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via Ajaccio 43 - 00198 Roma, tel. 0685358444 fax 0685833591
e-mail: qn@edizioniquasar.it – www.edizioniquasar.it

LE REGOLE DEL GIOCO TRACCE ARCHEOLOGI RACCONTI

STUDI IN ONORE DI CLEMENTINA PANELLA

a cura di
Antonio F. Ferrandes e Giacomo Pardini

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Aspects of the landscape environment of Rome in antiquity. Changes of landscape, shift of ideas

Antonia Arnoldus-Huyzendveld*

...the major lesson of earth science studies over the past 200 years is that the earth surface is a dynamic place even over very short time scales.
Wilkinson - Stevens 2003

1) The time scale challenge

The case studies presented here concentrate on some landscape environments of Rome and its surroundings that have evolved considerably within the archaeological time range, and eventually on the changed ideas about their formation. They mostly refer to published projects in which I have been involved over the years (**fig. 1**)[1].

Fig. 1 - Location of the places mentioned in the text: CT, Centocelle - Torre Spaccata; VP, Via Portuensis; PC, Harbour basin of Claudius; Co, Colosseum valley and Oppian hill.

I use here the word "landscape environment", since "landscape" has several meanings in the current literature. This concept has for me the connotation of a set of terrestrial forms, inseparable from the geological substrate, the vegetation and climate. Such an approach is rather similar to some aspects of environmental archaeology, which is "about reconstructing the physicality of the landscape in which people lived, hunted and farmed. In other words, assessing where rivers and streams ran, the shape and slope of hills, the fertility of soils, the depth of lakes, the distance to the sea, and the countless other variables of the physical environment"[2]. Those who approach archaeology from the earth sciences viewpoint must realize that in the archaeological literature in most cases the meaning is (rightly) the "cultural landscape", i.e. the distribution and interrelationships between sites and other cultural expressions of a specific period[3]. Or even that it may be referred to as what is perceived by people who live (or lived) in a "place", in contrast to "space"[4].

* Digiter S.r.l. (*www.digiter.it*), Rocca di Papa (RM).

[1] If not mentioned differently, the images are by the Author.

[2] Wilkinson - Stevens 2003.

[3] See e.g. Patterson 2004.

[4] Thomas 2001.

Cultures interact with the environment and *vice versa*. Archaeologist make it part of their work to understand the past local environment of a society and the natural resources available. Earth sciences may offer partial answers to these questions. Geoarchaeology deals specifically with Earth history within the time frame of human history, and has been defined as "the application of archaeological research using the methods and concepts of the earth sciences"[5]. Within the geoarchaeological framework, useful techniques and methods are offered in particular by physical geography (the study of the dynamics of the earth's surface), sedimentology (study of the processes of sedimentation and sediments), soil science (study of soils and transformation processes of the earth's surface) and geomorphology (study of the terrestrial forms and their origin and evolution). In geoarchaeology one has to evaluate on a case-by-case basis the possible impact on the paleo-environmental equilibrium of a society through geological processes like: neotectonics, volcanism, earthquakes, sea level changes, lateral shifting of meandering rivers, slope processes due to deforestation, variations in discharge of springs, effects of erosion on the equilibrium of the entire watershed even far downstream, climate variations, etc. Moreover, these impacts are not necessarily direct: there may be delayed responses, and responses variable in function of the structure and resilience of a given society. The inverse may also occur: a society exercising an impact on natural systems, most probably the biosphere and the soil-sediment system.

The modern conceptual base for geoarchaeology is to consider the interactions between the human ecosystem and the external paleo-land system[6]. Costanza *et al.* 2007 state about this: "Simple, deterministic relationships between environmental stress and social change are inadequate. Extreme drought, for instance, triggered both social collapse and ingenious management of water through irrigation. Human responses to change, in turn, feed into climate and ecological systems, producing a complex web of multidirectional connections in time and space." Resilience is a fundamental concept in this context. It can be defined as how fast a biotic community returns to a 'normal' situation (or rather equilibrium) following a change[7]. However, often human communities did not succeed in establishing a new equilibrium after a change of environment, like the wave of migration of the Germanic population from the Oder region in the 5th century, which was triggered, amongst others, by a worsening climate[8].

Events concerning archaeology occurred in the late Pleistocene - Holocene, rarely in the middle Pleistocene, of the geological time scale. There is a wide gap between both time scales, which makes it necessary in geoarchaeological practice to adapt to the short and high-resolution chronology of archaeology. In my opinion this is one of the major challenges for the application of Earth Sciences to Archaeology.

We know that the Italian landscape has undergone major changes within the archaeological time scale. But in practice, the larger part remained unchanged to the eye, at least if we exclude the vegetation cover and the infrastructures. In reconstructing the past landscape environment, one should strive after distinguishing between those parts of the landscape which, within a determined time span, have remained static in their morphology and environmental conditions, and the parts that were dynamic, i.e. underwent changes. And concentrate on the latter. The challenge in tracing the historical environmental record is to establish how much, how and when these factors changed.

[5] Rapp - Hill 2006.

[6] Rapp - Hill 2006.

[7] Wilkins - Stevens 2003, p. 33; see also Redman 2005; Berger *et al.* 2010.

[8] Volkmann 2010.

Within the period that coincides with the archaeological record, the strongest variations have occurred generally in coastal and valley landscapes and in recent volcanic areas. The 2007 Salerno conference[9] about recent geoarchaeological findings in Southern Italy had indeed numerous presentations which referred to coastal areas and volcanic zones of recent activity, and subordinately to fluvial environments. In this context, I consider particularly meaningful the volume "Geoarchaeology of the landscapes of classical antiquity"[10], which offers a majority of studies dedicated to valleys and coastal plains. Also, with his book *Alluvial Geoarchaeology* (1997), Antony Brown has succeeded in integrating the river dynamics with archaeological, botanical and zoological data, with a particular attention for the Mediterranean record.

Apart from the time scale, there are other factors that require the earth scientist to conform to the archaeological practice.

- Archaeological remains are scarce and excavation space is limited with respect to the geological survey reality. Often a paleo-environmental reconstruction has to be carried out on the basis of poor data, and for the most part collected at places less than ideal from the geological viewpoint. Moreover, not only the high level of detail applied in archaeological stratigraphy, but also the criteria used for the distinction and the scale of resolution are often different from those used in sedimentology, and require a revision of the traditional geological approach.
- The earth sciences are traditionally applied in originally natural environments, whereas the paleo-archaeological environment is often more or less urbanized.
- In contrast to geological layers, archaeological layers, once excavated, cannot be re-examined: the archaeological excavation leads almost always to the destruction of the stratigraphic context.
- A known factor of incomprehension is the dynamics of terrestrial processes. To the question asked most frequently to the geoarchaeologist working at an excavation – "how much time did it take to form this layer?" – almost never a useful answer can be given, especially if the layer has a strong natural component (e.g. sediments deposited by running water). This is due to the dynamics of terrestrial open systems, in which often the formation and destruction of layers alternate cyclically, with a frequency variable from daily to millennial or even wider. The archaeologist would like to know: "for how long have dominated in this place the specific environmental conditions testified by this layer?". And what the geologist sees is just the latest ephemeral expression, mostly survived by chance, of a situation that may have lasted a few days as well as hundreds of years.

Archaeologists should be aware that (as in any science) the ideas about the local physical landscape, i.e. the geological "paradigma", may change over the years, and with that the potential considerations on the interaction of past cultures with the environment. In reference to the system of knowledge that encompasses scientific theories, Thomas Kuhn[11] argued for an episodic model in which periods of conceptual continuity in normal science are interrupted by periods of revolutionary science. The discovery of "anomalies" during revolutions in science leads to new paradigms. New paradigms then ask new questions of old data, move beyond the mere solving of the previous paradigm and change the rules directing new research. The conceptual

[9] International congress "People/environment relationships from the Mesolithic to the Middle Ages: recent geo-archaeological findings in Southern Italy", Salerno (Italy), 4-7 September 2007.

[10] Vermeulen - De Dapper 2000.

[11] Kuhn 1962.

model may even change so strongly that one can speak of a "paradigma shift". Although later criticized[12], in my opinion it remains a useful reference in the geoarchaeological practice.

