Geological Society of America
Special Paper 408
2006

Chapter 6
A case study—Ancient Rome was built with volcanic stone from the Roman land

Donatella de Rita
Ciriaco Giampaolo
Dipartimento di Scienze Geologiche, Universita degli Studi di Roma–TRE, Largo San Leonardo Murialdo 1, 00146 Roma, Italy

RECENT GEOLOGICAL EVOLUTION OF THE ROMAN REGION

The Roman territorial framework is mostly the product of recent geodynamic processes affecting the western Mediterranean area. Rome's foundations are mostly the products of the Quaternary explosive eruptions in two volcanic fields, the Sabatini volcanic field (northwest), and the Colli Albani (Alban Hills) volcanic district (southeast). Volcanoes in both volcanic fields emplaced sequences of pyroclastic flows, the deposits of which formed plateaus deeply excavated by postglacial erosional processes.

About 1 million years ago, the Roman land was still submerged under the Pliocene sea; outcrops of clay and sandy-clay sedimentary rocks from this period (3.40–1.79 Ma) make up the highest part of the city, including the Vatican, Janiculum, and Monte Mario hills. These sediments were deposited in basins that developed as a consequence of the Apenninic orogeny and the subsequent opening of the Tyrrhenian Sea (Funiciello, 1995). They were uplifted to the present position by tectonic processes concurrent with volcanism. The Pliocene claystones, with a thickness of more than 800 m, constitute the bedrock of the Roman area; their tectonic and stratigraphic relationship with the younger volcanic sediments have strongly affected the urban development of Rome, and they are responsible for some of the problems affecting the land stability of entire sectors of the city.

The Roman area remained submerged until 0.88 Ma, but during this time interval, variations of sea level and tectonic processes created a setting for shallow-water sedimentation. Three main marine cycles have been identified during this time interval. The first, from 3.40 to 1.79 Ma, refers to the deposition of clay-marly sediments ("Marne del Vaticano;" Marra et al., 1995); the second to sandy and sandy-clay sediments ("Unità di Monte Mario;" Marra, 1993); and the third to the deposition of infralittoral clays ("Unità di Monte delle Piche;" Marra, 1994). The second and the third marine cycles occurred between 1.79 and 0.88 Ma and are separated by continental sediments that indicate a period of emergence (Funiciello, 1995).

At ca. 0.88 Ma, continental sedimentary conditions were dominant in the Roman area (Funiciello et al., 1992). This was an important step in the recent evolution of the Roman land, because from that time, the area was shaped by erosional and depositional processes in a manner similar to that at present. As an example, the course of the Tiber River was established. The previous Tiber River was east of its present course and was shifted by the effects of the extensional tectonism, which affected the coastal area of Latium, by glacio-eustatic variations of sea level, and by the emplacement of the oldest pyroclastic flows erupted from the Sabatini and the Colli Albani volcanic fields. The volcanic activity of these two districts began ca. 0.6 Ma and emplaced several sequences of pyroclastic flows, most of which reached the Roman area and formed large flat, plateaus.

Finally, fluvial erosion processes during the Würm glacial period eroded deep valleys into the plateaus. This is the origin of the famous seven hills of Rome.

The oldest part of the city was at the foot of two of these hills, the Campidoglio (Capitoline) and the Palatino (Palatine), next to the Isola Tiberina, in a place with easy access to the Tiber for commercial markets. Eventually the Romans moved to the hilltops for security and better climatic conditions. The geological setting was the determining factor for rapid development of Rome and the influence that made Rome one of the most famous cultures of the world.

de Rita, D., and Giampaolo, C., 2006, A case study—Ancient Rome was built with volcanic stone from the Roman land, *in* Heiken, G., ed., Tuffs—Their properties, uses, hydrology, and resources: Geological Society of America Special Paper 408, p. 127–131, doi: 10.1130/2006.2408(06). For permission to copy, contact editing@geosociety.org.

