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Geomorphological classification of urban landscapes: the case study of Rome (Italy)

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ABSTRACT
The results of a long-lasting geomorphological survey carried out in Rome are summarized. A method aimed at integrating survey data, historical maps, aerial photographs and archaeological and geomorphological literature produced a geomorphological map of the present-day historical centre. The geomorphology of Rome is related to the paleogeographical conditions prior to the founding of the City; they allow us to recognize the stages of landscape evolution of the ancient Caput Mundi (Capital of the World). The study area has been affected by continuous man-made changes to the drainage network and to the topographic surface over the last 3000 years. It has forced the authors to develop innovative solutions to undertake effective analysis of the urban environment and the legend of the geomorphological map in this peculiar context. The resulting map is useful for urban planning and archaeological research.

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Urban landscape; geomorphological mapping; man-made landforms; multitemporal analysis; Rome

1. Introduction

Rome includes a wealth of well-known historical and cultural sites, as well as a less-known but valuable natural landscape. The geological and natural heritage is, itself, a tourist attraction (Coratza & Giusti, 2005; Gregori & Melelli, 2005; Panizza, 2001; Reynard, 2008; UNESCO, 2005).

Many natural geomorphological features of the Aeterna Urbs have been modified by millennia of urbanization, but they are still recognizable amongst popular tourist attractions (i.e. see De Rita & Fabbri, 2009). They currently form a wide and unique worldwide ‘man-made layering’.

A geomorphological review of the Roman territory is here presented, based on the results obtained by a 19-year-long geomorphological survey, supported by analyses of many historical, archaeological, cartographic and photographic documents. The first detailed geomorphological map of the central part of Rome ever carried out was thus completed.

The geomorphological map of Rome (Main Map) contains major updates, novelties and re-interpretation of previous data, achieved through an accurate multidisciplinary and multitemporal investigation. In particular, man-made landforms and modifications to the original surface required a special in-depth analysis, as they presented the most challenging investigation and the development of innovative cartographic solutions.

2. Study area

Rome is located on the Tyrrenian side of Central Italy, west of the Latium-Abruzzi Apennines (Figure 1(a)). The study area corresponds to the Urbs, the ‘old town’ within Imperial Roman walls, continuously inhabited for millennia, and a part of the Suburbium, the area between the city and its countryside, called Agro Romano (Witcher, 2005).

Features of Rome’s ancient history are inscribed not only on monuments, but also on a varied landscape, characterized by hilly, volcanic settings and the Tiber fluvial system, which separates two distinct types of landscape.

On the east side of the Tiber River are the famous Seven Hills: Quirinale, Viminale, Esquilino, Capitolino (or Campidoglio), Palatino, Celio and Aventino, which hosted the first villages in approximately 2000 BC (Del Monte, Fredi, Pica, & Vergari, 2013).

The Seven Hills and other relief (i.e. Pincio Ridge, Parioli and Antenne Mounts; Figure 1(b)) were formed by erosion processes of the Tiber fluvial system, which deepened the distal volcanic plateaus built by Colli Albani and Sabatini volcanic districts. These plateaus, extending, respectively, from south-east and north-west of Rome to the main course of the Tiber (Figure 1), merge in the City’s central area. Here, a series of small flat-bottomed valleys, drained by tributaries of the Tiber, separate the Seven Hills; three of them appear...
Figure 1. (a) Geological sketch of the Latium region. Modified from Del Monte et al. (2013). (b) Geological sketch of the study area. The geological sketch of Rome city centre was mainly developed comparing the ‘Lithostratigraphic map’ by Ventriglia (2002) with the geological maps by Funiciello and Giordano (2008) and Marra and Rosa (1995).
Table 1. Correspondence between (a) lithologic units, landforms and deposits of the Main Map and (b) formal (in bold) and informal units of the lithostratigraphic map by Ventriglia (2002) and the geologic map by Funiciello & Giordano (2008).

| Lithologic units of the bedrock in the Main Map (landforms and deposits) | Ventriglia (2002)‘Territorio del Comune di Roma Carta litostratigrafica’ Scale 1:20,000 | Funiciello & Giordano (2008) ‘Carta geologica del Comune di Roma’ Scale 1:10,000 |
| (Man-made constructional landforms and deposits) | Quarry waste deposits, river levees and embankments | Anthropic deposits h |
| (Recent alluvial deposits) | Recent fluvial deposits qa | Active fluvial deposits SFTba Fluvial deposits SFTba Lacustrine deposits SFTfa |
| (Ancient alluvial deposits, terraced) | Formazione Fluvio lacustre Sf | Vitinia Formation VTN Aurelia Formation AEL |
| Pyroclastic rocks, mostly unconsolidated deposits | Tufo di Villa Senni Avs Pozzolana grigia Aps | Pozzolane VSNl (part of: Villa Senni Formation VSNl) Tufi Stratificati Varicolori di La Storta LTT |
| | Tufo de La Storta Sg1 | | |
| | Complesso delle Pozzolane inferiori Ap: Pozzolane nere Pozzolane rosse Tufo di Sacrofano S12 | | |
| Pyroclastic rocks, mostly consolidated deposits | Tufo lioneato Ati | | |
| | Tufo rosso a scorie nere Vv4 Tufi antichi Ata | | |
| | Tufo giallo della via Tiberina Sn2 | | |
| Transitional and Continental deposits, with different granulometry and cohesion, including travertine | Conglomerato giallo (part of: Compl. Pozz. Inf.) Ap: Formazione Fluvio palustre fp | | |
| | Clay, Sand and Gravel Complex qt | | |
| Marine deposits, mainly sandy sediments with arenaceous interbeds | Grey-blue clayey sand, yellow or red coarse sand, green grey sandy clay and yellow marl deposits with conglomerate layers, Siciliano-Calabriano Psi | Monte Mario Formation MTM |
| Marine deposits, mainly clayey-marly sediments alternated with fine sands | Blue clay, marly clay and grey-blue marl deposits with gypsum crystal, Piacenziano Pm | Monte Vaticano Formation MVA |

