapid morphological changes, even over short time periods.

To obtain information on the morphological changes over longer time periods, the geomorphological survey was supported by the analysis of aerial photographs from the last 70 years. The photos were obtained at the Earth Science Department of «La Sapienza» University of Rome and the National Aerial Photographic Archive.

We also consulted numerous old papers and historical and archeological books to collect information relevant to the geomorphologic characteristics that were present prior to the many modifications made by man. In addition, important information on natural landforms that are now hidden was obtained from interviews of elderly people who described the recent modifications and to whom we are very grateful. Useful information for the reconstruction of past geomorphological events was also collected from a database of drilling data (Ventriglia, 2002).

The criteria used to recognize and map the landforms are based on those proposed by several authors (Panizza, 1972, 1973; Pellegrini, 1976, 2000; Dramis & *alii*, 1979; Gruppo Nazionale «Geografia Fisica E Geomorfologia», 1994, 1995; Del Monte, 1996; Lupia Palmieri & *alii*, 1998, 2001; Ciccacci & *alii*, 2003; Aringoli & *alii*, 2005). The morphological elements in the study area were grouped according to genetic criteria, so each landform was classified according to the main type of geomorphic process.

The geosite inventory was performed by compiling information on cards (tab. 1) using and revising several national and international methods (Reynard & *alii*, 2007; Coratza & Giusti, 2005; Fattori & Mancinella, 2010). The aim of the inventory is to highlight the natural resources of the area; therefore, the geosites are evaluated and ranked to be prioritized for protection and enhancement.

The geosites found in this study led to the proposal of a geotourist trail, which is a synthesis of a great part of the Cultural Landscape (definition; UNESCO, 2005) of Rome's city center.

Study area

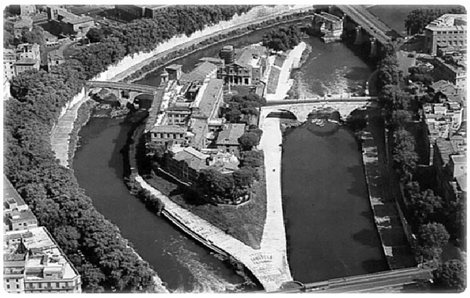
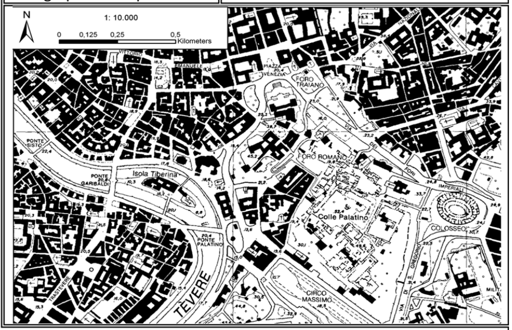
Rome, the Italian capital city, is located on the Thyrrenian side of central Italy, west of the Latium-Abruzzi Apennines. Rome's historical center contains many monuments and several large public parks. Features of Rome's ancient history are inscribed not only on monuments but also on a various landscape, that is characterized by hilly and volcanic settings that are cut by the Tevere River valley. Despite the heavy anthropic impacts over time, several interesting landforms that are of geotourist interest survive. The presence of the Tevere River separates two very distinct types of landscape characterizing the old city.

On the east side of the Tevere River (left bank) there are the famous Seven Hills ("*Septimontium*"): Quirinale, Viminale, Esquilino, Capitolino (or Campidoglio), Palatino, Celio and Aventino (Quirinal, Viminal, Esquiline, Capitoline, Palatine, Caelian and Aventine), which hosted the first human villages approximately 2000 B.C. (Touring Club Italiano, 1999). Fords across the river were located adjacent to each hill. The Seven Hills were formed by the erosion processes of the Tevere fluvial system, which deepened the volcanic plateau of the Latium Volcano (Colli Albani volcanic complex). This plateau covers the left slope of the Tevere River valley, extending from southeast of Rome to the main course of the Tevere and even west of it. A series of small flat-bottomed valleys, which are drained by the tributaries of the Tevere, separates the Seven Hills; two of them appear today as isolated domes (Capitolino and Palatino), while the others are small ridges.

On the West side of the Tevere River, the floodplain ends at the ridge of Monte Mario - Gianicolo (Mount Mario - Janiculum). To the west, this ridge is cut by the Aurelia Valley, which describes a counter-clockwise curve towards the alluvial plain of the Tevere next to Vatican City. While the ridge of Mt. Mario - Gianicolo reaches 137 m above sea level and has an uneven top, the Seven Hills have heights of approximately 50 m and flat tops.

The evolution of the region was controlled by the development of the hydrographic network during the peak sea level lowstand that corresponded to the last glacial maximum (22-18 ka), which led to deepening of the thalwegs of the main valleys. This was followed by a phase of fluvial deposition and valley-floor gradual aggradation due to sea level rise (17-5 kA) (Bellotti & *alii*, 2007).

TABLE 1 - An example of a compiled geosite inventory card

GEOSITE INVENTORY CARD											
IDENTIFICATION											
Name **TIBER ISLAND**				Database codex **RM_flu_01**							
Imagine				Cartographic excerpt							
											
Editor **ALESSIA PICA**											
Institute, agency **Earth Science Department, La Sapienza University of Rome**											
Data entry		field survey	√				bibliography	√			
Date **04/09/2012**											
LOCATION											
region **Lazio**	province **Rome**			municipality **Rome**				toponym **Isola Tiberina**			
geographical coordinates	**41° 53'25. 75" N**			**12° 28'40.25" E**							
altitude	**18,2m**										
cartografic reference		type	**c.t.r**	denomination							
		id number	**374100**	scale	**1: 10.000**						
DESCRIPTION											
The Tiber Island geosite is located in the historical heart of Rome, where the city developed next to the Tiber River over 2500 years ago. It is the only island in the Tiber's urban stretch. (..........)											
ICONOGRAPHIC DOCUMENTATION	(specify author and reference)										
	photo	annex1: Tiber Island north aerial view; annex2: Tiber Island south aerial view;(…)									
	scheme	annex4: counterflow scheme, Tiber Island origin; annex5:geomorphological sketch									
	film										
	other										
SCIENTIFIC INTEREST											
primary (one selection)	geomorphology	√	vulcanology		idrogeology		mineralogy				
	structural geology		paleontology		stratigrafy						
secondary (multiple selection, list)											
interest level	international		national	√	regional		local				
CONTEXTUAL INTEREST	culture	√	didactic		excursion		hystory	√	tourism	√	
	flora		fauna		landscape		archeology	√			
CHARACTERIZING ELEMENTS	litology	**fluvial sands and gravels, clayey sands and clays**									
	chronostratigraphic unit	**Holocene**									
	genetic process age	**Holocene (5000-500 b.c.)**									
TYPOLOGY	single element	√		whole of elements							
form	point	√	line		area						
exsposure	natural	√	artificial								
LAND USE	woody		meadowy		otucropping rocks						
	urbanized	√	tilled		untilled						
RESTRICTIONS											
is the geosite in a protected area?	yes		no	√	other restrictions	yes		no	√		
type	name of the protected area				type						
national park					landscape and environment Law						
regional park					paleontological						
state natural reserve					other						
regional natural reserve											
ZPS											
(…)											
CONSERVATION STATUS	good	√	moderate		bad						
GEOSITE ENJOYMENT											
recomended season to visit	spring	√	summer	√	autumn	√	winter	√			
ACCESIBILITY											
rising site	walking	√		by car		on boat	√		other		
submerged site	visible				visible in immersion						
underground site											
panoramic point	yes		no	√							
from afar visible point		√									
(…)				√							
REFERENCES	***Clericil E. (1911) - Una trivellazione eseguita (…) *Coarelli F. (2001) - Archeological guide Laterza. (…)**										

The bedrock in the study area consists mainly of clay and marl with foraminifers (Pliocene - Early Pleistocene), which were deposited during an extensional tectonic period that produced several NW-SE oriented horsts and grabens (parallel to the Apennines) (fig. 1).