VOLCANIC STONE USED FOR BUILDING FROM THE SABATINI AND COLLI ALBANI VOLCANIC FIELDS

Much of Rome's geologic foundation consists of tuffs (ignimbrites) from the Colli Albani volcanic field, with lesser volumes of ignimbrites from the Sabatini volcanic field in the northwestern part of the present city. The first tuffs in the Roman area were fall deposits, partially reworked, from the Sacrofano volcano (Sabatini volcanic district). They crop out in the northwestern edge of Rome. The first thick tuff deposit useful in construction is the "tufo pisolitico," which is the oldest pyroclastic flow deposit erupted from the central volcano (Tuscolano-Artemisio) of the Colli Albani district (de Rita et al., 1988). The tufo pisolitico was not deposited as a single unit but as a sequence of pyroclastic flows erupted during different cycles of the Tuscolano-Artemisio caldera complex (0.6 Ma) (de Rita et al., 1988, 1995, 2002; Rosa, 1995). These eruption cycles were separated by long periods of quiescence, as evidenced by the presence of paleosols. During the eruptions, there were magma-water interactions as evidenced by: (1) the fine grain size of the units, (2) the presence of accretionary lapilli (hence name of "pisolitico"), (3) the presence of trunks of trees or of their marks, (4) cross-bedded stratification of the pumice layers, and (5) zeolitic alteration of the glassy matrix (chabazite and phillipsite; Fornaseri et al., 1963). The eruptions produced moderate volumes of pyroclastic flows, which flowed as far as the Tiber valley with resulting thicknesses of 5–10 m (de Rita et al., 1995)

Concurrent with the Tuscolano-Artemisio activity, very similar pyroclastic flows were erupted in the Sabatini volcanic district and reached the northwestern part of what is now Rome. These are the yellow "Via Tiberina tuff," which is a pyroclastic flow deposit from the Sacrofano volcano, located 30 km north of Rome, in the eastern sector of the Sabatini volcanic field (de Rita et al., 1993). The Sacrofano eruption, dated at ca. 500,000 yr B.P., likely involved some interaction of water with rising magma. The eruption produced at least seven units, which covered a surface of more than 400 km^2 and had a total volume of ~8 km^3 (Cioni, 1993; de Rita et al., 1993; Rosa, 1995). The Sacrofano pyroclastic flows caused a significant impact on the surrounding environment, such as the obstruction of the Tevere (Tiber) River near Monte Soratte, where the valley was shifted to the east, approximately coincident with the present course of the river (Alvarez, 1972, 1973; Rosa, 1995). After the emplacement of these units, there was a period of quiescence during which the Roman area was affected by tectonism and intense local fluid circulation depositing travertine and altered sands. Probably this fluid circulation and alteration was facilitated by the presence of N-S faults that were partly responsible for the deviation of the river's course (Funiciello, 1995).

After that, with a cycles of ~100 k.y. (de Rita et al., 1993), a sequence of pyroclastic flows from the Colli Albani volcanic district reached Rome. The oldest of these units is called "pozzolane rosse" or "II colata piroclastica del Tuscolano-Artemisio" and represents the most important explosive unit during the history of the volcanic field, with an eruption volume of more than 34 km^3 (de Rita et al., 1988). The deposit consists of reddish-pinkish scorias in a loose scoriaceous matrix with free crystals of leucite, pyroxene, and biotite and thermo-metamorphosed sedimentary lithic clasts. Pipe structures (fossil fumaroles) are common, even far from the vent localities, e.g., those inside the present city area (more than 20 km from the source area). This unit, together with the younger "pozzolane nere," which is lithologically very similar, has been quarried since early Roman time and used to make concrete. The "pozzolane rosse" and the "pozzolane nere" deposits are separated by reworked tuffs and alluvial sediments, indicating a quiescent period between the two eruptions.

Finally, at ca. 0.4 Ma, a complex eruption in the Colli Albani deposited two more important flow units, the "Lionato tuff" and the "Villa Senni tuff" (336,000 yr B.P.), which concluded the activity of the Tuscolano-Artemisio volcano, causing the collapse of the central part of the edifice (de Rita et al., 1988; Funiciello et al., 1995). Both of these pyroclastic flow units reached the area of Rome. The lithological and depositional characteristics of the "tufo lionato" indicate that there was sustained but limited water-magma interaction during eruption, and that its high degree of lithification was caused by zeolitic alteration of the glassy matrix (herschelite, chabazite, and phillipsite; Fornaseri et al., 1963).