Geological principles were already applied to archaeology in the 19th century[13]. A major reference to archaeological site formation and stratification is the volume by P. Barker[14]. An attempt to integrate natural and cultural depositional and post-depositional processes, including the transformations occurring in the "surface environment" (which includes soils in the off-site environment) was given in Arnoldus-Huyzendveld 1995[15].

Classical geology is based upon a few basic principles, which were developed between the 17th and 19th century. For an overview of the history of geological thinking, see Gould 1987. Probably the first visitor to observe the rocks and soils of Italy from a modern viewpoint was Goethe, in the report of his travels between 1786 and 1788.

Besides the laws of stratigraphy, we have in geology the theory of Actualism (or Uniformitarism), formulated by James Hutton and developed by Charles Lyell. It states that observable present-day processes already existed in the geological past and that therefore all past geological features should be interpretable in terms of processes acting on the Earth today: "the present is the key to the past"[16]. Nowadays, actualism is not considered completely valid: geologists know that some of the factors that changed the Earth in the past cannot be seen at work today. But such considerations are referred to time scales beyond archaeological interest, so that for any practical purpose it remains a valid principle.

In its modern version, the catastrophism-gradualism discussion, which deals with the velocity and mode of terrestrial changes, is of foremost importance to the application of geology in the archaeological context. Catastrophism was an existing school of thought that was rejected by Charles Lyell in the 19th century. He turned to the earlier works of James Hutton, who had argued that the Earth was transformed not by unimaginable catastrophes but by imperceptibly slow changes, many of which we can see around us today: rain erodes mountains, while molten rock pushes up to create new ones; the eroded sediments form into layers of rock, which can later be lifted above sea level, tilted by the force of the uprising rock, and eroded away again. In this vision, valleys are not the work of giant floods but of the slow grinding force of wind and water. These changes are tiny, but on the long run they would produce vast changes. One may encounter many evidences for gradual changes, but also of the contrary: processes such as earthquakes and eruptions can instantaneously change mountain ranges. Major catastrophes may also affect cultures both in positive or negative, like the "volcanic veil" formed by the eruption of an unknown volcano in A.D. 536, which for some years changed the climate in large areas of Europe and beyond[17]. Actually, the catastrophism-gradualist discussion is partly a matter of scale: we could consider gradual changes to be composed as a series of catastrophes on a small scale; the geological records are full of them.

The more recent theories of science and geology are useful in the application of earth sciences to archaeology. The principal ones will be shortly mentioned hereafter.

[12] Mitra 1994.

[13] Rapp - Hill 2006, p. 7.

[14] Barker 1993.

[15] See also references therein.

[16] *Principles of Geology* 1830.

[17] Hodges 2010.

- Systems theory is about the interaction between phenomena, as opposed to the deterministic vision on processes in terms of causes and effects. In earth sciences, in particular in physical geography, it has been widely applied since the seventies[18]. Such a vision is useful to understand the interaction man - environment in a culture, and more generally the dynamics of exchange of energy and matter between systems (natural or cultural) on the Earth's surface and their surrounding environment. The first to apply this in archaeology was David Clarke in 1977. An application of this theory in geoarchaeology was given by John Bintliff in *Landscape change in classical Greece: a review* (2000). The author states: "Instead of having to decide on climate or anthropogenic causes as mono-causal alternatives, it would perhaps be wiser to investigate the many ways in which the natural and human impact factors interact to encourage or inhibit erosion and alluviation (..)". Moreover, Bintliff recognizes the importance of Vita-Finzi's (1969, *The Mediterranean Valleys*) insight that "significant, large-scale disruptions of the landscape preserved as alluvia and colluvia were discontinuous and temporally limited in time; most of the time major erosion was *not* occurring. This 'punctuated equilibrium' model remains very convincing (..)". Despite the latter work is not recent, I agree with the importance of this model. In the present context, it finds its equivalent in Bellotti's[19] description of the sea level rise after the last glacial maximum: not continuous but episodic ("punctuated"), with long periods of stasis (or eventually sea level lowering) alternating with rapid ascents, and in the pattern of the recent activity of the Colli Albani volcano.
- Chaos studies the behaviour of dynamical systems that are highly sensitive to initial conditions. Small differences in initial conditions yield widely diverging outcomes for such dynamical systems, rendering long-term prediction almost impossible. Chaotic behaviour can be observed in many natural systems, such as weather and water flows. Understanding that similar processes may affect the Earth's surface enables us to interpret the distribution of archaeological finds and to reconstruct the former landscape.
- The theory of Gaia was developed by James Lovelock and Lynn Margulis in the 1970. It proposes that organisms interact with their inorganic surroundings to form a self-regulating, complex system that contributes to maintaining the conditions for life on the planet. The importance for geoarchaeology is that this great vision refers potentially also to the mutual influence between culture and environment.

2) The Colli Albani volcano

This case study contains a typical example of a paradigma shift. Before ca. the year 2000, almost no one – geologist nor archaeologist – realized there had been volcanic activity near Rome in prehistorical and historical times. Most of the facts were known (the "Conglomerato del Tavolato" formation was already recognized in the 19th century as recent), but they were not put into what now is considered the right context. And that in spite of the reporting in the 19th century of Middle Bronze Age tombs covered by what seemed to be volcanic sediments, and the Roman age descriptions of the last spill-over of the lake of Albano in 398 B.C. reported by Plutarch, Dionysius of Halicarnassus and Livy, at the time mostly dismissed as legends. The

[18] Thompson 1986.

[19] Bellotti 2000.

breakthrough publication was Funiciello *et al.* 2002. A summery of this history is accounted by De Benedetti *et al.* 2008.

In this case, the dynamic parts of the landscape within the archaeological time scale turned out to be the plains and valley fills to the north-west of the volcanic edifice and the Albano crater itself. For any practical purpose, the other landscape elements can be considered static, i.e. from the morphological viewpoint they have not changed substantially in the last millennia. This does not exclude minor erosion and accumulation processes, which may generally influence site visibility during archaeological surveys[20].

The Vulcano Laziale or Colli Albani volcano is the impressive relief to the south-east of Rome, with a maximum elevation of 1000 m a.s.l. (Monte Cavo) and a diameter of 10 km. It is a predominantly explosive volcano, whose activity started about 550.000 years ago and continued until the Holocene with phreatic activity associated with the Albano maar. The final activity has consisted in a succession of eruptions from the eccentric craters Ariccia, Nemi and Albano, of which the latter two still contain a lake until the present day.

Until a decade or so ago, the *peperino of Albano* was considered the final product of the Colli Albani volcano, deposited about 29.000 years ago. Recent research has shown, instead, that there have been periods of activity until 6.000 years ago and beyond. In that period, *lahar* or mud flows (the *Tavolato Conglomerate* or *Succession*) were deposited in consequence of the spilling over of the Albano crater. These have filled in, on several occasions, the valleys extending to the north-west of the volcanic edifice, leaving uncovered only the hills at elevations higher than the blanket of mud and stones. This phenomenon may have been triggered by the injection on the lake bottom of fluids rich in carbon dioxide, which may have led to a sudden reversal of the contents of the lake[21].

Due to these events, the large plain of Ciampino was formed. Geological records show that not a single and continuous depositional phase has occurred, but rather a series of sedimentary events (catastrophic or not) interspersed with periods of stasis. Apart from the geological data, the most direct demonstration of the phases of sedimentary stasis are the rich traces of human occupation within the stratigraphy[22]. The deposition of a lahar ("debris flow"), which may reach a speed up to of 60 km/h, was undoubtedly a catastrophic event, which should have left behind, after the first destructive impact, a strip of land cleared from forest cover and characterized by a muddy surface with scattered volcanic boulders. The subsequent related events, namely the deposition of gravelly and sandy river sediments, should have been less catastrophic and more localized. During the periods of stasis of the crater activity, the landscape was probably characterized by extensive plains with highly fertile soils, crossed by small river incisions: a landscape not dissimilar to the present one[23].