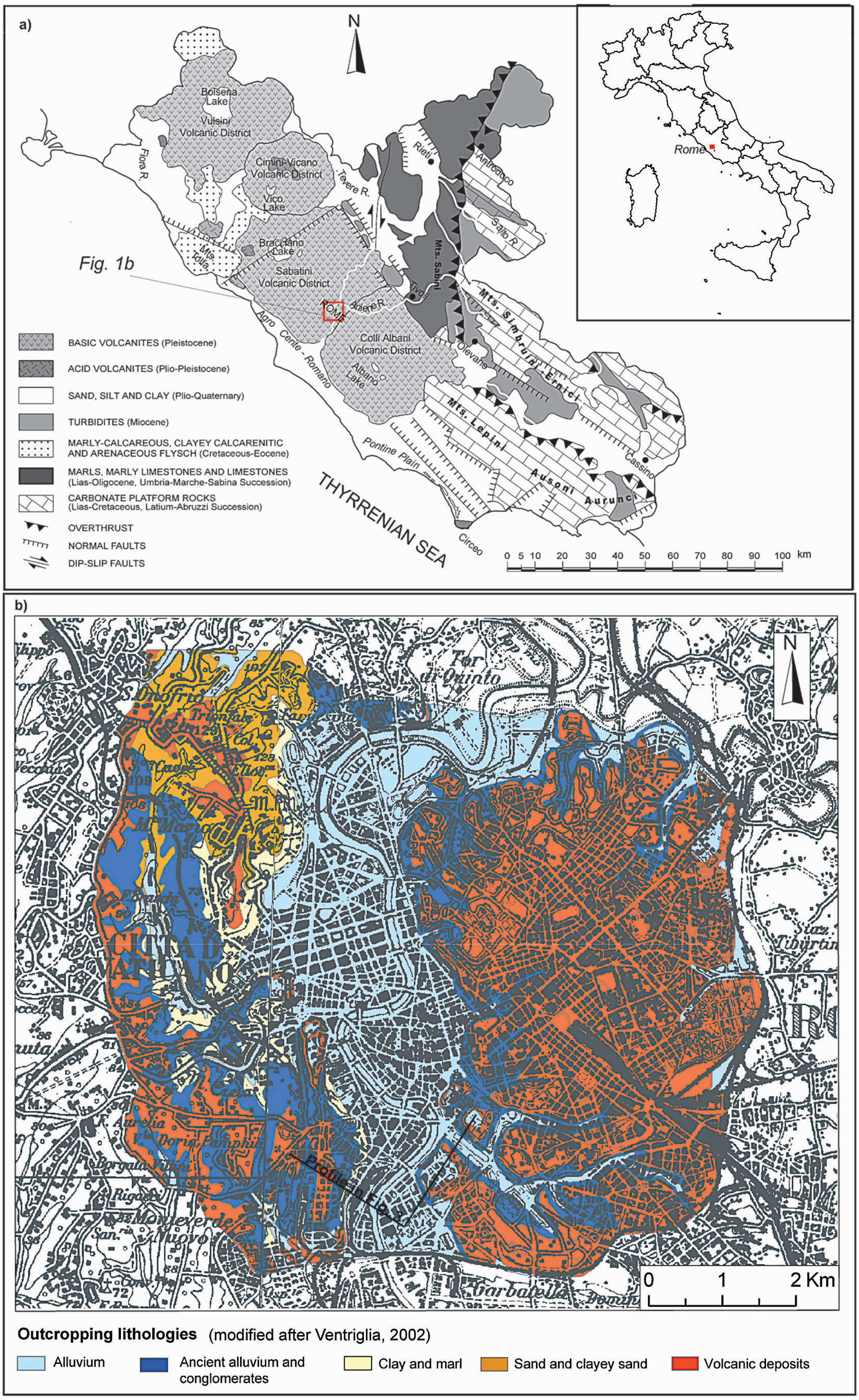


FIG. 1 - Geological sketches of *a)* Latium Region, and *b)* Rome's historical center.

Three major marine depositional cycles have been recognized in this period (Faccenna & *alii*, 1995). The first cycle (Lower Pliocene) included the deposition of the Blue Clays Unit ("Marne Vaticane"), while coarser-grained sediments of shallower water facies were deposited during the second and third cycles (Lower Pleistocene; Monte Mario Unit and Monte delle Piche Unit; Bozzano & *alii*, 2006).

The bedrock is overlain by up to 800 m thick epicontinental deposits (Marra & Rosa, 1995) that are related to slow and progressive crustal uplift. A series of depositional cycles of fluvial-marsh and marine-marginal environments began at 0.88 Ma (Milli, 1997); flood deposition occurred along Paleotevere (Ancient Tevere) and its tributaries. The two main cycles are linked to two different positions of the main Tevere stream channel and the river delta: the deposits include the depositional sequences of Ponte Galeria (Milli, 1997) or the Paleotevere 1 unit (Marra & Rosa, 1995) and the Paleotevere 2 unit (Marra & Rosa, 1995). The Paleoteve*r*e 2 unit is located in the historic center of Rome. These units are interdigitated with a thick layer of pyroclastic deposits produced by the Sabatini and Colli Albani volcanic complexes (Giordano & *alii*, 2006), ranging in age from 600 to 36 ka (Karner & *alii*, 2001). The volcanic outcrops are widespread throughout Rome and are represented by stratified tuffs, leucititic lavas, pyroclastic and volcaniclastic deposits. Continental sedimentation continued throughout these depositional cycles controlled by eustatic variations.

The stratigraphic relationships between the volcanic and sedimentary units are complex because the effects of erosion during the lowstands coincided with neotectonic processes and volcanic activity (Belisario & *alii*, 1999; Della Seta & *alii*, 2002; Ciotoli & *alii*, 2003; Cattuto & *alii*, 2005). The emplacement of volcanic deposits changed the topography and the hydrography of the area; the main stream of Paleotevere moved towards the Mt. Mario - Gianicolo ridge near the Colli Albani plateau.

During the last phase of the Würm glacial period at approximately 20 ka, the large drop in sea level (Gioia & *alii*, 2011) induced strong erosion processes. In the city of Rome, the Tevere River and its tributaries cut into the Plio-Pleistocene bedrock to a level of 50 m above the present sea level. The subsequent rising in sea level caused a depositional phase in which the previously incised valleys were filled by up to 60 m of alluvial deposits (Ascani & *alii*, 2008).

The rate of deposition over the last 17 ka is related to changes in the rate of sea level rise. By analyzing the facies in the Tevere delta, several authors have shown that the rate of sea level rise was not constant (Bellotti & *alii*, 1989, 1994, 1995, Amorosi & Milli, 2001). In particular, the post-glacial rise of sea level ended between 7 and 5 ka. The development of the marine delta at the mouth of the Tevere subsequently began (Bellotti & *alii*, 2007), and the coastal wetlands were filled during the Middle Ages.

The most recent stratigraphic layer overlies the flood deposits. This layer consists of alluvium and colluvium and contains materials from human activity that have accumulated throughout Roman history. This man-made layer covers the historic center and ranges in thickness from a few meters to tens of meters (Funiciello & Giordano, 2008; Funiciello & *alii*, 2008).

The landscape of the historic city of Rome is the result of these complex Plio-Quaternary events. Over the last 3000 years, human activities have generated important modifications of the topographic surface.

RESULTS

Geomorphological survey

The Rome area is characterized by landforms derived from the action of surface running waters, polygenic and structural and gravitational ones. In addition, several landforms were created by human activities (fig. 2).

The valleys along the Tevere River and its main tributaries have flat floors as a result of the Holocene depositional processes described above. On the hydrographic left, the «historical» hills have steep slopes and flat tops (fig. 3). The landscape on the West side of the Tevere, in contrast, is dominated by the Mt. Mario - Gianicolo ridge, which is higher, more rugged and has been subjected to more widespread and severe mass movements (fig. 2a and 2b).

FLUVIAL LANDFORMS

The landforms molded by surface running waters are recognizable throughout the study area and the entire Tevere River Basin. Although the study area is not large, its drainage network has particular characteristics. The axis of the main valley of the Tevere is oriented N-S, which is similar to the orientation of several other channels, especially on the west side of the river (Della Seta & *alii*, 2002). The orientation of the Apennines (NW-SE) is also reflected in many landforms; to the east of the Tevere, the Murcia Valley ends with a straight feature that is most likely controlled by the presence of horst and graben structures.