Notes: Only outcropping units in the study area are included. The stratigraphic order of the units of both the maps is not fulfilled, due to the lithologic aggregations.

today as isolated domes (Aventino, Capitolino and Palatino), the others are small ridges.

On the Tiber’s west side, the floodplain ends at the foot of the Mt. Mario-Gianicolo horst. In the same area, reclaimed in the first century BC, the Vatican Hill is located. While Mt. Mario-Gianicolo ridge reaches 139 m a.s.l. and shows an uneven top, the Seven Hills have heights of 50–60 m and flat tops.

Bedrock consists mainly of clay and marl (Pliocene – Early Pleistocene) deposited during an extensional tectonic period that produced several NW–SE-oriented horsts and grabens (Faccenna, Funiciello, & Marra, 1995; Mattei, Funiciello, & Parotto, 2008). Three major marine depositional cycles have been recognized in this period (Funiciello & Giordano, 2008; Marra & Rosa, 1995). The first (Pliocene) included blue clays (Monte Vaticano Formation), while coarser grained sediments of shallower water facies (Monte Mario Formation) were deposited during the second and third cycles (Early Pleistocene) (Figure 1(a), Table 1).

In the study area, these marine deposits reach a thickness of about 800 m. They are overlain by epicontinental deposits of variable thickness (up to 100 m). Some depositional cycles of fluvial-marsh and marine-marginal environments began in the upper part of the Early Pleistocene; flood deposition occurred along Paleo-Tiber and its tributaries. Only the later Paleo-Tiber deposits are located in Rome’s historical centre. These units are interdigitated with thick pyroclastic deposits produced by the Sabatini and Colli Albani volcanic complexes (Giordano et al., 2006), in this area ranging in age from 600 to 280 ka (Karner, Marra, & Renne, 2001). Continental sedimentation continued throughout these depositional cycles controlled by eustatic variations (Bellotti et al., 2007; Funiciello & Giordano, 2008; Marra & Rosa, 1995).

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 et al., 1999; Cattuto, Gregori, Melelli, Taramelli, & Bros, 2005; Ciotoli et al., 2003). The emplacement of volcanic deposits changed the topography and hydrography of the area (Heiken, Funiciello, & De Rita, 2005);
main stream of the ancient Tiber progressively moved towards the Mt. Mario-Gianicolo ridge (Faccenna et al., 1995).

During the Last Glacial Maximum period, at approximately 20 ka, a large drop in sea level (Lamb, 1995) induced intense fluval fluening. In Rome, the Tiber and its tributaries cut the Plio-Pleistocene bedrock up to 50 m below the present sea level. A subsequent rise in sea level caused a depositional phase; the valleys were filled by up to 60 m of alluvial deposits (Ascani et al., 2008).

Over the last 3 ka, human activities have contributed to a reshaping of all topographic surfaces. The most recent stratigraphic layer overlies flood deposits: it consists of a mixture of alluvium, colluvium and materials from human activity, accumulated throughout Rome’s history. This man-made layer covers the historical centre and ranges in thickness from a few metres on hill tops up to about 30 m in valley bottoms (Del Monte et al., 2013; Funiciello & Giordano, 2008; Testa, Campolunghi, Funiciello, & Lanzini, 2008).

3. Methods

The Geomorphological Map of Rome’s centre, represented at a 11,000 scale (Main Map), is based on a detailed geomorphological survey and multitemporal analysis of aerial photographs and topographic maps.

Monitoring of erosional processes recorded several rapid morphological changes, even over short periods. To obtain information on morphological changes over longer periods, the geomorphological survey was supported by analysis of aerial photographs taken in the last 80 years, as most changes are a result of anthropogenic activity over the last century. Specifically, the analysis was conducted on photographs by (a) SARA-Nistri (1934), the first complete flight of Rome producing stereoscopic aerial photographs; (b) several Second World War flights by the Royal Air Force (MAPRW, 1943–1944; Shepherd, Leone, Negri, & Palazzi, 2013) and (c) National Flight by GAI (1954).

The analysis also integrated non-stereoscopic aerial photos (the photomosaic of Rome (Nistri, 1919)) and more recent stereoscopic material (i.e. ETA, 1951/1958; RER national flight 1988/1989). Most of these were provided by ICCD-Aerofototeca Nazionale (National Aerial Photographic Archive) and analysed at the Laboratories of Earth Science Department of Sapienza University of Rome.