The archaeological site *Centocelle – Torre Spaccata*[24] is located about 15 km from the centre of the Colli Albani volcanic complex, in the eastern part of Rome. According to the most recent geological maps, the valley of the Torre Spaccata stream contains a distal extensions of the *Tavolato* formation (**fig. 2**). During the excavations of 2006, a modest lahar deposit (already identified in the nineties, but not recognized as such) came to the light, which was dated to the 5th - 4th centuries B.C. Also encountered were several natural river channels with infill denoting a typical torrential flow regime, and containing archaeological material from

20 Arnoldus-Huyzendveld 2009.

21 Funiciello *et al.* 2002; Funiciello *et al.* 2003.

22 Anzidei *et al.* 2010.

23 Arnoldus-Huyzendveld 2007a.

24 Gioia 2008; Gioia *et al.* 2010; Arnoldus-Huyzendveld 2008.

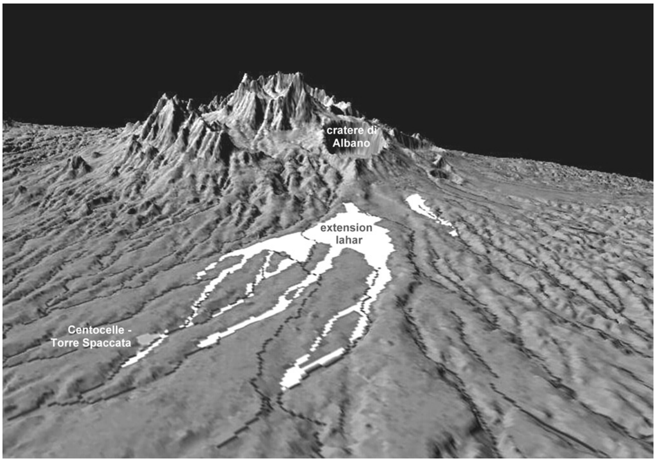

Fig. 2 - The Colli Albani volcano view from NW, with superimposed the lahar extension as mapped by Funiciello - Giordano 2005; the Centocelle - Torre Spaccata site was reached by a lahar deposit in the 5th - 4th century B.C.; 3D image derived from DEM, vertical exaggeration 5.75 x.

three distinct periods: Early Bronze Age, Mid-Republican and Imperial Roman and Early Medieval.

The presence of the lahar strip in the Torre Spaccata valley indicates at least one phase of primary sedimentation originating from the Albano crater, while the coarse textured fluvial deposits show that in the recent millennia the area has been subject to repeated, rather rapid high-energy, episodes of erosion and sedimentation, probably related to degassing of the crater or to phases of adjustment of the peripheral drainage network. The discovery of the lahar deposit in this area is particularly important because of its dating, which establishes it as the most recent of all the units known thus far. The chronology is based upon ceramics found inside the lahar deposit, which were dated between the 5th and 4th centuries B.C., while the pottery found in the immediately overlying layers was dated between the 5th and 1st centuries B.C. Through ^{14}C analysis, the female burial found in a pit next to the deposit was established to be of middle Republican age. Subsequent stratigraphy of the Torre Spaccata valley indicates that, after the lahar deposition in the 4th century B.C.[25], the environmental conditions were relatively calm. This may be due to exhaustion of the Albano crater or else to the effectiveness of the lake emissary dug on purpose by the Romans in 398 B.C. to defend themselves from further similar events.

The data collected in the *Centocelle – Torre Spaccata* project were also placed in a broader perspective[26]. The Eneolithic to Early Bronze Age ceramics found in the Torre Spaccata valley relate to a high concentration of known sites of the same period in the eastern suburbs of Rome. In the area between the Tiber and Aniene rivers 44 sites are known, while elsewhere around Rome contemporaneous sites are almost absent. It was also observed that the deep dark soils distinguished on the soil map of Rome[27] are limited to the proximity of the lahar, and that they might therefore represent its marginal extensions, not detectable in a geological section. The archaeological sites were classified according to their relationship with the lahar deposits (**fig. 3**). A clearly dominant spatial relationship of the sites with the lahar and dark soils came to the light. In the past decades, the high density of recent prehistoric sites in this area was already known[28], but at the time other explanations were given, like the vicinity to water flows.

A problem in the areas influenced by the lahar remains still unresolved: is the concentration of sites a consequence of human choice (deep and fertile soils, easy to work, a strip cleared naturally from the forest

25 Which is described by the ancient sources - Dion. Hal., *Antiquitates Romanae*, XII, 10-12.

26 Gioia *et al.* 2008.

27 Arnoldus-Huyzendveld 2003.

28 Bietti Sestieri - Sebastiani 1986.

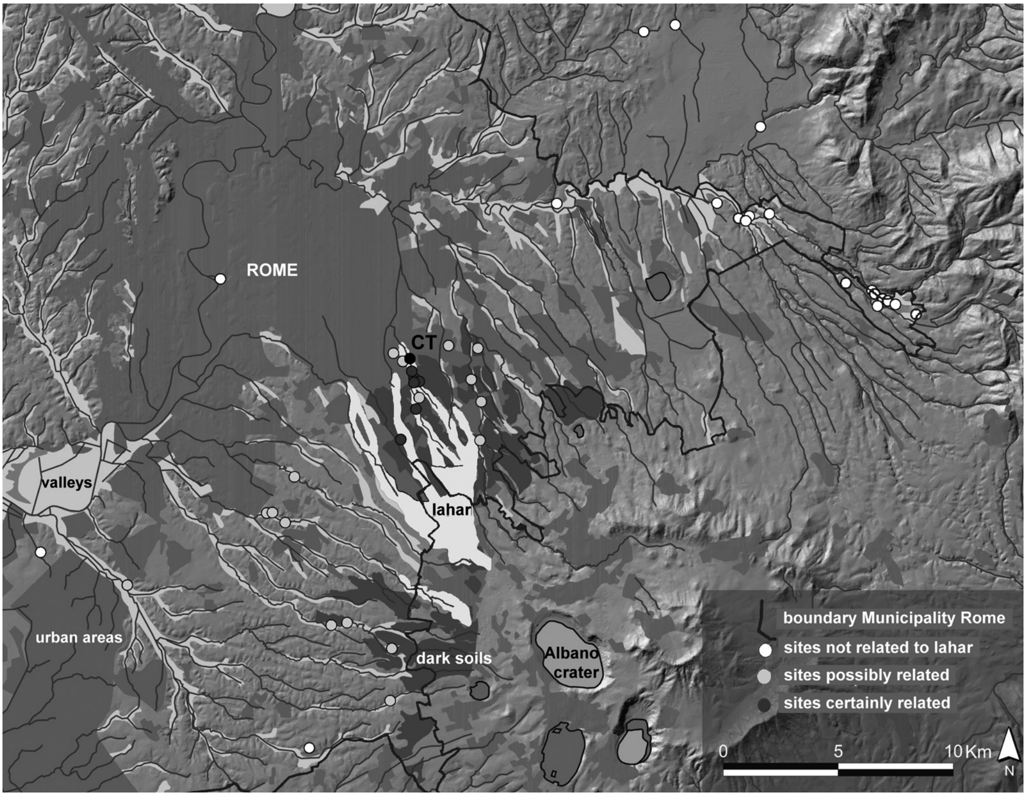

Fig. 3 - Centocelle-Torre Spaccara (CT). Distribution of the Eneolithic and Bronze Age sites, with indication of their spatial relationship with the lahar deposits (modified from Gioia *et al.* 2008).

cover, availability of water and volcanic boulders), or of the burial by the lahar sediments, or a combination of the two.

3) The coastal plain of Rome

Of all the surroundings of Rome, this is certainly the landscape environment that has most intensively changed, even until recently.

Also in this case a "paradigma shift" played a role: until as recent as 2009[29], the orientation of the harbour constructed by the emperor Claudius was given S-N, with a northern entrance and a rather square extension. Such an orientation was first proposed by Canina in 1830 and then accepted by several archaeologists, in spite of the extensive excavations carried out in the area until far into the 20th century[30]. This hypothesis required, in order to allow the harbour to function, the presence of a large coastal indenture to the north of the harbour, which was indeed drawn on the geological maps[31].

29 Giraudi *et al.* 2009.

30 Morelli 2005.

31 *Servizio Geologico* 1963.