Most of the hydrographic network, particularly the smaller streams, is currently affected by linear erosion. The major streams (including the Tevere River) show the effects of linear or lateral erosion even though they have been modified for erosion control or drainage management. Consequently, fluvial erosion is now developing many scarps along the valley floor and often also affects the embankments.

– West Side of the Tevere

A series of narrow and deep valleys cuts the western and eastern slopes of Mt. Mario - Gianicolo ridge. Small through-shaped valleys are common and indicate geomorphic evolution by both surface running waters and gravitational processes.

Runoff plays an important role in shaping the areas that lack vegetation. Gully and rill erosion is effective on clay outcrops and clayey soils and is even more effective on anthropogenic deposits, even in the presence of low

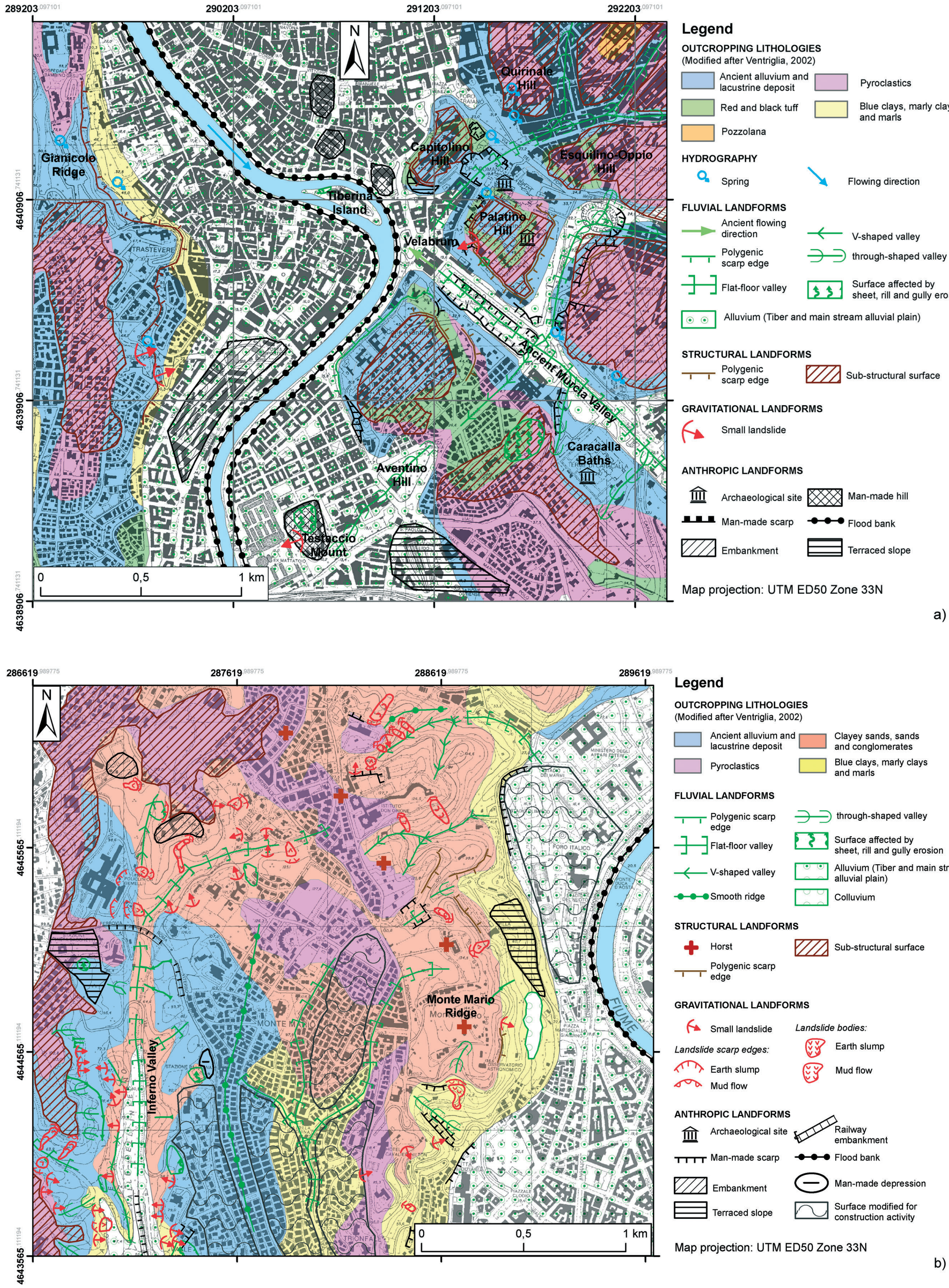


FIG. 2 - Geomorphological sketches of *a)* Tiberina Island and *b)* Monte Mario areas.

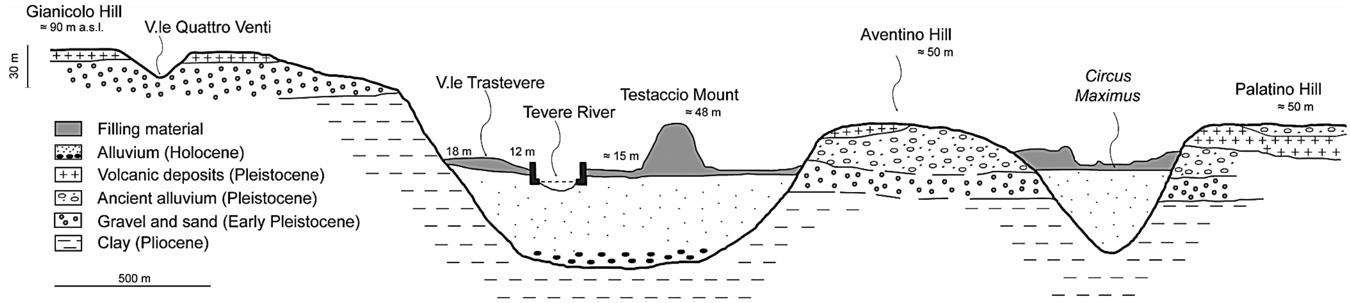


FIG. 3 - A profile across the city center showing the main geomorphological characteristics of the area.

slopes. The analysis of aerial photographs from 1974 showed how almost all man-made terraces built for urbanization have been heavily affected by runoff (e.g., Inferno Valley, fig. 2b) that quickly formed gullies and micro-badlands and caused subsurface erosion (due to tunneling and piping).

– East Side of the Tevere

The eastern part of the study area is characterized by a large, flat structural surface between the alluvial plain of the Tevere River and the Fosso dell'Acqua Bullicante (Acqua Bullicante Valley, Tiburtina Station area). The surface was formed by Quaternary activity of the Alban Volcano, which began at approximately 600 ka. The volcanic activity filled many of the old valleys and forced the Tevere's riverbed to move westwards (Della Seta & Del Monte, 2006). This volcanic plateau was afterwards deeply cut by the Tevere River and its tributaries; after a depositional phase during the Holocene, their valleys acquired their current flat floors.

Therefore, the valleys on the east side of the Tevere are similar to that of the Tevere River except for their smaller size. While the present flood plain of the Tevere River can reach 2 km in width, those of its tributaries are a few tens of meters wide. All these valleys have very steep slopes and contain outcrops of volcanic rocks interposed with fluvial deposits of "Paleotevere" (Ancient Tevere). Among the numerous ridges and isolated hills with flat tops in the area, those closest to the Tevere and to the Tiberina Island were preferred by the first inhabitants of Rome for their permanent villages (Touring Club Italiano, 1999).

It must be emphasized, however, that although the Capitolino and Palatino Hills appear to be isolated from the volcanic plateau described above, they were once joined to the ridges of the Quirinale and of Esquilino-Oppio (Opium hill), respectively. The ancient Romans excavated the depression between the Capitolino and the Quirinale Hills, in the 2nd century AD, to extend the area of the Roman Forum (Coarelli, 2001). In addition, the hill near the Colosseum (Velia Hill), between the Palatino and the Esquilino-Oppio hills, was removed about one hundred years ago (Insolera, 2001) for the construction of the Via dei Fori Imperiali.