The results of the aerial photo analysis were matched with the geomorphological study of the ‘Piano topografico di Roma e Suburbio’, a topographic map surveyed in 1907 for the Urbanisation Plan of Rome, and updated in 1924, at 1:5000 scale with a contour interval of 1 m (IGM, 1924). Furthermore, in order to detect previous modifications to the topographic surface, the analysis of historical cartography was conducted using available maps, surveyed with trigonometric methods. In particular, we examined the first edition of Tavolette from the Italian Geographic Military Institute (1:25,000 scale, 5 m contour interval; IGM, 1873a, 1873b), and other maps with planiometric precision and without contours. These included the maps by Moltke (1852) and Presidenza del Censo (1839), whilst the Urbe map by Nolli (1748) only covers the area inside imperial city walls. In addition, more ancient ‘bird’s eye’ maps were useful to detect some landforms (Dupérac, 1577; Falda, 1676).

For gravitational landforms, the results of aerial photo analysis were integrated with the Landslides Inventory of Rome (ISPRA, 2014) and the webGIS of CERI-Sapienza (Alessi et al., 2014). A number of old papers were also consulted, such as historical books and archaeological papers (i.e. Pinza, 1925; Quilici, 1990) and the archaeological map of Rome by Lanciani (1893–1901), in order to collect information relevant to the geomorphologic characteristics before most man-made modifications. In addition, important information on natural landforms now obscured was obtained from paintings, pictures and interviews with elderly people, who described the most recent modifications. Locally, useful information to detect the thickness of fill deposits was also collected from drilling databases (Rea, 2011; Ventriglia, 1971, 2002) and some geothematic maps, such as the ‘Anthropogenic deposit thickness’ maps (Corazza & Marra, 1995; Ventriglia, 1971).

The spatial distribution of bedrock was derived from the lithostratigraphic map by Ventriglia (2002), taking into account other geologic maps (Funiciello & Giordano, 2008; Marra & Rosa, 1995) and literature.

The multitemporal analysis of historical and more recent topographic maps was undertaken using a Geographic Information System. The spatial reference of the Main Map and figures is ED50, UTM projection, Zone 33 North.

The analysis of the materials described above has followed a structured procedure, summarized in Figure 2. This procedure represents a methodological proposal on how to approach the geomorphological analysis of an urban environment.

The criteria to recognize and map the landforms are based on those proposed by several authors (Arimgoli et al., 2005; Brancaccio et al., 1994; Cicciacci, Del Monte, & Marini, 2003; Del Monte, 1996; Della Setta, Del Monte, & Marini, 2006; Dramis, Gentili, & Pieruccini, 1979; Lupia Palmieri et al., 1998, 2001; Panizza, 1972, 1987; Pellegrini, 2000). Morphological elements were grouped according to genetic criteria; each landform was classified depending on the main type of geomorphic process. As usual, landforms were distinguished as ‘active’ and ‘inactive’; a third column, named ‘modified’, was added where necessary, to indicate a natural landform still recognizable, even if it appears greatly modified by human activity.
Due to an extraordinary variety of man-made modifications, the legend of landforms and anthropogenic processes has been significantly improved and integrated, attempting where possible to record the previously erased morphology.

4. Results

The natural landscape in which Rome has developed was primarily moulded by fluvial processes. Polygenetic, structural and gravitational forms are also widespread; in addition, many landforms were modified or created by human activities.

Man-made landforms and modifications to the original surface required in-depth discussion, as they presented the most challenging investigation. Specifically, the following rules were adopted:

1. man-made landforms were included in this category when they completely erased the natural morphology (in this case, an indication of the previous morphology was given, if possible);
2. natural landforms modified by man, but still recognizable, were grouped in the original morphogenetic process category, adding a special column to the legend, named ‘modified’.

4.1. Natural and modified fluvial landforms

Most of the hydrographic network is currently affected by linear erosion, even if the major streams are subject to erosion control and drainage management.

A series of narrow and deep valleys cut the western and eastern slopes of Mt. Mario-Gianicolo ridge. Small trough-shaped valleys are common and indicate geomorphologic evolution by both fluvial and gravitational processes. Runoff plays an important role in shaping unvegetated areas. Gully and rill erosion, as well as subsurface erosion (due to tunnelling and piping), are effective on clay outcrops and clayey soils and very effective on anthropogenic deposits, even on shallow slopes.

The eastern part of the study area is generally characterized by a substructural surface, formed by Quaternary volcanic activity. The volcanic plateau was subsequently deeply cut by the Tiber and its tributaries (Figure 3): the seven historical hills of Rome were shaped by fluvial erosion of the Tiber drainage system in the upper part of the Pleistocene and the Holocene, and then partially reshaped by man in the last part of the Holocene. After a depositional phase during the Holocene the valleys acquired their current floors.

In the City centre, the largest of the tributaries on the east side, the ancient Murcia Valley stream (Velabrum), formed a straight, flat-floored valley with steep slopes, now occupied by the Circus Maximus stadium (Figure 1(b)). The channel direction was structurally influenced; the ancient stream flowed into the Tiber counter-flow, supporting the Tiberina Island genesis (Del Monte et al., 2013).

Several ancient valleys have no topographic evidence, being completely filled by anthropogenic deposits, such as the upper Fosso di S. Agnese valley, close to the top of Pincio ridge, and other tributaries of the Aniene River (Fosso della Città Universitaria; Fosso...
di San Lorenzo: Luberti, 2014). Some left-tributaries have flat-floored valleys due to anthropogenic deposits more than fluvial ones, so they were classified as ‘modified’ fluvial landforms.