Some authors started to doubt this orientation[32], and discovered that already in the 15th - 17th centuries the orientation of the basin was designed E-W, with two long piers extending westwards into the sea. The lack of a large inlet of the coastline north of the harbour was then proven through a trench survey[33]. Finally, based upon 140 drillings, the extension of the harbour basin was established[34]. It turned out to be much larger than hitherto supposed, indeed oriented E-W with two western entrances, and with a distance between Monte Giulio and the lighthouse island of 2200 meters (**fig. 4**). Measures confronted with older maps, specifically the one drawn by Antonio Labacco in the 16th century, turned out to be correct[35]. As it seemed from the drilling cores, the basement of the western extremities of the piers was composed of loosely stacked fragments of *tufo lionato* and basalt, piled up on the former sea bottom without traces of hydraulic mortar[36]. The stone mass is now buried by several meters of dune sand and reaches a depth of ca. 14 meters below the present sea level (**fig. 5**).

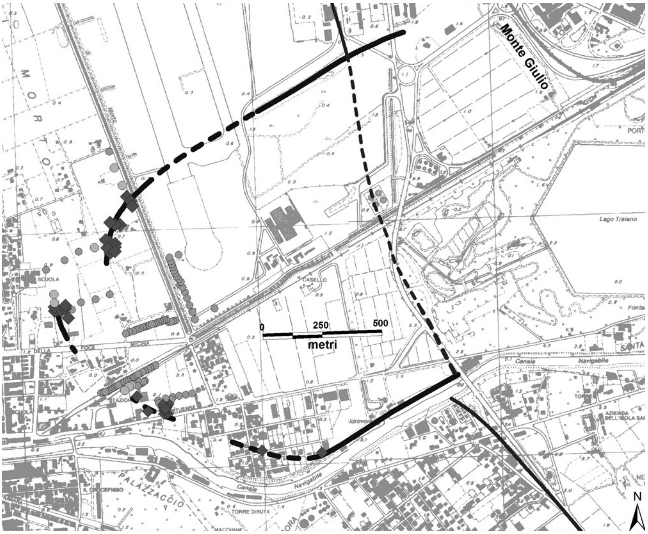

Fig. 4 - Extension of the harbour basin of Claudius established through drillins (modified from Morelli *et al.* 2011b); dark diamonds: basement of the piers; grey dots: no piers present. The presumed and ascertained pre-imperial coastline is traced.

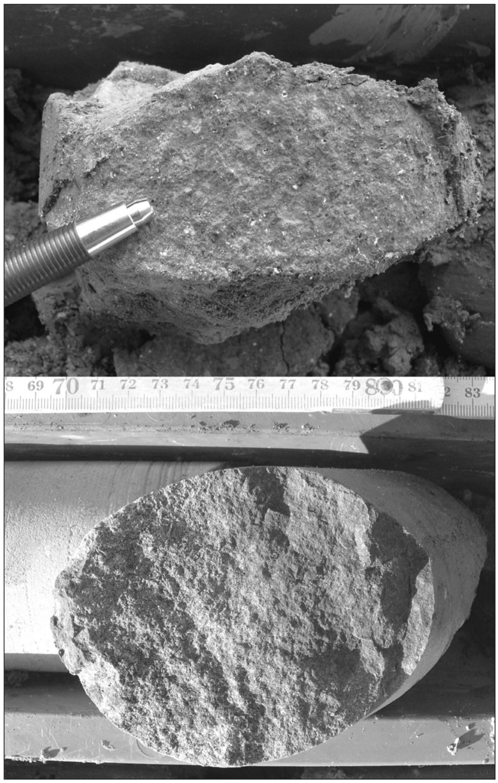

Fig. 5 - Some of the stone fragments that composed the basement of the piers, from the drilling cores: above *tufo lionato*, below basalt.

[32] Castagnoli 1963; Giuliani 1992.

[33] Arnoldus-Huyzendveld 2005.

[34] Morelli *et al.* 2011b.

[35] Morelli *et al.* 2011b.

[36] The nucleus of the central stretch of the southern pier is cemented by hydraulic mortar (Morelli *et al.* 2011a, p. 54). The same counts for the basement of the still exposed part of the northern pier (info Jean Philippe Goiran). The technique of constructing breakwaters in open sea by piling up loose blocks on the seafloor is described in Plinius Letters 6, 31 for the harbour of Civitavecchia.

Why the persistence of the idea of a S-N orientation? In this case there has been obviously an underestimation of the possible velocity of coast line expansion in historical times, proven to have reached, from the 16th century on, 7.5 m /year[37], and of the possibility of a complete masking of the harbour's remains by several meters of dune sand. The persistence, even until recent times, of the old hypothesis concerning the orientation and the size of the harbour basin was, in my opinion, a typical step in the process of paradigma shift.

Not all doubts have been resolved. Between the northern pier and Monte Giulio (the eastern limitation of the harbour basin), there was probably a channel[38], but we are still not sure if this was connected to the sea or to the inland lagoon. In some recent publications[39] there is still drawn a rather wide connection from that point to the sea, indicated as "possible northern entrance", which in my opinion could well represent a persistent trace of the formerly presumed coastal indenture north of the harbour. In a forthcoming publication we will argue that this is a highly improbable reconstruction.

Let's now follow the evolution of the coastal belt of Rome as we see it now. It is interesting to follow how environmental conditions and resources of the coastal plain have changed over time, and have been exploited in different ways. I will deal only briefly with the pre-Roman and post-Roman periods. I cannot skip those completely, since the events in the former period are the prelude to the Roman age, and the latter the "filter" which hampers our vision on the historical landscape environment. It is worth noting that to the abundant publications referring to the coastal zone of Rome, recently were added several that have cast a new light on the paleo-environmental events of the last millennia[40].

Pre-protohistoric and Etruscan age.

Although from the geological viewpoint it is a short lapse of time, in the coastal area of Rome there have been considerable environmental landscape changes between about 20.000 and 3.000 years ago. This landscape is the result of a complex geological history, which has witnessed the interaction between the sea, the rivers and volcanism. I propose to follow this evolution since the last glacial peak, when the sea level was extremely low, since much water was concentrated in the Earth's polar ice caps and mountain snow, and the Tiber valley was deeply incised. With the subsequent increase in temperature, the sea rose stepwise from ca. -120 m until approximately the present level, and the lagoon and the Tiber valley began to fill in. These events have had a profound influence not only on the landscape environment of this area, but also on the natural resources available. As static elements to be excluded from this development we may consider the sedimentary hills covered with volcanic sediments and the coastal terraces, all of them older, and located more inland and at higher altitudes than the coastal plain.

The stability of the sea level has been reached approximately 6.000 years ago. In this period, a series of coastal barriers were laid in place, gradually isolating the lagoon from the sea. The river system continued to fill in the lagoon and the valley with clayey and silty sediments, but at a lower pace than before. The coast line was set back some kilometres with respect to the current one. An important environmental event that occurred before or during the Etruscan period, with an almost stable sea level, is the transformation of the lagoon water from sweet into salt/brackish, enough to allow the construction of salt works near the lagoon of

[37] Bellotti *et al.* 1989.

[38] Goiran *et al.* 2011.

[39] Keay 2013.

[40] Particularly Di Rita *et al.* 2010; Di Rita *et al.* 2012; Bellotti *et al.* 2011; Di Bella *et al.* 2011; Milli *et al.* 2013.

Maccarese[41]. The cause of this transformation should have been the (natural?) re-opening of the connection with the sea.

The imperial age

At this stage, as in the former periods, the hills and terraces formed the "backstage" of the events that took place in the coastal belt.

We assist to the expansion of Ostia, the construction of the harbour basins of Claudius and Trajan with attached structures and channels¸ the Via Ostiensis and Portuensis, the aqueducts of Ostia and Portus, and salt works along the lagoons. A natural resource of the dune belt has always been the presence of a sweet water aquifer close to the surface, also known in ancient Ostia[42]. The lagoons to the south and north of the Tiber (Maccarese and Ostia) had natural openings to the sea, probably re-excavated to create channels for feeding the salt works.

As is well known, the harbour basin of Claudius was soon subject to silting. The early filling in of the northern corner of the basin, known from the discovery of the ships of Fiumicino in the early sixties (2^{nd} - 4^{th} century A.D.[43]), has been related to the presence of the piers protruding into the sea, in analogy to the effect of modern breakwaters placed transverse to the coast in order to protect the beach, which cause sand accumulation in front of the obstacle and a retraction of the beach behind it due to a minor sediment supply and to erosion by the sea currents[44]. With the direction of the marine currents from south to north, this mechanism would also be perfectly consistent with the position along the coast, directly north of the basin, of an inscription of the 3^{rd} century A.D., referring to the regulation of sand quarrying[45]. In the first centuries A.D., the sea level has still risen approx. 1 m with respect to the Republican period level[46]. This factor, together with the impact of the imperial structures and the frequent floods, has undoubtedly worsened the environmental conditions of the Tiber valley.