All seven historical hills, therefore, are ridges that were shaped by fluvial erosion processes by the Tevere drainage system in the Late Pleistocene and the Holocene and were partially reshaped by the Romans in the last part of the Holocene.

In the city center, the largest of the tributaries on the east side, the ancient Murcia Valley stream, flowed following a straight direction between the Terme di Caracalla (Baths of Caracalla) and the confluence with the Tevere River. The stream formed a straight, flat-floored valley with steep slopes, approximately 100 m wide, that was the ideal landform on which to build a large stadium like the Circus Maximus, during the Roman period. The Romans drained the Murcia Valley and other neighboring areas (Velabrum) in the sixth century B.C. (Coarelli, 2001), and the stream flow was directed to the Tevere River by an underground pipe system through the Cloaca Maxima, which is still in operation. Therefore, before Rome was founded (753 B.C.), the channel that drained the waters of the Murcia Valley (Velabrum Maius) had a counter-flow confluence with the Tevere.

STRUCTURAL LANDFORMS

A low plateau with extensive sub-horizontal surfaces that extend above the floodplain is common on both the right (west) and left (east) sides of the Tevere River (fig. 4). To the west, this plateau corresponds to outcrops of the Sabatini Volcano, which are represented in Rome by a succession of pyroclastic deposits (with scoriaceous lava and lava layers) a few meters thick that erupted between 470,000 and 500,000 years ago (Funiciello & *alii*, 2008). These rocks alternate with reworked volcaniclastic horizons and marsh deposits. To the east, the structural surface is considerably larger, lower (just over 50 m) and is related to activity of the Alban Volcano, whose deposits extend up to the foot of the Mt. Mario - Gianicolo ridge. The Latium Volcano caused several diversions of the Tevere drainage network.

These flat surfaces were cut by erosion processes that incised deep valleys. The outliers (such as the Seven Hills) were once part of a large mesa; their tops today correspond to structural surfaces or, more commonly, to substructural surfaces in locations where areal erosion has generated undulating topography. The volcanic outcrops

FIG. 4 - A portion of Rome's historical center, which covers the Tevere valley floor. Part of the Colli Albani volcanic plateau, Pincio ridge, rises above the alluvial plain. Monte Mario Ridge is visible on the left.

have been affected, especially on the less steep slopes, by pedogenic processes and human activities.

The structural and substructural surfaces are often separated by scarps that have been shaped by various weathering and denudation processes. In the western region, many of these scarps are located at lithologic boundaries between volcanic units and the underlying Monte Mario Unit (clay and sand). In the eastern region, the higher scarps are on slopes of the hills above the Tevere alluvial plain (Capitolino, Aventino and Pincio hills); outcrops of volcanic rocks (De Rita & Fabbri, 2009) can be observed here (fig. 5).

GRAVITATIONAL LANDFORMS

Several scarp edges and deposits of landslides have been identified in the study area. They are caused by flows, slumps and falls. The falls are present on the more cohesive outcrops, while the slumps and mud-flows often occur in areas where clays, sands and clayey sands outcrop.

Deformation features induced by creeping have also been identified on natural or modified surfaces with low slopes. These slopes display surface undulations, terracettes (a few cm high), trees with curved trunks and stakes inclined towards the valley.

Landslides are widespread in the western part of the study area and particularly common on the slopes of the Mt. Mario ridge. Numerous landslides occur where the slope gradients are high (greater than 20%) in the Aurelia Valley - Inferno Valley and at the head of the Fosso dei Frati basin, as well as on Monti della Farnesina and on the eastern slope of Mt. Mario. In the Aurelia Valley - Inferno Valley, the crowns of the landslides are located at the edges of substructural surfaces, on the boundaries between the volcanic and the underlying sedimentary rocks, or along scarps that border flat human deposits («anthropic terraces»). In the remainder of the western region, slides often are developing on slopes where the Monte Mario Unit outcrops clayey sands, sands and conglone rates in (fig. 2b).

Several flows affect the Mt. Mario - Gianicolo ridge. These flows also are developing in areas of moderate slope gradients (8-10%), and they sometimes occur within older landslide deposits. Although they are less important than the other landslide types in terms of their volumes and widths, the flows may cover long distances. Their spatial distribution is not related to the different slope aspects.

FIG. 5 - The southern slope of Capitolino Hill, which corresponds to the Rupe Tarpea geosite. The products of several eruptions of Latium Volcano can be observed with man-made remains.

Finally, several trenches have been identified on a slightly inclined surface next to a steep slope on the left side of the Inferno Valley. The trenches trend parallel to the main rim of the slope escarpment. The first is located approximately 400 m east of the Gemelli Hospital, at an altitude of approximately 100 m a.s.l. The second is located approximately 500 m to the northeast of the first, about 250 m southwest of the Via Trionfale on a slightly inclined surface with private houses, greenhouses and gardens. These trenches indicate possible mass movements of large volumes of material.

Gravitational phenomena are less common in the eastern region than in the western region. The large plateau has low amplitude of relief, which reduces the possibility of landslide development. Mass movements are located mainly on the steeper slopes of fluvial valleys that cut the volcanic plateau, often at the boundary between the volcanic units and the underlying fluvial-lacustrine deposits. Several small landslides are affecting the artificial embankments or reshaped scarps, but these gravitational deposits are rapidly removed, the embankments are reconstructed, and the scarps are strengthened.

MAN-MADE LANDFORMS

The study area has been affected by a variety of activities from ancient human settlements. The signs of these are superimposed and juxtaposed with those that were caused by natural processes.

Rome has hosted stable settlements since the Bronze Age and the ancient town is now an area of extraordinary archaeological interest. The mining activities, which are inactive today, started from VI-V century BC (Cifani, 2008) and produced numerous caves with straight scarps and step-like slopes. The more recent changes to the topographic surface are due to open-pit mining for clay extraction.

Surface modifications have increased due to anthropogenic activities since the end of the 19th century. The city's population increased rapidly in the 1950s, generating intense urban expansion that led to the development of vast neighborhoods.

In addition to buildings being constructed on all the sub-horizontal surfaces, numerous flat embankments and stepped slopes have been produced where the topography was too steep for buildings to be built. Intense erosion processes have acted on these man-made deposits, causing mud and debris flows, runoff and piping. Among the most significant changes made by the ancient settlements are the excavation of the saddle between the Capitolino and Quirinale hills and the removal of the Velia hill between the Palatino and Esquilino ridges. Construction activities have covered the surface of the historical city center several times, producing a continuous layer of materials made up of the remains of collapsed buildings, rubbish, and the ruins of ancient temples mixed with colluvium and alluvium. The thickness of the filling materials is between 0 and 18 meters (Funiciello & *alii*, 1995), in the study area (fig. 3).

Human activity has also created artificial hills. A well-known example is Testaccio Mount (fig. 3), which reaches 48 m a.s.l. (the height of the nearby Aventino and Palatino hills). This hill was created by the accumulation of so-called «Cocci» (shards), which are fragments of broken amphorae of the ancient Romans. On the Tevere alluvial plain, several other man-made mounds appear as small hills (e.g., Mt. Savello, Mt. Citorio, Mt. della Farina and Mt. dei Cenci).

Geosite inventory

The evaluation of Rome's interesting geological sites led to the selection of two geosites: Tiberina Island (fig. 6), and Testaccio Mount (fig. 7).

FIG. 6 - Tiberina Island, the only fluvial island in the city center of Rome.