Moreover, the analysis of ancient topographic maps and other literature (Corazza & Lombardi, 1995; Quilici, 1990) have highlighted the presence of landforms otherwise unrecognizable, much as the alluvial fan north-west of the Tiber alluvial plain, and ancient marshy areas southwards. Finally, the geomorphological survey allowed us to recognize Middle Pleistocene alluvial terraces.

4.2. Natural and modified structural landforms

During the Middle Pleistocene the volcanic materials of Sabatini and Colli Albani volcanoes covered the entire area, generating a large ignimbritic plateau that gave rise to a flat summit surface. During the peak sea level lowstand, fluvial erosion cut this structural surface.

The outliers (such as the Seven Hills) were once part of a large mesa; their tops preserve some remains of structural surfaces, surviving only in limited portions of the study area. In some areas of the city centre (i.e. Termini and Esquilino), a large flat surface is the result of centuries of human activity, which produced a wide and thick layer of fill deposits. Such evidence, provided by archaeological and borehole data, suggests the introduction of the ‘modified substructural surface’ landform.

The structural and substructural surfaces are often bounded by scarps shaped by various weathering and denudation processes. In the eastern area, many scarps overlooking the Tiber alluvial plain (Capitoline, Aventino and Pincio hills) have polygenetic origin: erosion started by fluvial incision along the lines of tectonic weakness. In the western area, several scarps follow boundaries between volcanic and the underlying clayey and sandy units. Some stream elbows (i.e. Aurelia Valley) indicate a tectonic control on drainage network development. Finally, the area is also characterized by many rounded and flat ridges, isolated by fluvial incision; the main ridge (Mt. Mario) is a structural horst.

4.3. Gravitational landforms

A lot of scarp edges and landslide deposits have been identified in the study area, many of them according to the Landslide Inventory (Alessi et al., 2014; ISPRA, 2014), and mapped with a temporal reference, when known. They were caused by flows, slumps, falls and toppling. The last two are present on the more cohesive outcrops, while the slumps and mud-flows often occur in areas with clay, sand and clayey sand outcrops (Figure 4). Deformation features induced by creeping
have also been identified on natural or modified surfaces with low slopes. Landslides are widespread in the western part of the study area, and particularly on the slopes of Mt. Mario (Bozzano, Martino, & Priori, 2006). A number of landslides occur where the slope gradient is high (>20%) and clay and sand outcrop. Several flows are developing in areas of moderate slope gradients (8–10%) and sometimes occur within older landslide deposits. Although smaller than other landslide types, they may cover long distances.

The east side of the Tiber has low amplitude relief, which reduces the possibility of landslide development. Mass movements, especially falls and topples, are located mainly on the steeper slopes of the fluvial valleys. They have also affected the travertine deposits outcropping along some vertical slopes of the Parioli Mounts (Amanti, Cesi, & Vitale, 2008, 2012; Carrara, Chiessi, & D’Orefice, 2012). Several small landslides are affecting artificial embankments or reshaped scarps; these gravitational deposits are rapidly removed, embankments reconstructed and scarps strengthened.

Several landslides have been mapped using a specific point symbol, if they are very small or characterized by uncertain limits but certain occurrence.

4.4. Man-made landforms

The study area has been greatly affected by a variety of human activities beginning in ancient times. The signs of these activities are superimposed and juxtaposed with those caused by natural processes.

Rome has hosted stable settlements since the Bronze Age. During the Roman age, the population grew up to 1 million people and the urbanized area, the Urbs, became larger than the area included in the Imperial Walls (Witcher, 2005). After decay of the Roman Empire, part of the Urbs and the suburban area were abandoned; later, they hosted cropland and rural settlements until the 1960s.

Mining activities, currently inactive, started in the sixth to fifth century BC (Cifani, 2008) and produced numerous caves with straight scarps and step-like slopes. In addition, a dense network of underground cavities were dug to extract material for construction, particularly lithic tuffs (tufo litoidi) and unconsolidated pyroclastic deposits (pozzolane), to distribute and collect waters and to build under-ground cemeteries (catacombe). Furthermore, underground caves are related to the presence of buried spaces, such as remains of buildings (Crescenzi, Piro, & Vallesi, 1995; Ventriglia, 1971). More recent changes to the topographic surface are due to open-pit mining for clay extraction (i.e. Inferno and Balduina valleys). These activities are related to the construction of new buildings (Amanti, Troccoli, & Vitale, 2013; Funiciello & Testa, 2008), since Rome became the capital of Italy (nineteenth century).

Most parts of the study area were definitively urbanized in the 1950s, when the city’s population growth generated the development of vast neighbourhoods, and a dense network of roads and railways. The new buildings and road network required sub-horizontal surfaces, produced by filling ancient valleys and terracing slopes (Figure 5). Among the most significant anthropogenic changes are the excavation of the saddle between the Capitolino and Quirinale hills, in Roman times, and the removal of Velia hill (Figure 6), located between the Palatino and Esquilino, in 1932 (Insolera, 2001). Construction activities and other historical events, in addition to earthquakes, floods and subsidence (Berti et al., 2004), have covered the surface of the historical City centre several times, producing a continuous layer of materials made up of the remains of collapsed buildings, rubbish and the ruins of ancient temples and monuments mixed with colluvium and alluvium. The Tiber River embankments, built in the last century, now protect the city centre from flooding.