After 336,000 yr B.P., the area occupied by Rome was not again covered by pyroclastic deposits because the volcanic activity of the Colli Albani and of the Sabatini volcanic districts began to wane and smaller-scale explosive activity affected only the areas of the volcanic fields. Southeastern Rome, close to the tomb of Cecilia Metella, was reached by a large lava flow ("Colata di Capo di Bove"). This lava flow erupted ~280,000 yr B.P. from the Le Faete edifice in the central area of the Colli Albani volcanic district (Bernardi et al., 1982; de Rita et al., 1988). The lava was channeled in a valley nearly radial from the central volcanic edifice and flowed 20 km to the edge of the area on which Rome was eventually built. The flow was named after the ox head perched on the tomb of Cecilia Metella, which was built at the distal end of the flow. Cecilite was the previous scientific name (after Cordier, 1868) of this aphyric variety of melilite leucitite. The highly undersaturated chemistry of the lava permitted it to flow a great distance and to form a very smooth and flat upper surface, which was directly exploited by the Romans for the foundation of the ancient Appian Way road.

The deposits described herein were used by the Romans for construction materials; loose pozzolan was used in the preparation of cement, and the lithified nonwelded ignimbrite was used as building blocks. But Romans, during the first part of the Imperial period, also used building blocks that were quarried far from the city. The most common tuffs used for building blocks are famous, called "peperino," which refers to two different lithotypes: the lapis Gabinus and the lapis Albanus. Both of these deposits are the result of violent hydromagmatic eruptions, the former related to the Gabii or Castiglione crater and the later related to the Albano crater. The Castiglione and Albano craters, on the slopes of the

$12\ (OH)^{-}$

Colli Albani, were formed during the most recent hydromagmatic activity of the Colli Albani volcanic district (de Rita et al., 1988, 1995). This region was still active ca. 200,000 yr B.P. and also very recently: in particular lapis Albanus came from a detrital flow deposit erupted from the Albano crater during its final phase, at least 20,000 yr ago (Mercier, 1993). The two deposits have very similar lithologies, and, as their principal characteristic, a high level of lithification because of zeolites in the rock matrix derived from the alteration of volcanic glass. Both rocks have chabazite, phillipsite, and harmotome in the zeolitic matrix. These rocks were used everywhere in Rome during the Imperial epoch. Late in the Imperial period, another stone, named sperone, was used for the construction of the most representative monument of the epoch: the Coliseum. Sperone is a welded scoria deposit formed by lava fountains erupted from the fractures that controlled the collapse of the central part of the Colli Albani volcano less than 336,000 yr ago (de Rita et al., 1988, 1995). These rocks compose the entire northern border of the Tuscolano-Artemisio belt and are located at an elevation between 200 and 600 m.

THE USE OF THE BUILDING STONES IN THE DEVELOPMENT OF ROME

An ancient morphological map clearly shows that Rome developed mainly on the southeastern margin of the present city and that the seven hills were all located on the east side of the Tiber valley. This part of Roman territory was underlain by volcanic deposits from the Colli Albani district, which overlay clay sediments of Pliocene-Pleistocene age. The seven hills were isolated by deeply eroded valleys occupied by river courses flowing directly into the Tiber. The sedimentary substratum is exposed in deeply eroded valleys; many of these outcrops are obscured because of urbanization. During the Archaic period, common erosional processes affecting the sides of the valleys of the seven hills produced large erosion blocks that could be used for many purposes, including building stones, defensive walls, or shelters. It is then not surprising that the oldest structures of the city were constructed of tuff blocks excavated in areas within the city walls.

The Tufo Pisolitico or Cappellaccio

During the Archaic period the most-used stone was the cappellaccio, or tufo pisolitico, from the oldest pyroclastic flows erupted from Tuscolano-Artemisio volcano of the Colli Albani district. The name "cappellaccio" has been improperly used to indicate different tuffs; quarrymen used this name for any friable material, which was in some places weathered to soil without specific reference to a particular rock type or stratigraphic unit. This is probably the reason for the confusion, especially in the archaeological literature, about this name and the stratigraphic units. In some cases, the same name refers to building stones of the litoide, or lionato pyroclastic flow unit, which is another deposit that erupted from the central area of the Colli Albani volcanic field in a later eruptive cycle and is present in some monuments of later periods. For these reasons, we prefer the name of "tufo pisolitico," and we propose to drop the "cappellaccio" term. During the Archaic period, Romans used mainly blocks from this tuff for the infrastructure of the city. Although the physical-mechanical characteristics of the pisolitic tuff are definitely inferior to those of subsequently used building stones, the ease of excavation and limited amount of transport made this material an efficient choice during the Archaic period.