The salt works of imperial age along the eastern margin of the Maccarese lagoon have been investigated[47]. A long cross dam was built to isolate a bay from the main lagoon body, in order to manage its water level through channels with dams. These salt works have been ascertained from the 2^{nd} century B.C. on. In the Republican and Imperial eras, an extensive network of channels was dug in the peri-lagoonal areas. Some of these must have been in the service of the salt marshes, others had likely the function of soil drainage.

The final stretches of the Via Portuensis and the aqueduct of Portus ran through the Tiber valley. The road followed first the well-drained and slightly higher soils of the alluvial fan of the Galeria river, before continuing alongside the Tiber and the aqueduct of Portus. In the intermediate section, recently investigated[48], the road was constructed on a raised viaduct. Here the valley floor was poorly viable and characterized, even before the construction of the Roman road, by a series of shallow round depressions, each containing one

[41] Giraudi 2004; Di Rita *et al.* 2010, Di Rita *et al.* 2012.

[42] Ventriglia 1990; Scrinari - Ricciardi 1996.

[43] Boetto 2010.

[44] Arnoldus-Huyzendveld 2005.

[45] Testaguzza 1970, pp. 75-76.

[46] Leoni - Dai Pra 1997; Goiran *et al.* 2009.

[47] Morelli 2008; Morelli *et al.* 2011a.

[48] Arnoldus-Huyzendveld *et al.* 2009; Morelli *et al.* 2011a.

or more pools. The depressions are several meters deep, wide about ten and distant between them 30-100 meters, and later on filled in with fluvial sediment with calcareous incrustations. This environment seems to have forced the Romans to construct the road on a viaduct, and, specifically, to have constrained its passage over several bridges crossing the pools, of which thirteen have been excavated. The conical depressions were probably formed by the emission of gas and water from the subsoil, a phenomenon well know in the area of Fiumicino[49]. They testify to local hydrothermal activity, referable to the final stage of the Colli Albani volcano, which is still affected by intense degassing, either localized or diffuse. The hydrothermal activity was also testified by the presence of calcareous crusts upon the viaduct and bridges of the Via Portuensis and in the underlying sediment. Near one of the bridges, four orders of calcareous crusts have been recognized and sampled: a first one cut by the foundations of the road, dated to the time interval 900-400 B.C., two deposited within the collapse layers, of the which the second was dated to 750-1300 A.D., and a fourth deposited after the abandonment of the road in the 16th century[50].

There are still several issues to be clarified about the hydrothermal phenomena encountered, such as whether the road stretch could have avoided the area of the pools, and if possibly the Roman structure itself may have promoted the passage of the mineralized water through the upper layers of the substrate. Moreover, the chronology of events remains uncertain: we don't know if the emissions were continuous over time or if they have occurred intermittently (as it seems), in analogy to the activity pattern of the Colli Albani volcano over the last 6000 years[51]. One problem is that no bibliographic references exist for hydrothermal activity in a valley environment.

The Middle Ages

The harbour of Trajan functioned until the 9th - 10th century[52], and, as a consequence, the Via Portuensis lost its importance. There has been a seawater intrusion probably in the 6th century A.D., as is testified by a layer rich in marine malacofauna encountered in the trenches[53], which covers all the Roman remains. This intrusion may have destroyed as well the dam of the imperial salt works.

In the Maccarese plain there are rich testimonies of fish ponds from this period. The ^{14}C datings carried out on their wooden parts are concentrated in the period between the 11th and 13th centuries[54]. There are also written records on fish farming in the medieval coastal plain of Rome[55], in particular documentation on the management of fishing facilities located along the Tiber river and in the delta from the 10th to the 13th century. These sources show how, at the time, the swamps were centres of an extremely vital fishing economy. The "piscarie" plants were quite elaborate wooden structures, which acted as labyrinths from which the fish, once entered, could not return to the sea. In most cases, evidence was found of connected channels to divert sea water into the fish ponds.

49 In Fiumicino, an outflow of gas and water occurred even recently (September 2013).

50 Tuccimei *et al.* 2007.

51 Funiciello - Giordano 2010.

52 Paroli 2005.

53 Hitherto unpublished data.

54 Morelli *et al.* 2011a.

55 Vendittelli 1992.

In the areas investigated up to now[56], no traces of salt works were found for this period, although we know that those of Maccarese have functioned at least until the end of the 15th century. It is highly probable that the salt works of this period were structured in serial basins, like those of *La Trappola* known from the Grosseto plain, operative between 1386 and 1758[57]. Georgius Agricola in 1556 (book XII) recommended to build salt pans by evaporation *"near that part of the seashore where there is a quiet pool, and there are wide, level plains which the inundations of the sea do not overflow"*. The low tidal range of only 30-40 cm, common to all coastal plans along the Tyrrhenian Sea, should make it impractical, but not impossible, to use the high tide for letting the marine waters enter the salt basins.

The renaissance and modern age

Between the 15th and 17th century the strongest environmental degradation in the coastal plain of Rome occurred. Since the end of the Roman era, the dune belt had grown wider, slowly at first and then faster. For the advancement of the coastline has been calculated an average value of 0.8 m/year for the period 540-1420, and an intensification up to 7.5 m/year between the latter date and 1950[58].

This process has also affected the harbour basin of Claudius, up to the point to delete the historical memory of its size and shape. The salt marshes of Ostia have continued to function until the 19th century. At the time, the abandonment of the coastal plain is total; it is described by Carlo Fea in 1831 as an unhealthy marshy environment.

4) The lower Tiber stretch

Next I will deal with the evolution of the final stretch of the Tiber, the third[59] river of Italy in length, and with the largest water charge among the rivers reaching the Tyrrhenian coast. It is a meandering river, whose course has been subject to significant lateral shifts, a process that has continued until relatively recent times. The Tiber is an ancient river, running already, more or less, in the current position before the volcanic period. During the Middle Pleistocene volcanism, its course has undergone several major shifts, due to the disruption of the drainage network by the pyroclastic products[60]. The evolution of the Tiber drainage network is also linked to the changes in sea level: during low stands natural incision of the valleys took place, and during high stands the filling in of the valley floor, at least when there was no the interference from volcanic sedimentation. Due to the absence of volcanic activity, the last valley incision, contemporaneous with the glacial peak of 20.000 years ago, was indeed much deeper than the previous ones[61].

Pre-Roman and Republican times

Bellotti *et al.* 2011 provided a challenging and unitary model on the development of the river network of the coastal area of Rome over the last millennia. The several phases of migration of the Tiber are recorded

[56] Under the supervision of the Soprintendenza Speciale per i Beni Archeologici di Roma - sede di Ostia.

[57] The preserved drawings are from the "La Trappola" salt works between the 16th and 18th century. Caprasecca 2011; Arnoldus-Huyzendveld 2007c.

[58] Bellotti *et al.* 1989.

[59] Length 405 km.

[60] Marra - Rosa 1995.

[61] Giordano - Mazza 2010.

by the different positions of the delta cusp. In the first phase, from ca. 3000 B.C. until the 8th - 7th century B.C., a cusp spread out over the entire area from *Capo Due Rami* to the place of the later imperial harbours, and unto the outer margin of the *Stagno di Ostia*. The transition to the second phase coincided with the sudden migration of the Tiber to the south, at first flowing into the *Stagno Ostiensis* and later breaking through the dune belt near future Ostia. With the opening of the channel of Trajan (early 2nd century A.D.) a new complex system of delta progradation developed, with two river branches active almost simultaneously (the third phase).

The hypothesis of a temporary presence of the Tiber mouth near the future imperial ports, before its natural migration to the south, is now generally accepted. This hypothesis, first formulated by Dragone *et al.* 1967 and Segre 1986, has been confirmed by drilling data[62], and is also evident from the study of the direction of the coastal barriers by Bellotti *et al.* 2011. Several radiocarbon datings from drilling cores, both in the imperial harbour area and near Ostia, have established the period of lateral displacement between the 8th and 6th - 5th centuries B.C. The lateral migration is considered by Milli *et al.* 2013 as "brusque", and probably the result of a major flood.