In many valleys (i.e. Fosso di San Lorenzo), core drilling data have shown several metres of alluvial deposits containing the remains of human activity, demonstrating the high rate of erosion for first-order stream channels during the historic age (Luberti, 2014).
Human activity has also created artificial hills. A well-known example is Testaccio Mount, which reaches 48 m a.s.l. (the same height of Aventino and Palatino). This hill was created by the accumulation of so-called «Cocci» (shards), fragments of broken amphorae of the ancient Romans. On the Tiber alluvial plain, several other man-made mounds appear as small hills (e.g. Montecitorio).

Depressions filled by man-made materials were mapped as depositional anthropic landforms where the thickness of anthropic deposit is over 5 m and hides the depression. They were distinguished, based

Figure 5. Multitemporal analysis of the anthropogenic modifications of the drainage network and landslide processes that occurred in the Gemelli Hospital area. In (a) the rural landscape in 1924 (IGM Piano Topografico di Roma); in (b) the present-day situation (CTR Lazio 374060–374070). This area is characterized by several valleys that have been heavily modified due to urbanization; some of them were previously affected by landslides. The figure highlights that in 1924 the selected area was characterized by natural landforms, including fluvial valleys (green), landslides (red) and structural surfaces (brown). Currently some man-made landforms (black) have been superimposed on natural landforms, such as filling material in ancient valleys; other natural landforms were partially buried and reduced in extent. A more detailed description of the landforms represented can be found in the legend of the Main Map.

Figure 6. Excavation work on Velia Hill in the 1930s: (a) view from the Colosseum to NW, the Capitolino Hill and the Vittoriano are in the middle background, the Basilica di S. Francesca Romana in the upper left corner of the picture; (b) view from the Basilica di S. Francesca Romana to SE, to the Colosseum.
upon the original landform, in ‘filling material covering’ (a) an ancient valley (Figure 5), (b) an abandoned quarry (Figure 7) and (c) a previous anthropogenic excavation due to building activity or other purposes.

A special case of man-made deposit is the anthropogenic deposit over 15 m high on the previous flat top of Palatino Hill (Di Luzio, Bianchi Fasani, & Bretschneider, 2013). This deposit causes a landform similar to the previous one: a Middle Pleistocene alluvial terrace, today completely hidden by human activity.

Finally, between the man-made landforms, the ancient Roman walls and related moats (buried or not) were also mapped, and now form monumental features characteristic of Rome’s landscape.

5. Conclusion

The geomorphological survey carried out over several years in Rome allowed the description of the geomorphological evolution of the study area. The ancient *Caput Mundi* (Capital of the World) includes many well-known historical and cultural sites, but also peculiar geomorphological features and typical natural landscapes.

The survey resulted in a geomorphological map of the city, which aimed at highlighting the connections between the area’s history, urban planning and geomorphological processes. The peculiarity of the analysed territory, affected by continuous man-made changes over the last 3000 years, has forced the authors to develop innovative solutions to undertake the analysis of the urban environment as well as their cartographic representation. The analysis of the urban environment required a method for integrating survey data, historical aerial photos and maps and archaeological as well as geological, geothematic and geomorphological literature. The methodological proposal contributes to a national (Lucchetti & Giardino, 2015) and international (Rodrigues, Machado, & Freire, 2011) approach to urban environmental analysis. The legend concerning anthropogenic landforms has required remarkable additions when compared to the current standards, as the symbology derives from the analysis conducted in this heavily urbanized area. The results obtained highlight a significant landscape transformation.

To conclude, it can be stated that this is the first reconstruction of the geomorphological characteristics of the whole historical centre of Rome. The *Main Map* will also be useful for urban planning and archaeological research. The landform inventory, including landslides and floods, has additional and potentially useful implications for hazard zonation.

Software

Esri ArcGIS was used to create the original geodatabase and to produce the *Main Map*, including improving the map graphics and adding the extra data and figures on the map.