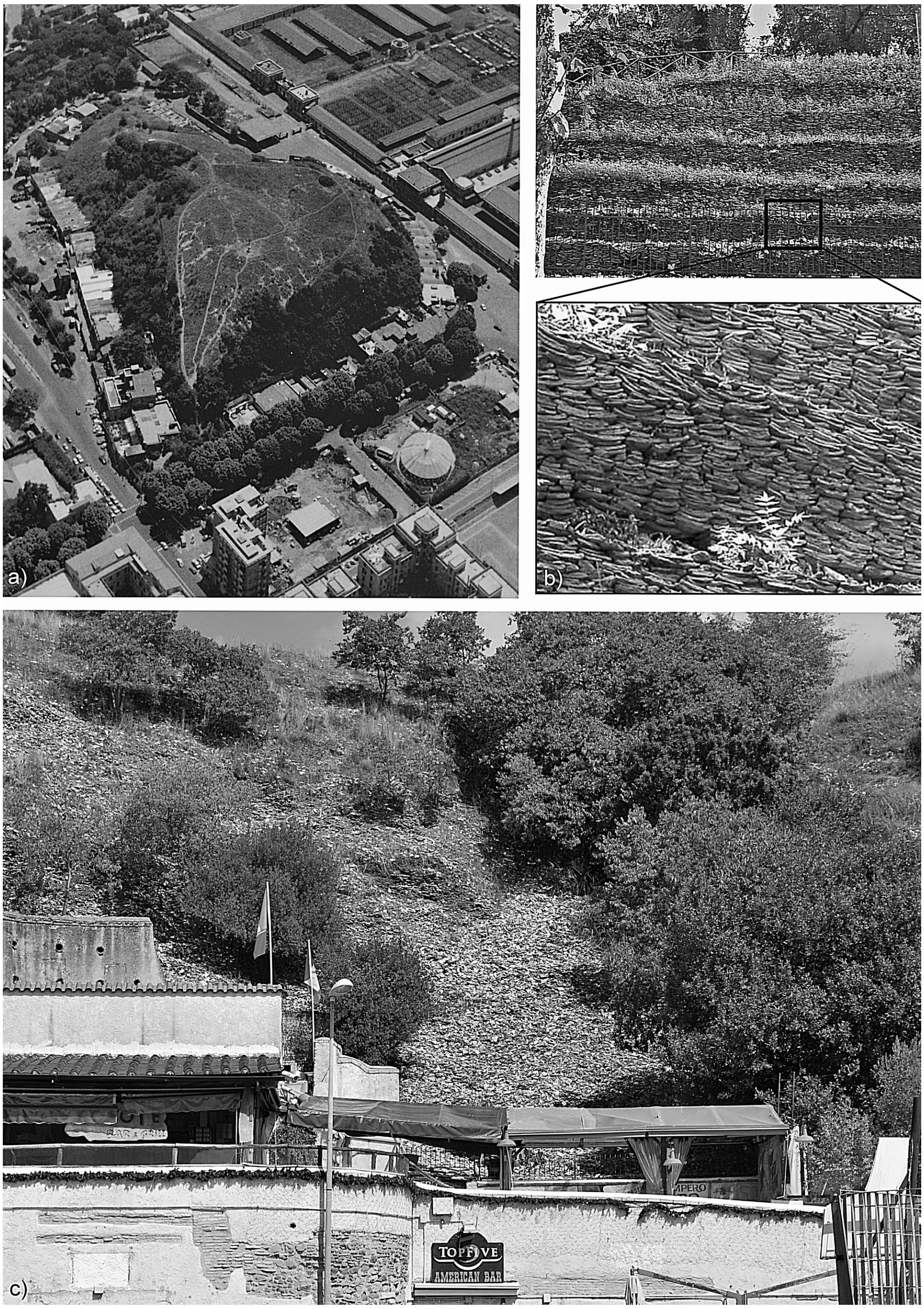


FIG. 7 - *a)* Testaccio Mount, which was created by the accumulation of the so-called «Cocci» (shards) in a landfill (Photographic Archive of American Academy in Rome, Aronson Collection, 291, 1979), *b)* The internal structure of the shards accumulation. *c)* The shards of the southern slope of Testaccio Mount, now evolving by mass movements.

The geomorphological survey of the study area identified landforms of scientific, scenic/aesthetic and historical/cultural value. The authors present some of them as geosites according to the inventory and evaluation model proposed modifying the Latium Parks Regional Agency model (ARP), (Fattori & Mancinella, 2010). In this model, the characteristics of each geosite are described on an inventory card (tab. 1). The Geotourist Value of a Site (VSG) is defined by several attributes. Representativeness (RP) is the correspondence between the geological phenomenon represented in the geosite and the ideal model of the same geological phenomenon; it also defines the peculiarities of the geosite and variety of interests. Rareness (RR) depends on the frequency with which the geological feature is represented in a given geographical area (local, regional, national, global). Scenic-Aesthetic value (SCE) quantifies the attractiveness of a geosite from the points of view of a specialist and a non-specialist; it is a fundamental attribute for the enhancement of an area, but at the same time it is difficult to quantify because the attractiveness of a site is tied to emotional reactions to it. Storical-Archeological-Cultural value (SAC) is function of the geosite relationship with local history and culture, besides the bonds system to which it is subjected. Finally, the Accessibility value (AC) evaluates the availability of a geosite, through the analysis of the ways and the difficulty to reach the site, and of the presence of tourist facilities in the neighborhood. Each attribute is described by a value and the sum of these attributes gives the VSG index.

Below, we briefly describe the geosites, as presented in the inventory card.

The Tiberina Island geosite was proposed by the authors because of its peculiar morphological origin.

Tiberina Island

Location: Italy, Lazio Region, Rome

Geographic Coordinate WGS84: latitude 41° 53' 25.75" N; longitude 12° 28' 40.25" E

Scientific Interest: Geomorphology

Reason of Scientific Interest: An extaordinary counter flow confluence, nearly to 180° angled (most likely controlled by a tectonic feature) caused a large river bar that grew to become the only island along the Tevere's urban stream channel (fig. 8).

Contextual Interests: Historical, Archeological, Cultural

Description: The Tiber Island geosite is located in the historical heart of Rome, where the city developed next to the Tevere River over 2500 years ago. It is the only island in the Tevere's urban stretch. The Tevere received water from several tributaries in these areas which were once characterized by a floodplain and marshy lands (Velabrum and Forum Boarium) at the base of Capitolino, Palatino and Aventino hills.

The ancient Roman stadium Circo Massimo (Circus Maximus) was built on Holocene alluvial deposits in the flat-floored Murcia Valley. The Velabrum Maius, streaming in this valley, flowed to the Tevere and entered the river at a counter-flow confluence angle of approximately 180° (fig. 8), as already observed by Pinza (1925). The extraordinary confluence angle of the Murcia Valley stream suggests structural controls on the straight stream and the straight valley axis.

The valley slope outcrops include Paleotevere units, which are composed of blue clays of the Middle Pleistocene and pyroclastic materials and tuffs of the Latium Volcano (Middle-Upper Pleistocene). The whole area between Velabrum and Murcia Valley was drained by the Romans, through the Cloaca Maxima (the main drain pipe), because of its proximity to the Tevere river. It became a trade area (Forum Boarium) and a place of cultural importance.

The Murcia Valley may have developed along a line of weakness that continues to the northwest beyond the confluence between the Tevere and the Velabrum Maius and that also affects the geometry of the Tevere drainage network (Ascani & *alii*, 2008; Della Seta & *alii*, 2002). The straight Tevere segment upstream of the Tiberina Island is oriented NW-SE and is aligned with the axis of the Murcia Valley, but elsewhere, the Tevere channel meanders. In addition, the strong erosion that has always characterized this straight segment of the Tevere may be correlated with the presence of a tectonic lineament.