The paleo-environmental reconstruction of Bellotti *et al.* 2011 could clarify the apparent discrepancy between archaeological and historical sources on the origin of Ostia, which the latter sources have set around the last quarter of the 7th century B.C., but for which no archaeological proofs have been found. The authors state that, just after the Tiber migration to the south, the coastal barrier belt separating the marsh of Ostia from the sea would have been still too narrow and insecure against storms to support a permanent human occupation. Therefore, in the 7th century B.C. there would have been only an outpost, with the aim of controlling the strategic river mouth and, eventually, to set up the first salt works in the marsh. In fact, the data of pollen and molluscs in the drilling cores indicate around 600 B.C. a sudden intrusion of sea water, which would have allowed salt extraction. It is not clear if this is a natural event of a man induced breakthrough of the barrier belt. Only later, around 450 B.C., when the cusp had expanded more than 1 km into the sea, the sandy substrate was supposedly large and safe enough to set up a fortified camp (*castrum*) and to further develop the salt works. Fragments of bricks, mortar and tuff at the base of a drilling carried out along the outer border of the *Stagno di Ostia* suggest the presence of permanent buildings, probably belonging to peripheral infrastructures of the settlement.

The Imperial period

At the time, most of the Tiber valley was composed (like today) of calcareous silty-clayey and fine loamy sediments deposited during floods, which gradually filled in with clayey sediments also the lagoons.

The Tiber course was broadly similar to the current one (if we exclude the natural cut off of the *Fiume Morto* meander, which occurred later), with the exception of a probably general smaller amplitude of the river bends. There are several indicators that support this hypothesis: the investigations carried out in the *Magliana* area[63], the Tiber bend undercutting the Via Ostiensis near Ostia, and the curvature of the river course in the *Fiera di Roma* area (4 km SW of Ponte Galeria) in a position that seems to cut off the Via Portuensis and the aqueduct of Portus. If we rule out for the latter case a slight curvature of the antique Via Portuensis in this location[64], we might be dealing

[62] Giraudi *et al.* 2009; Bellotti *et al.* 2007; Goiran *et al.* 2010; Di Bella *et al.* 2011.

[63] Catalli *et al.* 1995.

[64] Serlorenzi *et al.* 2004.

with the same phenomenon reported for the river stretch in the *Magliana* area, i.e. an amplitude increase of the bend with respect to Roman times. A support to this hypothesis is the presence detected on the bottom of the Tiber of a series of blocks[65], which could represent the remains of the road and the aqueduct collapsed into the river during a major flood (**fig. 6**). Knowing that the Via Portuense remained functioning until the great flood of 1557[66] it could well have been precisely that one.

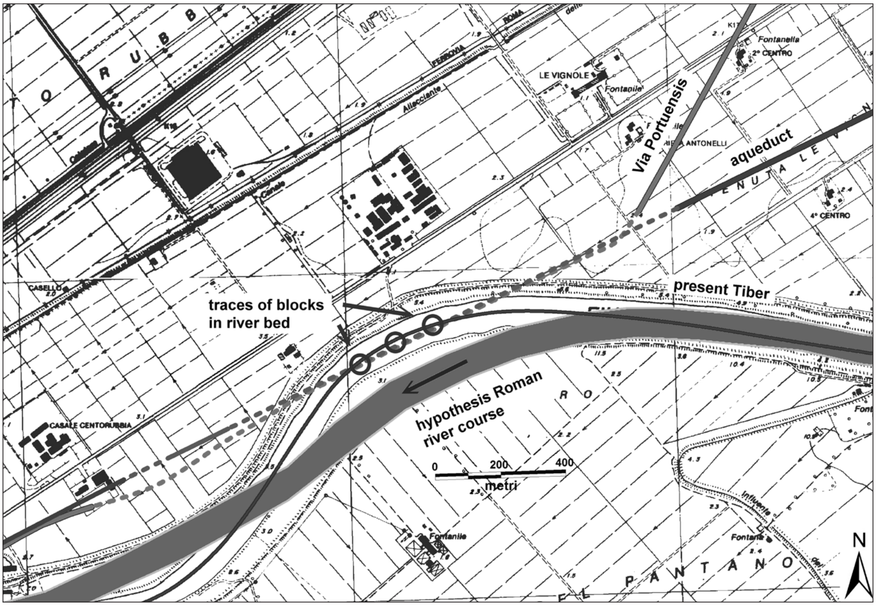

Fig. 6 - Hypothesis on the Tiber course in roman times in the area of the *Fiera di Roma*; solid lines, ascertained paths of the road and aqueduct, dashed lines hypotheses.

It is interesting to notice that lateral mobility of river courses could be estrange to the traditional archaeological paradigma. Wilkinson - Stevens 2003 state that "it was still common well into the twentieth century for archaeologists to think that topographic changes were not relevant in their studies". "However, the major lesson of earth science studies over the past 200 years is that the earth surface is a dynamic place even over very short time scales."[67]

The Tiber inundations that occurred in the Roman period are well known[68]: about thirty exceptional floods have been recorded. Traces of flooding from the Roman period have been recognized in many layer sets, but rarely dated like in the following cases: in the *Fiume Morto* area to the 1st century A.D.[69], in the *Magliana* area probably to the years 15 or 16 A.D.[70]. At the beginning of the 5th century, *Rutilius*

[65] The blocks on the Tiber bottom were reported by Professor Marcello Bernabini and Eng. Luciana Orlando, Faculty of Engineering, University of Rome "La Sapienza" - unpublished data.

[66] Morelli *et al.* 2011a.

[67] Wilkinson - Stevens 2003, p. 48.

[68] Le Gall 2005; Bersani - Bencivenga 2001.

[69] Arnoldus-Huyzendveld - Pellegrino 2000.

[70] Catalli *et al.* 1995.

Namatianus[71] describes how the final stretch of the Tiber is impractical due to the sandbanks, so that one must follow the channel of Trajan to reach the sea. Evidently, sediment load and inundation frequency are related.

The Middle Ages

There are relatively few reports of Tiber flooding between 500 and 1100 A.D., on average only one per century. The flood of 589 was recorded in many other parts of Italy, so it must have been substantial. Later floods are memorized in particular through inscriptions on stone slabs preserved in several locations of Rome[72].

The Renaissance and modern age

In this period, simultaneous with the strong progradation of the coastline, the Tiber valley was further raised by flood sediments. Specifically, the severe flood of 1557 has caused the inaccessibility of the Via Portuense, covering it with several decimetres of river sediment.

The 16th century is the period of the Tiber "unleashed", with more than six exceptional floods[73]. Those who recorded the highest levels ever reached by the Tiber in Rome occurred in the years 1530, 1557 and 1598. The flood of 1557 has also been reported in other parts of Italy: the Arno in Florence, the Ombrone near Grosseto. Until 1557, the Tiber river near Ostia followed a tight meander, enclosing an area belonging in Roman times structurally to the city of Ostia, and known as *Trastevere Ostiensis*. The flood of 1557 has cut off this Tiber bend, leaving behind an imprint of the old course as a characteristic "oxbow" lake which still existed more than 100 years ago[74], and also an isolated area, that since then carried the name *Fiume Morto* (Dead River). This event has completely isolated the castle of Ostia, built 60 years earlier, from its strategic position along the river mouth. The abandoned *Fiume Morto* is clearly visible on a bird's eye fresco in the Vatican Museum of the area of Portus, painted in 1582 by Andrea Danti[75] and on an aerial photograph taken from a balloon in 1911[76]. During the excavation of a section of the inner edge of the abandoned meander, traces of the lateral meander displacement during the floods of 1530 and 1557 were recognized[77].

In the 17th century there have been still five exceptional floods, but the effects were less disastrous than from those of the previous century. In the century thereafter, no major inundations occurred. Most floods were recorded in Rome, but only of the event of 1530 we have an eyewitness account from the coastal area, because at the time the papal court has made the trip from Ostia to Rome[78].

[71] Fo 1992.

[72] Di Martino - Belati 1980; Bersani - Bencivenga 2001.

[73] Di Martino - Belati 1980.

[74] Amenduni 1884.

[75] On indication of his brother Egnazio (reproduced in Testaguzza 1970).

[76] Shepherd 2006.