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References
Alessi, D., Bozzano, F., Di Lisa, A., Esposito, C., Fantini, A., Loffredo, A.,… Varone, C. (2014). Geological risks in large cities: The landslides triggered in the city of Rome (Italy) by the rainfall of 31 January–2 February 2014. Italian Journal of Engineering Geology and Environment, 1, 15–34.
Amani, M., Cesi, C., & Vitale, V. (2008). Le frane nel territorio di Roma. In: Funiciello R., Praturlon A., Giordano G. (Eds.) ‘La geologia di Roma. Dal centro storico alla periferia’. Memorie Descrittive della Carta Geologica d’Italia, 80, 83–117.
Amani, M., Chiessi, V., & Guarino, P. M. (2012). The 13 November 2007 rock-fall at viale tiziano in Rome Italy. Natural Hazards and Earth System Sciences, 12, 1621–1632.
Amani, M., Troccoli, A., & Vitale, V. (2013). Pericolosità geomorfologica nel territorio di Roma Capitale. Analisi critica di due casi di studio: la Valle dell’Inferno e la Valle dell’Almone. Memorie Descrittive della Carta Geologica d’Italia, 93, 35–66.
Arlingoli, D., Del Monte, M., Fazzini, M., Fredi, P., Gentili, B., Lupia Palmieri, E.,… Trovato, G. (2005). Carta geomorfologica e note illustrative del Foglio n°389 Anagni. Carta geologica d’Italia alla scala 1:50000, S.E.L.CA, Firenze, Servizio Geologico Nazionale, Roma.
Ascani, F., Bozzano, F., Buccellato, A., Del Monte, M., Matteucci, R., & Vergari, F. (2008). Evoluzione del paesaggio e antiche vie di drenaggio nell’area de ‘Il Castellaccio’ (Roma) da indagini geologiche, geomorfologiche e archeologiche. Geologica Romana, 41, 93–116.
Belisario, F., Del Monte, M., Fredi, P., Funiciello, R., Lupia Palmieri, E., & Salvini, F. (1999). Azimuthal analysis of stream orientations to define regional tectonic lines. Zeitschrift für Geomorphologie, Suppl.-Bd, 118, 41–63.
Bellotti, P., Calderoni, G., Carboni, M. G., Di Bella, L., Tortora, P., Valeri, P., & Zernitskaya, V. (2007). Late Quaternary landscape evolution of the Tiber River delta plain (Central Italy): new evidence from pollen data, biostatigraphy and 14C dating. Zeitschrift für Geomorphologie, 51(4), 505–534.
Berti, D., Esposito, E., Giusti, C., Luberti, G. M., Piccardi, L., Porfido, S.,… Vittori, E. (2004). Geological setting, hazards and urban growth in some historical towns in Italy. Atti 32nd IGC-Firenze, Memorie Descrittive della Carta Geologica d’Italia, 63(6), 1–72.
Bozzano, F., Martino, S., & Priori, M. (2006). Natural and man-induced stress evolution of slopes: The Monte Mario hill in Rome. Environmental Geology, 50(4), 505–524.
Branacchio, L., Castiglioni, G. B., Chiarinni, E., Cortemiglia, G., D’Orefice, M., Dramis, F.,… Pellegrini, G. B. (1994). Carta Geomorfologica d’Italia – 1:50000. Guida al rilevamento. Quaderni del Servizio Geologico Nazionale, Serie III, 4, 42 pp.
Carrara, C., Chiessi, V., & D’Orefice, M. (2012). I travertini metogeneici dei Monti Parioli-Valle Giulia (Roma): aspetti geologici e geomeccanici in relazione ad eventi franosi. GEAM – Associazione Georisorse e Ambiente, 137, 5–22.
Cattuto, C., Gregori, L., Melelli, L., Taramelli, A., & Broso, D. (2005). I conoidi nell’evoluzione delle conche intermontane umbre. Geografia Fisica e Dinamica Quaternaria, 7 (Suppl.), 89–95.
Ciccacci, S., Del Monte, M., & Marinini, R. (2003). Erosion and recent morphological change in a sample area of the upper Orcia river basin (Southern Tuscany, Italy). Geografia Fisica e Dinamica Quaternaria, 26, 97–109.
Cifani, G. (2008). Architetture romana arcaica: edilizia e società tra monarchia e repubblica. L’Erma di Bretschneider, 40, 404 pp.
Ciotoli, G., Della Setta, M., Del Monte, M., Fredi, P., Lombardi, S., Lupia Palmieri, E., & Pugliese, F. (2003). Morphological and geochemical evidence of neotectonics in the volcanic area of Monti Vulsini (Latium, Italy). Quaternary International, 101–102, 103–113.
Corazza, P., & Giusti, C. (2005). Methodological proposal for the assessment of the scientific quality of geomorphosites. Il Quaternario, 18(1), 307–313.
Corazza, A., & Lombardi, L. (1995). Idrogeologia dell’area del centro storico di Roma. In: La geologia di Roma: il centro storico. Memorie Descrittive della Carta Geologica d’Italia, 50, 179–211.
Corazza, A., & Marra, F. (1995). Carta dello spessore dei terreni di riporto. In: La geologia di Roma: il centro storico. Memorie Descrittive della Carta Geologica d’Italia, 50, tav. 13.
Crescenzii, R., Piro, M., & Vallesi, R. (1995). Le cavità sotterranee a Roma. In: La geologia di Roma: il centro storico. Memorie Descrittive della Carta Geologica d’Italia, 50, 249–278.
De Rita, D., & Fabbri, M. (2009). La Rupe Tarpea: The role of the geology in one of the most important monuments of Rome. Memorie Descrittive della Carta Geologica d’Italia, 87, 53–62.
Del Monte, M. (1996). Rapporti tra caratteristiche morfometriche e processi di denudazione nel bacino idrografico del Torrente Saldarello (Basilicata). Geologica Romana, 32, 151–165.
Del Monte, M., Fredi, P., Pica, A., & Vergari, F. (2013). Geosites within Rome city center (Italy): A mixture of cultural and geomorphological heritage. Geografia Fisica e Dinamica Quaternaria, 36(2), 241–257.
Della Setta, M., Del Monte, M., & Marinini, R. (2006). Caratteristiche geomorfologiche dell’area della Riserva Naturale Monteranno (Lazio settentrionale). Geologica Romana, 39, 43–54.
Di Luzio, E., Bianchi Fasani, G., & Bretschneider, A. (2013). Potential rock falls and analysis of slope dynamics in the palatine archaeological area (Rome, Italy). *Geologica Acta*, 11(2), 245–264.