The tuff units are thickest in the paleovalleys, and, in some cases, totally filled the valleys (de Rita et al., 1992). Tuff-filled paleovalleys are still visible in outcrops near the historical center of Rome. For example, in the area of the Campidoglio (Capitoline Hill), outcrops of the tufo pisolitico and the upper litoide allow reconstruction of the recent geological history of this area. Here, the relationships between the outcrops suggest that the pisolitico filled a paleovalley located approximately in the ruins of the Foro di Cesare (Forum of the Caesars). The valley was totally filled with tuff deposits, and the river course was shifted toward the present Via dei Fori Imperiali. After a long period (from 0.5 to 0.3 Ma), when no other pyroclastic flows reached the Campidoglio (Capitoline Hill), the litoide pyroclastic flow was deposited, filling the new valley. The pisolitico and the upper litoide ignimbrites were isolated and are now visible in the cliffs that surround the Capitoline Hill.

Many examples of the tufo pisolitico blocks are still visible in Rome, but probably the best example is the Mura Serviane (Servian Walls), which was the first defensive wall around Rome. Some of the quarries that supplied the building stone for the walls are still recognizable in archaeological excavations below Termini railway station.

Many other works of the Archaic period, preserved near the Foro di Cesare (Forum of the Caesars), were constructed with this stone; for example, an Archaic cistern was excavated in the tuff, and its walls were lined with small blocks of the same material (opus quadratum; Lugli 1957). In addition, the earliest hut village at the top of the Palatino (Palatine) hill was constructed from pisolitic tuff.

The Tufo Giallo Della Via Tiberina

With improving technological ability and an expanding territory, small blocks of tuff from outside the city walls began to be used in Rome. One of the first rock types that was substituted for the pisolitic tuff was the yellow Via Tiberina tuff, which crops out north of Rome at Grotta Oscura (the Grotta Oscura tuff; Coarelli, 1974, and bibliography therein) along the Via Tiberina.

Because the physical-mechanical characteristics of the Via Tiberina tuff are significantly better than those of the pisolitic tuff (Nappi et al., 1979), the Via Tiberina tuff was commonly used as an ornamental stone or as a building stone for houses. It is important to note that the use of this tuff became common only after the Roman conquest of Veio, the Etruscan city that dominated the region rich in this natural resource (Coarelli, 1974). The use of this tuff in Roman buildings during the entire Roman period is still well documented, as the monument called Ara di Cesare in the Caesar Forum, but the first use of this tuff was for the restoration of the Servian Walls. These walls were largely restored with this stone after 396 A.D., following the damage caused to the original wall by the Gaelic invasion. Where presently visible, the wall is constructed of rows of 59-cm-high blocks, alternatively placed horizontally and vertically, thereby creating a structure that is up to 10 m high and sometimes greater than 4 m thick (Coarelli, 1974, and bibliography therein). The restoration took place in various locations simultaneously, as testified by the reconstructed rock junctions that do not always fit together perfectly. The total length of the wall has been calculated at around 11 km, encompassing a surface of 426 hectares, and thus enclosing the largest city on the Italian peninsula.

The Capo di Bove Lava Flow (Melilite Leucitite)

The Roman ability to obtain building stones with optimal physical-mechanical characteristics was great during the Republican Period (end of the fourth and third centuries B.C.), as demonstrated by the extensive use of lava blocks for paving stone. The Via Appia, a consular road between Rome and the Colli Albani area, was built during this period directly on the upper surface of the Capo di Bove lava flow. The use of lava blocks for paving stone became common, and many examples of lava roads are still visible inside and outside of the city. Lava blocks are still used for paving city streets. At the present, these small lava blocks are called Sanpietrini and have the shape of a truncated square pyramid.