[77] Also was recognized a lateral displacement of several meters resulting from a flood of the first century A.D. Today one may still be observe some traces of the former bend on the territory, e.g. in Via Stefano Morcelli in Ostia Antica, which near the *Casalone del Sale* crosses visibly the depression left behind by the abandoned Tiber meander; Arnoldus-Huyzendveld - Pellegrino 2000

[78] Di Martino - Belati 1980.

It seems that, on the whole, in this period there has been a change in the equilibrium of the river-sea system. The well-known change of land use inland[79] may have been one of the triggering factors: ever steeper slopes have been cleared, causing increase of erosion, which, in turn, caused an increase in solid charge of the rivers, and thus of flood frequency and intensity, the growth of the valley level and the progradation of the coast line. A contributory cause of the flood intensity would have been the presence of obstacles in the river in Rome (occluded passages of bridges, floating mills). The increase in amplitude of the meanders can be seen as another consequence of the changed environmental balance. A contribution to the changed river balance may have been given by the start of the colder and rainier climate phase peaking in the 16th - 19th centuries.

5) The centre of Rome

The modern city of Rome rests upon layers of anthropogenic debris, which over the ancient river incisions may reach a depth of more than 20 m[80]. Nevertheless, within the city one can still grasp the former morphology: many modern streets follow the direction of ancient valleys whereas the original hills still rise over the Tiber valley. The morphology has been altered intensively already in Roman times, e.g. the adjustment of the western slope of the Quirinal hill to host the Forum of Trajan. In the first half of the 20th century, a part of the Velia hill was brutally exported for the construction of the Via dell'Impero.

For a concise overview of the geological evolution of the area of Rome, see Funiciello et al. 1995. Two volcanic centres are located nearby, one to the south (Colli Albani) and one to the north (Sabatino volcano), with the Tiber running in the depression separating them. The seven hills of Rome (Quirinal, Viminal, Esquiline, Caelian, Capitoline, Palatine and Aventine) originated from a large plateau extending from the Colli Albani volcanic edifice, which was formed during explosive eruptions that occurred sporadically between 550.000 and 350.000 years ago. Most volcanic layers were deposited more or less horizontally, but some of them (lavas and ignimbrites) have an linear extension.

The periphery of the tuff plateau has been "carved" by the natural erosive forces of the tributaries of the Tiber, to form small, isolated hills with steep slopes, not higher than 60 meters above sea level. The tuff deposits overlay sedimentary rocks of Pleistocene age, which are often exposed at the base of the hill slopes[81]. The last and deepest incision of the valleys took place during the last low sea level stand of the glacial peak of ca. 20.000 years ago.

As for the general form of the "seven hills" of Rome, one notes that only the Aventine, Palatine and Capitol are surrounded on all sides by high and steep slopes, whereas the others (Quirinal, Viminal, Esquiline and Caelian) are surrounded only on three sides by slopes, while the fourth side blends without gradients into the large volcanic plateau east of Rome.

The insight on the original geology and landform of the centre of Rome has developed stepwise with the ongoing excavations and drillings, since most of the original morphology is masked by constructions, debris layers, flood deposits and quarries. Due to the difficulty of observing the geological strata, only in 1934 De Angelis D'Ossat could state that the "seven hills of Rome" were originally connected in a single plain, which subsequently (after uplifting) was incised by river erosion.

79 Sereni 1987.

80 Ventriglia 1971.

81 Heiken *et al.* 2005.

An exhaustive overview of the history of geological mapping in and around Rome is given in Funiciello - Rosa 1995. In the last decades, several detailed geological maps of the centre of Rome were published, by Ventriglia 1971, Funiciello 1995, Ventriglia 2002 and Funiciello *et al.* 2008. A first geomorphological map of Rome, with explanatory notes, was composed by Brocchi 1820. It represents the "physical state of the soil" before human interventions, and has turned out to be basically correct. Interesting is the presence of a large indent along the northern side of the Caelian hill, which is not easy to detect from the modern urban morphology. A small part of this map is reproduced in **fig. 7**, turned around 180° to enhance comparison with the other figures.

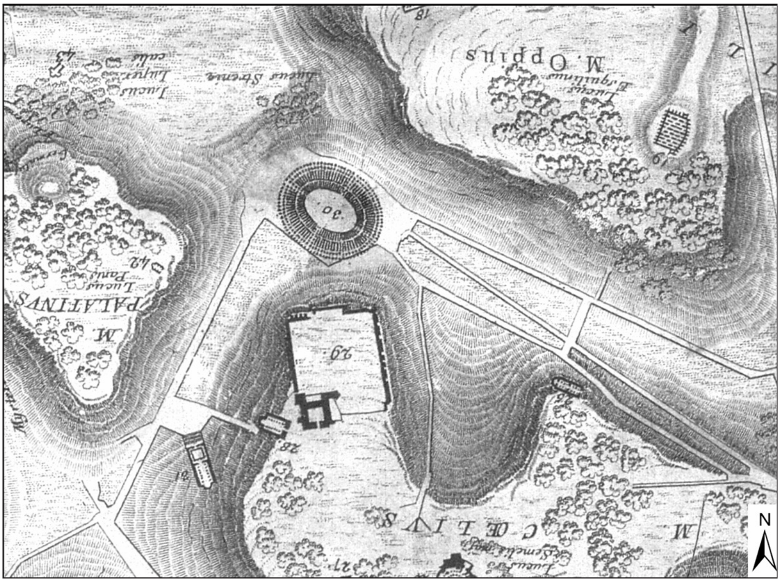

Fig. 7 - Cut out of the first geomorphological map of Rome, Brocchi 1820: "*Carta fisica del suolo di Roma nei primi tempi della fondazione di questa città*", covering the Oppian hills and the Colosseum valley. The north/south orientation is inverted with respect to the original map.

Next I will shortly present two studies aimed at the reconstruction of the original morphology of the centre of Rome, specifically the Oppian hill and the Colosseum valley.

The Oppian hill

The western part of the Esquiline hill is divided into Fagutal, Oppio and Cispio. Also the "Carinae" belong to this relief, forming the connection with the Velia. The top of the Fagutal reaches a level of approx. 45 m. a.s.l. The geological and morphological reconstruction presented here, concerning the pre-Trajan period, pertains to the entire western side of the Esquiline.

During the archaeological excavations of the Oppian hill, part of a town quarter of the 1st century A.D. was encountered, gathered around an open space (probably marked on the north side by a road following an east-west direction) in front of the building of the "*Città dipinta*"[82]. The area is located in the central part of the hill, but obviously at too low an altitude (Roman street level ca. 31 m a.s.l.) to correspond to a position on the summit (confront the altitudes on **fig. 8**). Excluding, for archaeological reasons, in this position a deep artificial cut, the hypothesis was advanced whether the quarter could have been laid out in a hitherto unknown valley of

82 Volpe 2000; Volpe 2010.

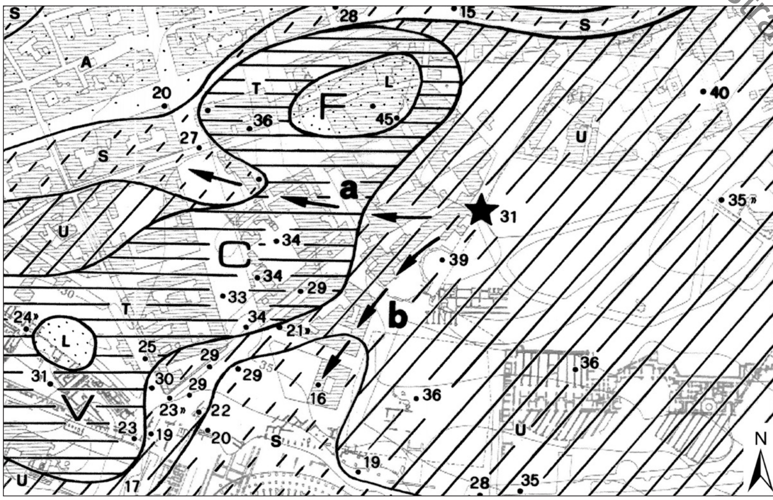

Fig. 8 - Geological and morphological map of the Oppian hill. With a dot are indicated the data points, with the maximum altitude reached by the geological layers or by the base level of the archaeological structures; if the geological stratigraphy is deeply notched, the number is followed by the symbol “>>”. The location of the pre-Trajanic open space and buildings is indicated by a star. Legend: **S**, the prevolcanic complex of clay, sand and pebbles of the Sicilian and the *formazione fluvio-palustre* (Ventriglia 1971) = CIL (Funiciello - Giordano 2008); **U**, *tufi antic*hi = PTI; **T**, tufo lionato = VSN1; **L**, the postvolcanic *formazione fluvio-lacustre* = AEL; **a**, reconstructed natural outflow towards the Spinon river; **b**, reconstructed natural outflow towards the Colosseum valley; **V**, Velia; **C**, Carinae; **F**, Fagutal.

the drainage network of the centre of Rome, which was then artificially filled in for the construction of the Baths of Trajan[83].