Dramis, F., Gentili, B., & Pieruccini, U. (1979). La carta geomorfologica del medio bacino del Tenna (Marche centro meridionali). *Geologia Applicata e Idrogeologia*, 14(2), 199–206.

Dupérac, E. (1577). *Nova Urbis Romae Descriptio*. Provided by the Roma Tre University, Architecture Dept. Library.

Faccenna, C., Funiciello, R., & Marra, F. (1995). *Geomorfologia quantitativa e morfodinamica del territorio abruzzese*. II – Il bacino idrografico del Fiume Tordino. *Geografia Fisica e Dinamica Quaternaria*, 21, 113–129.

Falda, G. B. (1676). Novissima et accuratissima delineatio Romae veteris et novae. In viatorum usum et commoditatem excusa. One 500×590 mm sheet map. Provided by the Archivio Capitolino, Comune di Roma.

Funiciello, R., & Giordano, G. (2008). La nuova carta geologica di Roma: litostratigrafia e organizzazione stratigrafica. In: Funiciello R., Praturlon A., Giordano G. (Eds) *Memorie Descrittive della Carta Geologica d’Italia, (2)*, 245–256.

Funiciello, R., & Giordano, G. (2008). La nuova carta geologica di Roma: litostratigrafia e organizzazione stratigrafica. In: Funiciello R., Praturlon A., Giordano G. (Eds) *Memorie Descrittive della Carta Geologica d’Italia, (2)*, 245–256.

GAI. (1954). *Volo Italia*. Gruppo Aereo Italiano, Istituto Geografico Militare Italiano. Photographs of Rome, 23×23 cm, provided by the Dpt. of Earth Sc., Sapienza University, Roma.

Gregori, L., & Melelli, L. (2005). *Geoturismo e geomorfologia del medio bacino del Tenna (Marche centro meridionali)*. *Geologia Applicata e Idrogeologia*, 14(2), 199–206.

Gregori, L., & Melelli, L. (2005). Geoturismo e geomorfologie: The GIS solution. *Il Quaternario*, 18(1), 285–292.

Heiken, G., Funiciello, R., & de Rita, D. (2005). *The seven hills of Rome*. Princeton, NJ: Princeton University Press.

IGM. (1873a). *Tavoletta 150 IV NO ‘Castel Giubileo’*. Istituto Geografico Militare. Scale 1:25000 map, provided by the Società Geografica Italiana, Roma.

IGM. (1873b). *Tavoletta 150 IV SO ‘Roma’*. Istituto Geografico Militare. Scale 1:25000 map, provided by the Società Geografica Italiana, Roma.

IGM. (1924). *Piano Topografico di Roma e suburbi, Fogli 1–12*. Istituto Geografico Militare. Maps surveyed in 1907, updated in 1924. Scale 1:5000 maps, provided by the Archivio Capitolino, Comune di Roma.

Insolera, I. (1985). *Le città nella storia d’Italia – Roma*. Laterza, Bari, 468 pp.

Insolera, I. (2001). *Roma Fascista nelle fotografie dell’Istituto Luce*. Editori riuniti, Roma, 271 pp.

ISPRRA. (2014). *Progetto frane Roma*. Inventario dei fenomeni franosi nel territorio di Roma Capitale. Italian National Institute for Environmental Protection and Research, (ISPRRA). Retrieved September 17, 2015, from: http://sgi.isprambiente.it/franeroma/default.htm.

Karner, D. B., Marra, F., & Renne, P. R. (2001). The history of the Monti Sabatini and Alban hills volcanoes: Groundwork for assessing volcanic-tectonic hazards for Rome. *Journal of Volcanology and Geothermal Research*, 107, 185–215.

Lamb, H. H. (1995). *Climate, history, and the modern world*. London: Routledge. 384 pp.

Lanciani, R. (1893–1901). *Forma Urbis Romae*. Ulrico HOEPLI, 46 pls.

Luberti, G. M. (2014). Segnalazione dell’esistenza di un fosso nell’area di San Lorenzo e del Verano e relative implicazioni sulla carta geologica del Comune di Roma. *Professione Geologo*, 38, 17–21.

Lucchetti, S., & Giardino, M. (2015). Historical archives data for the reconstruction of geomorphological modifications in the urban area of Turin (NW Italy). In: Lolli G et al. (eds), *Engineering geology for society and territory*. Springer International Publishing, 8, 447–452, doi: 10.1007/978-3-319-09408-3_46.

Lupia, Palmieri, E., Centamore, E., Ciccacci, S., D’Alessandro, L., Del Monte, M., Fredi, P., & Pugliese, F. (1998). Geomorfologia quantitativa e morfodinamica del territorio abruzzese. II – Il bacino idrografico del Fiume Tordino. *Geografia Fisica e Dinamica Quaternaria*, 21, 113–129.

Lupia Palmieri, E., Centamore, E., Ciccacci, S., D’Alessandro, L., Del Monte, M., Fredi, P., & Pugliese, F. (2001). Geomorfologia quantitativa e morfodinamica del territorio abruzzese. III – Il bacino idrografico del Fiume Saline. *Geografia Fisica e Dinamica Quaternaria*, 24(2), 157–176.

MARPW. (1943–1944). *Royal Air Force flights on Rome*. Mediterranean Allied Photo Reconnaissance Wing. Photographs, 23×23 cm, provided by the Aerofototeca Nazionale (AFN), Ministero dei beni e delle attività culturali e del turismo, Istituto Centrale per il Catalogo e la Documentazione, Roma.