The origin of Tiberina Island in this position is explained by the conditions described above. The Murcia Valley stream flow hindered the flow of the Tevere and caused deposition due to the decreased stream velocity, which generated the river bar. Over time, the growth of

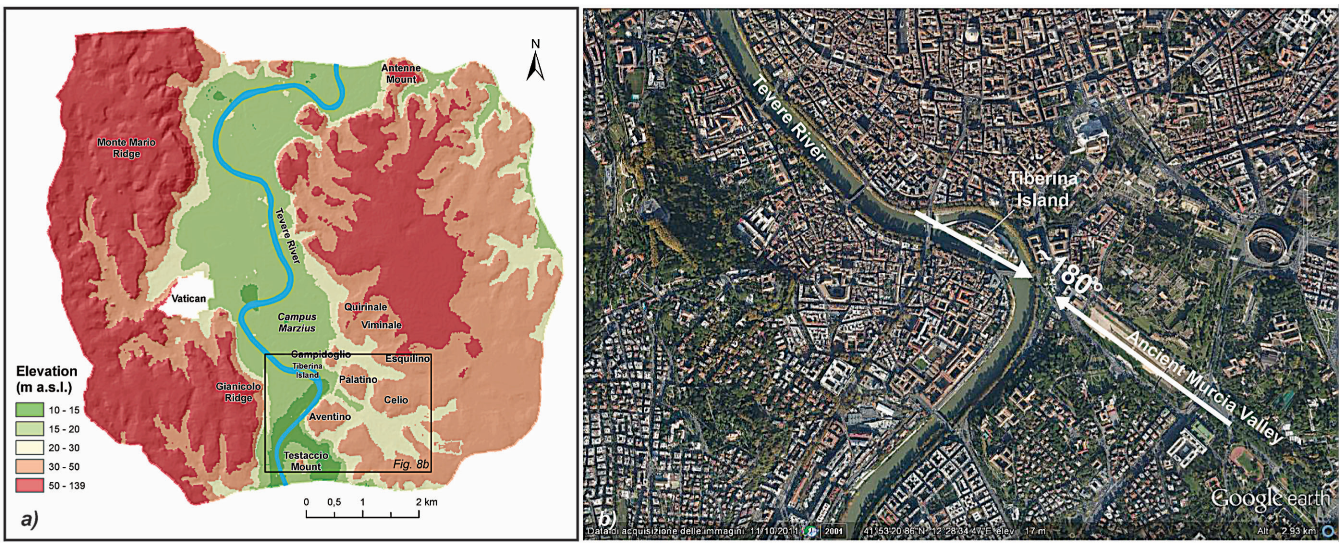


FIG. 8 - *a)* Location of the Tiberina Island in the study area, *b)* The origin of the Tiberina Island is related to the Tevere counter-flow confluence with the Valle Murcia stream.

the bar formed the island; geological drilling on Tiberina Island (Clerici, 1911; Ventriglia, 2002) confirms that the island is formed of fluvial sediments, supporting its alluvial origin and excluding the other hypotheses formulated in the past (De Angelis D'Ossat, 1944).

The Testaccio Mount geosite has been proposed by the authors because it represents the most important morphogenetic agent of the urban environment: humans.

Testaccio Mount

***Location*:** Italy, Lazio Region, Rome

***Geographic Coordinate WGS84*:** latitude 41° 52' 34.87" N; longitude 12° 28' 30.71" E

***Scientific Interest*:** Geomorphology

***Reason of Scientific Interest*:** an anthropogenic hill composed of broken amphorae fragments; it was a Roman dump.

***Contextual Interests*:** Historical, Archeological

***Description*:** Testaccio Mount is the highest artificial hill of Rome, with a height of 48 m a.s.l. and a circumference of 1 km (fig. 7). It is located on the left side of the Tevere River in the southeast part of the city center. The geosite is peculiar because it is made up of countless layers of neatly arranged shards (in Latin *testae*, hence the name of the mountain). The shards are derived from oil amphorae from the nearby Emporium fluvial port, where the *annona publica* (food commodities for the people) were stored (Coarelli, 2001). Recent studies indicate that the amphorae fragments were routinely thrown away and accumulated between the Augustan period and the mid-third century A.D. (www.sovraintendenzaroma.it,).

An accumulation of this magnitude and height was made possible by a ramp and two side roads for wagons carrying the shards and amphorae fragments; these materials were placed in terraces contained by walls made of the same intact amphorae, which were also filled with shards. The Romans often covered the accumulation with lime to eliminate problems caused by the decomposition of organics; the lime added cohesion and stability to the hill.

Over the centuries, the accumulation became a small mountain, vegetation grew, and erosion occurred on the slopes. Water erosion effects and small landslides are present on the hill (fig. 2a). Over the centuries, the function of Testaccio Mount has changed several times. After construction of the Aurelian walls (3^{rd} century), Testaccio Mount was no longer used as a dumping ground. The connections with the port changed greatly, and the sub-Aventino plain was somehow protected from the most destructive Tevere River floods. Originally a port and commercial district, in the Middle-Ages the Testaccio area became an area of vineyards. Several caves were dug on the flanks of the hill and used as wine cellars. «Prati del popolo», meadows of the people, who were used for picnics until the 19^{th} century, were located on top of the hill and are still recognizable. The different land uses of Testaccio Mount over the centuries produced a certain degradation of the landform; however, the process is now limited, thanks to the protection of the Archeological Goods of Rome Special Office (Soprintendenza Speciale per i Beni Archeologici di Roma).

The geotourist itinerary proposed in this work includes another interesting geosite: the Rupe Tarpea (Tarpeian Rock) (fig. 5). Rupe Tarpea geosite was identified by the Latium Regional Park Agency (ARP) (Arnoldus-Huyzendveld & *alii*, 1997; Fattori & Mancinella, 2010) and consists of an ignimbritic upland (Tufo Lionato Auct. Formation), which was deposited in a paleovalley and was then incised by the intense erosional activity of the Velabrum Minus stream. The place has historical value because ancient Romans threw traitors from its rocky scarp.

ENHANCING CULTURAL AND GEOMORPHOLOGICAL HERITAGE OF ROME

The geomorphological investigations performed in this study allowed us to propose the geotourist enhancing of Rome heritage through a geotourist trail within the city. The itinerary develops in 9 stops, each one tells about the present landforms of Rome and the paleogeographic ones, melted with the role that they assumed over the 2000 years of roman history.

The itinerary «Historic Rome in the Tevere Valley» (fig. 9) crosses the valley starting from Palatino Hill to Gianicolo Hill. The route highlights the recent geomorfological evolution of Rome and how the Tevere fluvial system shaped the famous Seven Hills and created a wide floodplain (fig. 10). Rome's history is characterized by these landforms; the hills guaranteed a stronghold, while the river's waters were a resource for the city and helped the Roman culture to develop.

Describing the 9 stops of the itinerary, in the text below, we will see how the landforms showed in the geomorphological survey become part of the cultural landscape of Rome.

«Historic Rome in the Tevere Valley»

Palatino is one of the Rome's seven historic hills and is located next to the Tevere. It has a maximum height of 51 m a.s.l. The Circo Massimo is located to the south of it, and the Roman Forum is located to the north. The itinerary starts at the Circo Massimo (fig. 9, stop 1), which is easily reached by underground. Here, we have a good view of Palatino Hill and its ruins. Palatino is an open museum and is one of the oldest sites in Rome. A legend tells that the city began as a small village on this hill ("Roma Quadrata", Squared Rome). The village was surrounded by swamps, from which the Romans could control the course of the Tevere (Coarelli, 2001). The Circo Massimo was a stadium built for chariot races (6^{th}-2^{nd} century B.C.); it was built on the Murcia Valley's flat-bottom. This landform, located at the foot of the Emperor's Villa on the Palatine (in Latin, «*Palatium*» = palace), was particularly suitable for this use. The large valley is enclosed by hills, and we can imagine its extension upstream, towards the Terme di Caracalla, and