The Peperino and the Lionato Tuff

The most interesting period relative to the goals of this study is Imperial Rome, a time span that marked the beginning of a long period of prosperity for Roman civilization. During this time, Rome greatly extended its dominion across the entire Mediterranean area, and as a result, the Romans introduced many "exotic" stones for ornamentation and construction of both their public and private buildings. However, many of these buildings still used local building stones for their foundations and internal structures. The higher technological ability allowed a more rigorous selection of lithotypes. The monuments of this epoch used three principal types of volcanic building stone from the Roman area: the lionato (or litoide), the peperino, and the sperone tuffs.

The most significant examples of these tuff blocks are visible in the Imperial Forums. In the most ancient of these forums, that of Caesar, the Temple of Antonino and Faustina was constructed in part with lapis Albanus. In contrast, the Forum of Augustus was largely created using lapis Gabinus and the lionato tuff (or litoide), with the latter unit also being used for the forum brick work and as a base for the temple of Marte Ultore. In addition, lapis Gabinus forms the foundation and walls of the Tabularium building at Campidoglio. The contemporaneous use of the lapis Gabinus and the lionato tuff suggests that the two rock types were from adjacent quarries in the volcanic field. In fact, the lapis Gabinus quarries were located along the border of the Castiglione crater (in the northern sector of the district near the Aniene River), not far from the lionato tuff quarries located along Via Tiburtina. It is highly probable that the Aniene River was the most direct route for transporting these two rock types from the countryside into the city. The lionato stone used during the Roman epoch was most likely excavated in the Settecamini area (tufo dell'Aniene); other quarries were located closer to the city at the foot of the Monteverde hill (tufo di Monteverde). The tuff quarried at this last locality was used to a limited extent, probably because of its low quality and also because the quarries were located in a dangerous locality. In fact, the hill of Monteverde, composed of the lionato tuff directly overlying clay and alluvial sediments, is continuously subject to slides. The Roman quarries of the lapis Albanus were located along the northern borders of the Albano crater, near the city of the same name, or in the valley below the town of Marino. The lapis Albanus differs from the lapis Gabinus because it was excavated until the end of the most recent epoch and is still quarried to a small extent today.

The Sperone Tuff

Finally, the monument that represents the most important symbol of Imperial Rome is the Coliseum. The structural base of the Coliseum was built with large blocks of travertine and sperone, a rock type that was used infrequently. Although no definitive Roman quarries have been found, it is highly probable that the original sources were located near the present towns of Grottaferrata and Frascati in the Colli Albani and close to the principal transportation routes to Rome. These quarries have been obliterated by the growth of these two cities. The densely welded scoria (sperone) has optimum physical and mechanical properties, and it is likely that its use was limited only because of the difficult access and transportation to and from the quarries. All the depositional and lithological characteristics of the sperone can be clearly observed in the Tuscolo area, one of more impressive localities related to the history of Rome in the Colli Albani volcanic field. The perfectly preserved remains of a Roman village and a small theater built entirely with the sperone are still visible at this location.

After the Imperial epoch, the study of volcanic rocks used as building stones in Rome becomes almost impossible, as the Romans began to use manufactured bricks as their most important construction materials. Furthermore, they commonly reused the stones of more ancient monuments that were in ruins, deteriorated with age, or demolished by subsequent emperors. The borders and power of the Roman Empire were by this point so vast that the importation and use of stone from around the world were common. Beyond this point, the link between man and his environment extended to the vast regions that reflected the power of Rome.

CONCLUDING REMARKS

The use of volcanic stone as a construction material served the needs through time of the evolving civilization, representing the inseparable bond between man and nature. In this chapter, we identify seven important volcanic building stones that were used for the construction of many of the important monuments in ancient Rome. The types of stones used by the Romans to build, protect, and beautify the city closely followed their society's technological development. With time, rocks with increasingly better physical-mechanical characteristics were chosen and excavated at increasingly longer distances from building sites. Each monument contains the history of a period or of a fundamental phase of the evolution of Roman civilization.

The rock types used for construction show comparable physical-mechanical characteristics (Penta, 1956); all have an elevated level of lithification because of zeolites in the rock matrix (minerals which formed during alteration of the glassy matrix). Furthermore, all units were produced by eruptions that involved the interaction of rising magma with groundwater. These observations become extremely interesting in the research and characterization of the building stones and underline the necessity of mankind to clearly understand his environment in order to obtain the best benefits.