Marra, F., & Rosa, C. (1995). Stratigrafia e assetto geologico dell’area romana – In: La geologia di Roma: il centro storico. *Memorie Descrittive della Carta Geologica d’Italia*, 50, 49–118.

Mattei, M., Funiciello, R., & Parotto, M. (2008). Roma e contesto geodinamico recente dell’Italia centrale. In: La geologia di Roma dal centro storico alla periferia. *Memorie Descrittive della Carta Geologica d’Italia*, (2), 13–24.

Moltke, H. K. B. Graf Von. (1852). *Della Roma e organizzazione stratigrafi*

Nistri, U. (1919). Roma dall’aeroplano. *Nistri. Fotomosaic of four photographs, 34.5×40.5 cm each, provided by the Aerofototeca Nazionale (AFN), Ministero dei beni e delle attività culturali e del turismo, Istituto Centrale per il Catalogo e la Documentazione, Roma.*

Nolli, G. B. (1748). *Nuova pianta di Roma data in luce da Giambattista Nolli l’anno MDCCCLXIII*. Alla santità di nostro signore papa Benedetto XIV la nuova topografia di Roma ossequiosamente offerrae e dedica l’umilissimo servo Giambattista Nolli comasco. Map of 12 elements: 430×440×680/690 mm and 480×720 mm. Provided by the Archivio Capitolino, Comune di Roma.
Panizza, M. (1972). Schema di legenda per carte geomorfologiche di dettaglio. *Bollettino della Società Geologica Italiana*, 91, 207–237.
Panizza, M. (1987). La cartografia tematica delle Scienze della Terra nella pianificazione territoriale. *Memorie della Società Geologica Italiana*, 37, 503–509.
Panizza, M. (2001). Geomorphosites: Concepts, methods and examples of geomorphological survey. *Chinese Science Bulletin*, 46, 4–5.
Pellegrini, G. B. (2000). Note illustrative della Carta Geomorfologica d’Italia alla scala 1:50000, Foglio 063 Belluno. Servizio Geologico d’Italia, Roma.
Pinza, G. (1925). *Introduzione geomorfologica alla storia della Civiltà Latina dalle origini al V sec. a. C.* Pontificia Accademia Romana di Archeologia, Roma, 45 pp.
Presidenza del Censo. (1839). *Carta topografica del subur- bano di Roma, desunta dalle mappe del nuovo censimento e trigonometricamente delineata nella proporzione di 1.15000 per ordine dell’E.mo e R.mo Principe Sig. Cardinale Gio. Francesco Falzacappa. Stato Pontificio, Roma.* Provided by the Archivio Capitolino, Comune di Roma.
Quilici, L. (1990). Forma e urbanistica di Roma arcaica. In M. Cristofani (Ed.), *La grande Roma dei Tarquini* (pp. 29–44). Rome: L’Erma di Bretschneider.
Rea, R. (2011). *Cantieristica archeologica e opere pubbliche: la linea C della metropolitana di Roma.* A cura di Rossella Rea. Mondadori Electa, Milano, 299 pp.
Reynard, E. (2008). Scientific research and tourist promotion of geomorphological heritage. *Geografia Fisica e dinamica Quaternaria*, 31, 225–230.
Rodrigues, M. L., Machado, C. R., & Freire, E. (2011). Geotourism routes in urban areas: A preliminary approach to the Lisbon geoheritage survey. *Geo Journal of Tourism and Geosites*, 8(2), 281–294. ISSN 2065-0817, E-ISSN 2065-1198.
SARA-Nistri. (1934). *Aerial photograph flight on Rome.* SARA-Nistri. Photographs, 18×13 cm, provided by the Aerofototeca Nazionale (AFN), Ministero dei beni e delle attività culturali e del turismo, Istituto Centrale per il Catalogo e la Documentazione, Roma.
Shepherd, E. J., Leone, G., Negri, A., & Palazzi, D. (2013). *La collezione aerofotografica British School at Rome (BSR) conservata in ICCD-Aerofototeca Nazionale (AFN).* Report 2013 sullo stato di avanzamento delle attività. Ministero dei beni e delle attività culturali e del turismo, Istituto Centrale per il Catalogo e la Documentazione, Roma. Retrieved September 17, 2015, from: http://www.iccd.beniculturali.it/getFile.php?id=2726
Testa, O., Campolunghi, M. P., Funiciello, R., & Lanzini, M. (2008). Il problema dei riporti e le modificazioni della forma originaria. In: La geologia di Roma dal centro storico alla periferia. *Memorie Descrittive della Carta Geologica d’Italia*, 80(1), 145–168.
UNESCO. (2005). *Operational Guidelines for the Implementation of the World Heritage Convention,* UNESCO World Heritage Centre, Paris, 83–84. Retrieved September 17, 2015, from: http://whc.unesco.org/archive/opguide05-en.pdf
Ventriglia, U. (1971). *La geologia della città di Roma. Amm. Prov. Roma,* 417 pp.
Ventriglia, U. (2002). *Geologia del territorio del Comune di Roma.* Amm. Prov. Roma, 810 pp.
Witcher, R. (2005). The extended metropolis: Urbs, suburbium and population. *Journal of Roman Archaeology*, 18, 120–138.