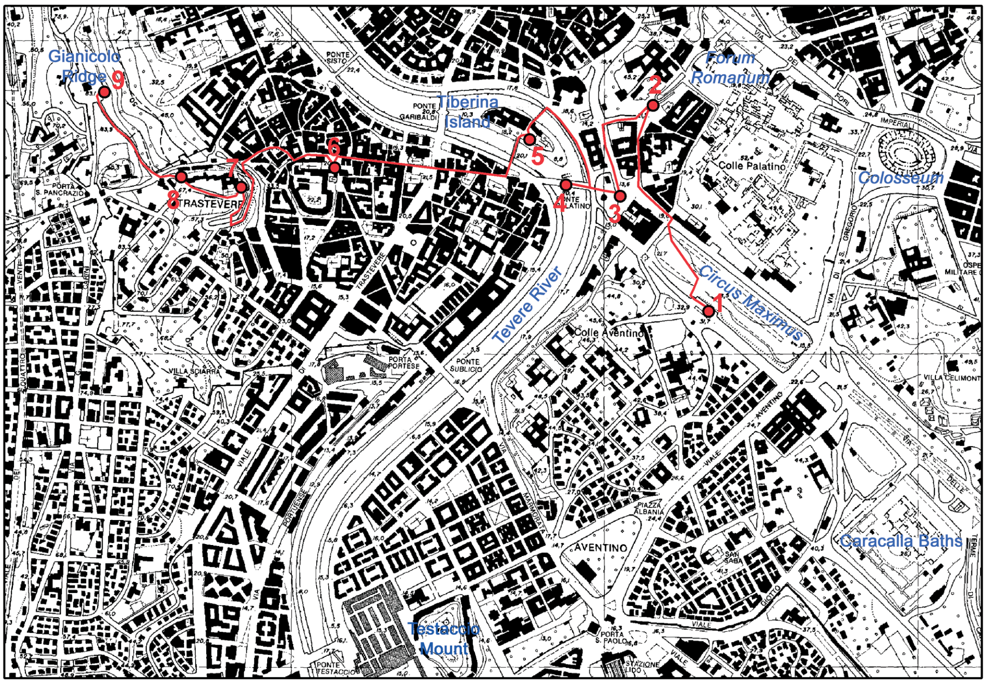


FIG. 9 - Proposal of a geotourist trail within the city center. The itinerary includes the following stops: 1) Circo Massimo and Palatino Hill; 2) Rupe Tarpea geosite and the Seven Hills; 3) Murcia Valley - Tevere River confluence; 4) Ponte Rotto; 5) Tiberina Island geomorphosite; 6) Trastevere; 7) Vaticano-Gianicolo area springs; 8) Fontanone del Gianicolo and Testaccio Mount geomorphosite; 9) Historic Rome in the Tevere Valley.

downstream, where the Velabrum Maius flowed into the Tevere (see the geosite's description). Circo Massimo is the greatest stadium ever built; it could hold, depending on the time and the extent of the renovations, between 250,000 and 385,000 spectators (Coarelli, 2001). Today, it is often used for shows because it can hold such a large number of people (approximately 700,000). In the Roman period it was the place where the mythical episode of the rape of the Sabines ("Ratto delle Sabine") took place,during the games organized by Romulus in honor of the god Consus.

West of Circo Massimo, we enter "via dei Cerchi" and continue to "Piazza Santa Maria in Cosmedin", crossing the ancient Forum Boarium. It was located in a large swampy area, where the legend of Rome birth began; Romolo and Remo, the twin founders of Rome, were discovered here in a hamper. The marshy land was reclaimed by the Romans, who built a hydraulic work, the Cloaca Maxima, in the 6^{th}-4^{th} centuries B.C., nowadays still in operation. This area became a place of worship and of trade, especially of cattle (in latin, «*boarium*» = of cattle) and salt.

Through the square, we enter "via S. Giovanni Decollato" and reach the Rupe Tarpea (fig. 9, stop 2), which is another site of natural and cultural history. The Rupe Tarpea has been acknowledged by Lazio Region Law (D.G.R. Lazio n.859/09, Regional Decree of Geoheritage Enhancement) as a geosite because of the outcrop of "Tufo Lionato", a type of ignimbrite that is particularly representative of Rome's geologic history (fig. 5). The Rupe Tarpea is on the southern slope of Capitolino Hill, one of Rome's seven hills. The seven hills were dissected by fluvial erosion of the volcanic plateau that was created by the explosive activity of Latium Volcano. The outcrops of Rupe Tarpea show evidence of several phreatomagmatic eruptions; moreover, the Tufo Lionato has a very limited and thin exposure, so this outcrop is very peculiar. The tuff is composed of yellow pumice, black scoria, lava and holocrystalline (leucite and pyroxene) lithic fragments dispersed in the matrix. The name "Lionato" comes from the yellow color of the ashy matrix, which resembles hair on a lion's head; the color is due to the lithification of the tuff and zeolitization of its ashy matrix. These processes also give the tuff its hardness (De Rita & Fabbri, 2009). The Rupe Tarpea is famous in cultural history and is widely considered to be a symbol of Rome. Several legends refer to it (Puliga & Panichi, 2012). In one of the legends, Tarpea was the name of the daughter of Tarpeo, a defender of the Capitolino Hill. She was in love with the Sabines' king, but there was a war between the Sabines and the Romans. Romulus organized the kidnapping of the Sabine women ('Ratto delle Sabine') and their imprisonment in the buildings of the Capitolino Hill. When the king of the Sabines convinced Tarpea to open the doors of the Capitolino and allow the Sabine forces to enter the fortress, the Romans immediately executed Tarpea as a traitor, throwing her from the top of the Capitolino Hill. Since then, the hill has been called Rupe Tarpea (Tarpeian Rock), and any traitor has been punished in a similar way (Puliga & Panichi, 2012).

After returning to the "Piazza Santa Maria in Cosmedin", we enter the homonymous church where the famous "Bocca della Verità" (Truth Mouth) is located. The "Bocca della Verità" is a representation of a fluvial god that, according to legend, is an oracle (the Romans actually used it as a trap-door for surface water drainage). In front of the church there are the ancient Forum Boarium (fig. 9, stop 3) and its two temples. Here was the swampy area due to the poor drainage caused by the counter-flow confluence between the Murcia Valley stream and the Tevere;