The published geological maps agree broadly on the structure of the hill, although significant differences occur in detail, in particular, with regard to the extension of the *tufo lionato*[84] and the *formazione fluvio-lacustre*[85]. For a detailed reconstruction it was essential to collect the maximum altitudes of both the geological units and the archaeological remains of Roman age. The map highlights the presence of two residues of the *formazione fluvio-lacustre*: one at the top of the Velia and one on the Fagutal. The underlying *tufo lionato* was mapped as a continuing extension between Velia and Fagutal.

New are the two reconstructed depressions in the tuff cover: one along the southern side of the Oppio, leading towards the Colosseum valley, and the other along the north-western side, towards the Spinon valley. Both should correspond to valleys cutting the margins of the hill complex composed of the soft *formazione fluvio-palustre*[86]. It was not possible to establish to which of the two identified valleys the pre-Trajanic urban area could have been connected, or even if the valleys could have been united in their upper ends to form a morphological saddle splitting the surface of the Oppian hill.

[83] Arnoldus-Huyzendveld 2000.

[84] Indicated with the code “VSN1” on the geological map of Funiciello - Giordano 2008.

[85] Term used by Ventriglia 1971; code “AEL” of Funiciello - Giordano 2008.

[86] Term used by Ventriglia 1971; code “CIL” of Funiciello - Giordano 2008.

The Colosseum valley

The hills around the Colosseum depression are composed of pre-volcanic, volcanic and post-volcanic layers[87]. In Arnoldus-Huyzendveld - Panella 1996, the environmental units of the Colosseum valley for the pre-urban period have been identified by collecting all data available from drillings, excavations and geological maps.

During the last glacial peak, the valley was deeply incised due to the lowering of the base level of the drainage network. The incision often reached the pre-volcanic sediments, so in many places the volcanic layers are missing. In the western and northern parts, the Colosseum valley was not so deeply dissected as in the centre and the south, where the incision arrived locally below the present sea level, i.e. at least 21-23 meters below modern street level.

During the post-glacial sea level rise, between 17.000 and 6.000 years ago, the valley was filled in with lacustrine sediments. At the end of this phase, the surface of the loamy and clayey Holocene infill of the "floodplain" of the Colosseum depression must have been stagnant and rather flat, with a top level at 14-15 m. a.s.l. This fill did not reach the whole depression, but was limited to the central and southern parts. To the north and the west, instead, the top of the older (Pleistocene) formations rise gradually from below the Holocene infill, reaching the surface near the boundary with the surrounding hills (Palatine, Velia, Oppio / Esquiline). Environmental conditions in pre-urban times must have been more favourable there compared to the "floodplain", since the morphology was slightly sloping and the surface composed of more permeable sediments. The boundary between this environment and the former must have followed a curved line, crossing the Colosseum (eccentric to the north), then the *Meta Sudans* and finally the centre of the Arch of Constantine; see also Funiciello *et al.* 1995.

This area was dissected by the natural drainage network. The main river, the "Fosso Labicano", followed first below the modern Via Labicana a narrow valley, which gained width in the Colosseum area, where the river ran along the southern side of the depression. Then it exhibited a sharp turn to the south before flowing into the narrow valley between the Palatine and Caelian hills, and finally joined a tributary of the Tiber, the "Nodinus", in the valley of the *Circus Maximus*. In the period before the urbanization, the surface was dissected not only by the *Fosso Labicano*, but also by at least two minor tributaries, which were identified by means of finalized drillings, see **fig. 9**. First a tributary that came from the north and passed along the later *Meta Sudans* (drilling M1[88]). Second a small, probably intermittent, tributary originating near the morphological saddle of the Arch of Titus (drilling S1-1996 west of the *Meta Sudans*), which was also identified to the south of the *Meta Sudans* in the 2001 drillings[89].

The major insights from the collected data have been that the Holocene infill of the Colosseum valley reached a top level of 14-15 m a.s.l., and was then dissected by the natural drainage network at least down to 9.34 m a.s.l. These valleys were partially accessible, since around 700 B.C. a road was laid out along the westernmost one[90]. In geomorphological terms: after the closure of the post-glacial sea level rise / valley infill, the drainage system has been "rejuvenated". Therefore, at the time of the foundation of Rome, the top of the Holocene infill must have been a kind of fluvial terrace, i.e. a dissected floodplain, and therefore better drained than the hitherto presumed stagnant valley floor with groundwater close to the surface.

[87] See Funiciello - Giordano 2008, sheet 374100; Arnoldus-Huyzendveld 2007b.

[88] Arnoldus-Huyzendveld - Panella 1996.

[89] See Panella - Zeggio 2004; Panella 2001.

[90] Zeggio 2005; Zeggio - Pardini 2007.

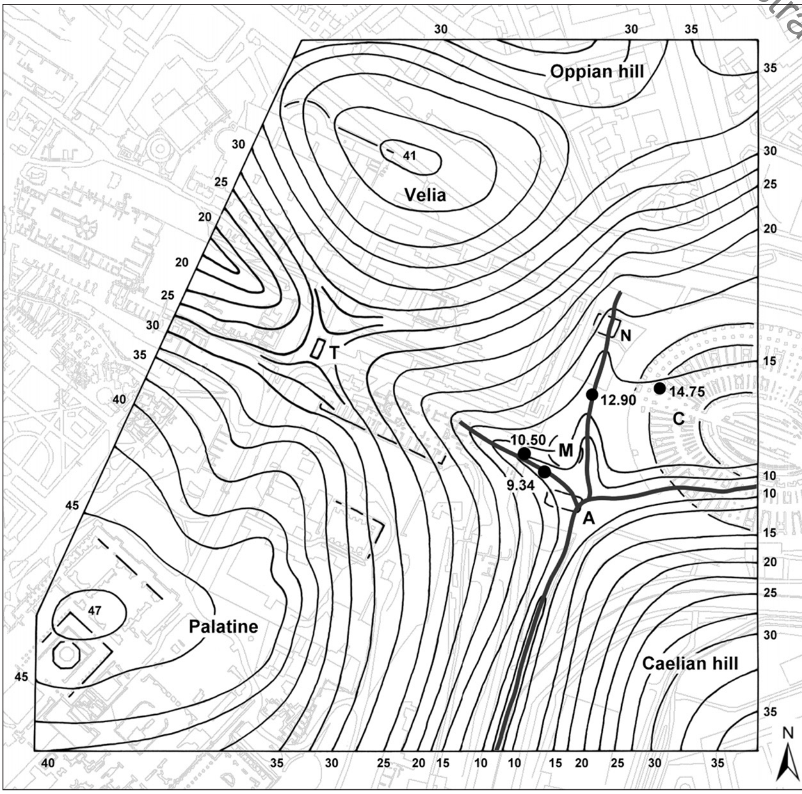

Fig. 9 - Reconstruction of the pre-urban morphology of the Colosseum valley and surrounding hills, with contour lines each 2.5 meters. **T**, Arch of Titus; **N**, base of the statue of Nero; **M**, Meta Sudans; **C**, Colosseum; **A**, Arch of Constantine. The dots refer to the drillings mentioned in the text, the numbers indicate the top level of the geological layers, which were the pre-volcanic *formazione fluvio-palustre* for the three drillings to the west, and the Holocene infill for the one to the east. In dark grey is traced the reconstruction of the pre-urban drainage system.

It is highly probable that before the full urbanization of the area, the valley floor became stagnant (again), due to the minor rise of the base level of drainage[91], the general increase in erosion (testified by the strong and frequent inundations[92]) and the urbanization itself.

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[91] Induced by the known sea level rise in the Republican and Imperial period; Leoni - Dai Pra 1997; Goiran *et al.* 2009.

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