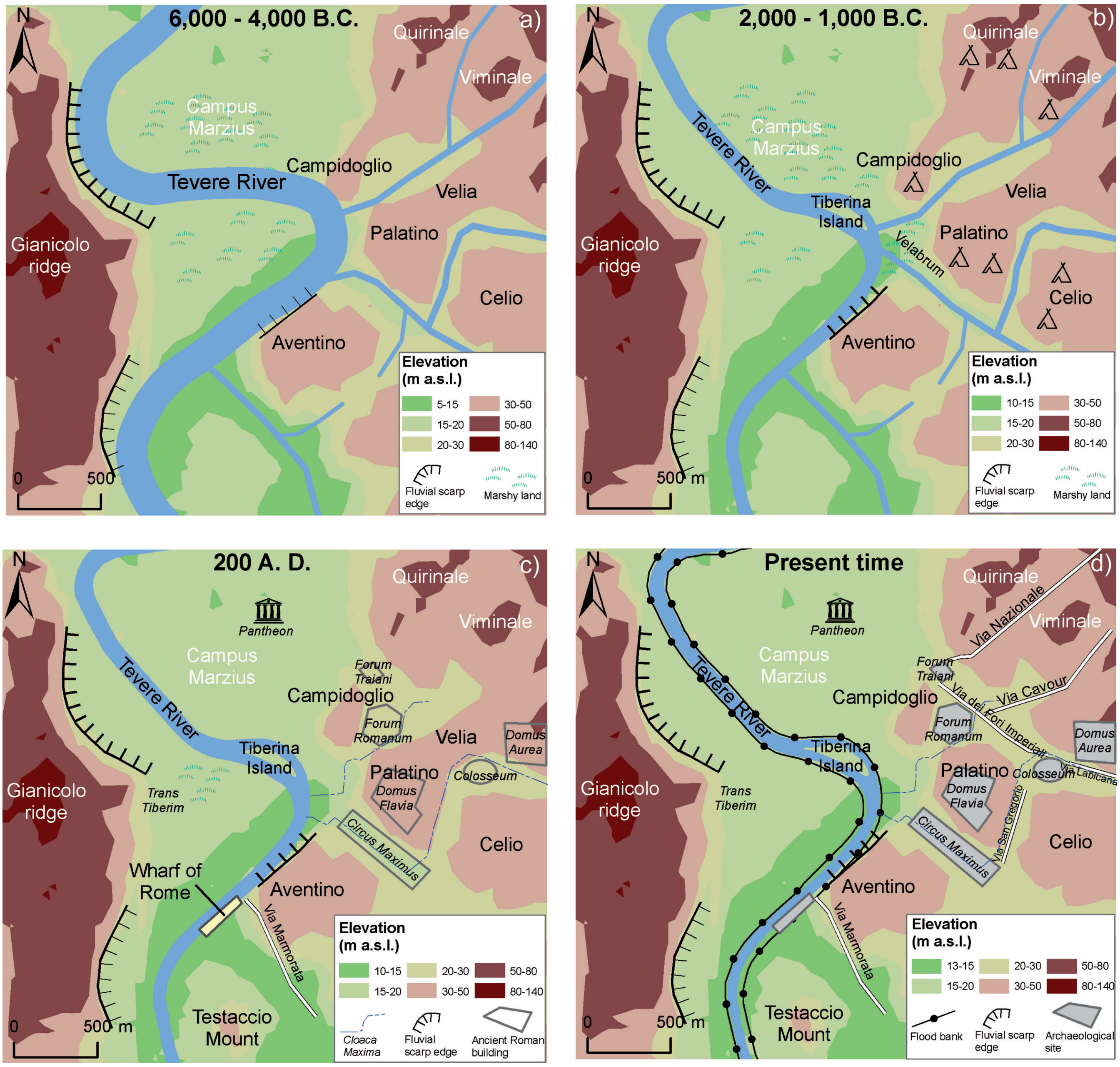


FIG. 10 - Geomorphological evolution of Rome: a) One of the possible scenarios of about 4000 years before its foundation; b) A few thousand years later, the Tiber Island was formed next to the confluence with the Velabrum. Meanwhile, the hills on the Tiber left hosted shepherds' huts; c) 500 years after the founding of Rome, the area resulted profoundly transformed by man: a depression had been dug, separating the Capitoline Hill and the Quirinal; numerous wetlands disappeared; the Velabrum was drained by the Cloaca Maxima, different constructions interested the floodplain, including the port Emporium, whose landfill became Testaccio Mount; d) The center of Rome today is completely urbanized and rich in archaeological sites. The construction of the Via dei Fori Imperiali erased the Velia hill.

this type of confluence causes the water to flow slowly, so it was the ideal place to construct the port and a suitable area for the founders' hamper stranding. The port was protected by two temples that can still be recognized today. One of these temples was dedicated to Portuno, the Pagan god of ports.

After crossing the "Lungotevere Aventino", we reach the bank of the Tevere on "Ponte Palatino" (ponte = bridge). From here we can see the ruins of Ponte Rotto (the name means "broken bridge") (fig. 9, stop 4), which is the oldest stone bridge in Rome and has been destroyed several times by the extraordinary energy of the Tevere at this point. The west side of Tevere Island and the dikes are visible from Ponte Palatino; they were built to protect the embankment and the bridges downstream from the floods.

Returning to "Lungotevere Aventino" and continuing straight, we reach "Ponte Fabricio" and cross to Tiberina Island (fig. 9, stop 5), which is the main geomorphosite in this geotourist itinerary. The island was created by depositional processes at the confluence of the Velabrum Maius and the Tevere (see the geomorphosite's description). Several legends describe the island's origin. One legend describes the accumulation of mud from the Tevere on Tarquin the Proud's crops, which were thrown in the river when the last king of Rome was expelled (Touring Club Italiano, 1999). Another legend tells of a snake that was sacred to Aesculapius, the Pagan god of medicine, which was brought on a boat from Epidaurus (a Hellenic city) to Rome. The city was being affected by a pestilence, and the snake was intended to be a solution, but it escaped from the ship and took refuge on the island. This legend influenced all the representations of Tiberina Island over time; even the island's perimeter is made of embankments in the outline of a boat. Take a look of the boat shaped profile in the figures in tab. 1. For this reason, Tiberina Island housed the temple of Aesculapius, the medicine god, on which Christians built the basilica of San Bartolomeo; today it also hosts one of the most important hospitals in Rome. Despite reaching 18.2 m in height, Tevere Island was often submerged by floods. Memorial tablets on many of the island's buildings mark the levels of the floods in 1870 and 1937.

After leaving Tiberina Island and passing through "Ponte Cestio", we cross "Lungotevere degli Anguillara" and reach "Trastevere", one of the oldest neighborhoods in the city. Trastevere (from the Latin «*trans tiberim*» = beyond the Tevere) was a hostile Etruscan area at the time of Rome's foundation on the opposite bank of the Tevere. The Romans expanded their control of the river into the swampy area of Trastevere, and many poor sailors, fishermen and immigrants inhabited the area. Over time, this area became wealthier, and Roman villas, temples, buildings, and churches were built. For example, one of the most beautiful churches in Rome is Santa Maria in Trastevere (fig. 9, stop 6). The large square in front of the church suggests the flat shape of the ground; the entire neighborhood stands on the Tevere floodplain.

Passing through Trastevere, we reach "Via Garibaldi" and climb the Gianicolo hill. We leave behind the flat Tevere alluvial plain and walk on hillslope characterized by gravel and limestone clasts. Several springs are located at the contact between these materials and the alluvial deposits: so, 2000 years ago, a large and deep stadium was built here for naval battle performances (in latin *Naumachia Augusti*).

On the right bank of the Tevere, the lower Pleistocene Mt. Mario sands and Mt. Ciocci gravels outcrop above the Pliocene clays on the ridge of Mt. Mario-Vaticano-Gianicolo Hill. The outcrops of these deposits are a recognized geosite by Lazio Regional law (D.G.R. Lazio n. 859/09). We cannot see the outcrops in this itinerary, but it is important to note that these deposits contain an unconfined aquifer that is fed by rainfall on non-urbanized areas and by percolation from pipes. This aquifer supplies several springs (some of which still exist) on the contact with the underlying clay. Among the most important historical springs in the Vaticano-Gianicolo area there are the "Acque Corsiniane" spring, which is located inside the Botanical Garden of Rome (Via Corsini), and the "Acqua Innocenziana" spring (fig. 9, stop 7), whose waters flow into a fountain located below the S. Pietro in Montorio monastery. We can stop here and visit the church and the court where the famous "Tempietto del Bramante" is located.

Whereas the permeable Pleistocene deposits are in contact with Pliocene clays at altitudes above the flood plain of the Tevere River, the groundwater of the hills on the right bank of the Tevere and the underground water of the Holocene alluvial deposits of the Tevere valley are not in contact (Lombardi & Corazza, 1995). These springs were not sufficient to supply the residents of Trastevere, so Pope Paul V restored, in the 1608 a.d., the ancient Traiano aqueduct to supply water from the Bracciano lake north of Rome. The aqueduct is today called the "Paolo Aqueduct"; the famous "Fontanone del Gianicolo" (Gianicolo Fountain) (fig. 9, stop 8) celebrates the work. A balcony is located in front of the fountain; much of the city center and its landforms are visible from this location, including the Tevere River floodplain and the eastern hills of Rome. The erosion processes molded them cutting the flat top of the structural surface in Latium Volcano pyroclastic materials.

The balcony in front of the fountain is also a good perspective on the entire route. Moreover, across the road, there is an observation point of the Testaccio Mount geological site. Visible on the plain of the Tevere, on the east of the river, are the side of the Circo Massimo, the Aventino Hill and the Testaccio Mount. Viewed from this point, is evident the Testaccio's proximity to the Tevere River and to the important river port. The intense trade activity in the port generated the material that was used in the landfill of Testaccio Mount.

The itinerary ends at the "Passeggiata del Gianicolo", which is the promenade that climbs the Gianicolo hill (fig. 9, stop 9). The entire landscape described above can be observed from this location, including all seven hills on the floodplain of the Tevere and many of the most famous monuments. Do not be surprised if you hear a gunshot; according to tradition, the old "Cannone del Gianicolo" (the gun of the Gianicolo) is fired at noon each day.

CONCLUSION

A geomorphological survey was conducted over several years in Rome, the capital of Italy, and has described the geomorphological evolution of the region. This is the first consistent reconstruction of the geomorphic characteristics of the historical center of Rome. The survey resulted in a geomorphological map of the city, which is shown as a simplified sketch in this paper, and a geotourist trail aimed at pointing out the connections between the area's history, urban planning and geomorphological characteristics.

Moreover, the geotourist trail clearly shows why the Romans built certain structures in certain places based on the geomorphic characteristics of the area.

Finally, we proposed two new geosites, which are essentially geomorphosites, because they not only represent topics of geological interest (e.g., an important outcrop on a rocky scarp) but are also typical expressions of landscape evolution. The first geomorphosite (Tiberina Island) is related to the foundation and the history of the City, while the second (Testaccio Mount) is a significant man-made hill, which is a morphological consequence of landfill activity by an advanced society two thousand years ago.

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(Ms. received 1 November 2012; accepted 1 May 2013)