REFERENCES CITED

Alvarez, W., 1972, The Treia valley north of Rome: Volcanic stratigraphy, topographic evolution and geological influences on human settlement: Geologica Romana, v. 11, p. 153–176.

Alvarez, W., 1973, Ancient course of the Tiber river near Rome: An introduction to the middle Pleistocene volcanic stratigraphy of central Italy: Geological Society of America Bulletin, v. 84, p. 749–758, doi: 10.1130/0016-7606(1973)84<749:ACOTTR>2.0.CO;2.

Bernardi, A., de Rita, D., Funiciello, R., Innocenti, F., and Villa, M., 1982, Geology and structural evolution of Alban Hills volcanic complex, Latium, Italy: Abstract of the Workshop on Explosive Volcanism, San Martino al Cimino, Italy: Consiglio Nazionale delle Ricerche, Italia and National Science Foundation, USA.

Cioni, R., 1993, Il complesso di Bolsena e il vulcanismo alcalino-potassico del lazio settentrionale [Tesi di Dottorato V ciclo]: Pisa, Università degli Studi di Pisa, 236 p.

Coarelli, F., 1974, Guida archeologica di Roma: Venezia, Arnoldo Mondadori Editore.

Cordier, P.L.A., 1868, Description des roches composant l'ecorce terrestre et des terrains cristallins: Ed. Ch. D'Orbigny Savy Paris, 553 p.

de Rita, D., Funiciello, R., and Parotto, M., 1988, Carta geologica del complesso vulcanico dei Colli Albani: Roma, Consiglio Nazionale delle Ricerche, scale 1:50,000.

de Rita, D., Funiciello, R., and Rosa, C., 1992, Volcanic activity and drainage network evolution of the Colli Albani area (Rome, Italy): Acta Vulcanologica, v. 2, p. 185–198.

de Rita, D., Funiciello, R., Corda, L., Sposato, A., and Rossi, U., 1993, Volcanic units, *in* Di Filippo, M., ed., Sabatini volcanic complex: Consiglio Nazionale delle Ricerche, Quaderni della Ricerca Scientifica, v. 11, p. 33–78.

de Rita, D., Faccenna, C., Funiciello, R., and Rosa, C., 1995, Stratigraphy and volcano-tectonics, *in* Trigila, R., ed., The volcano of the Alban Hills: Roma, Raffaello Trigila, p. 33–71.

de Rita, D., Giordano, G., Esposito, E., Fabbri, M., and Rodani, S., 2002, Large volume phreatomagmatic ignimbrites from the Colli Albani volcano (middle Pleistocene, Italy): Journal of Volcanology and Geothermal Research, v. 118, p. 77–98, doi: 10.1016/S0377-0273(02)00251-2.

Fornaseri, M., Scherillo, A., and Ventriglia, A., 1963, La regione vulcanica dei Colli Albani: Vulcano Laziale: Roma, Consiglio Nazionale delle Ricerche.

Funiciello, R., (coordinatore scientifico), 1995, La geologia di Roma, Il centro storico: Memorie Descrittive Carta Geologica d'Italia, v. L, 550 p.

Funiciello, R., Giuliani, R., Marra, F., Salvi, S., 1992, Superfici strutturali plio-quaternarie al margine sud-orientale del Distretto Vulcanico sabatino: Studi geologici Camerti, volume speciale 2 (1991), Progetto Crosta Profonda (CROP) 11, p. 301–304.

Lugli, G., 1957, La tecnica edilizia Romena con particolare riguardo a Roma e Lazio: Roma, Bardi editore, v. I, p. 169–359.

Marra, F., 1994, Stratigrafia ed assetto geologico-struttturale dell'area romana compresa tra il Tevere e il Rio Galeria: Geologica Romana, v. 29 p. 515–535.

Marra, F., Rosa, C., De Rita, D., Funiciello, R., 1995, Stratigraphic and tectonic features of the Middle Pleistocene sedimentary and volcanic deposits in the Roman Area (Italy): Quaternary International, v. 47/48, p. 51–63.

Mercier, N., 1993, The thermoluminescence dating technique: Applications and possibilities [abs.]: Rome, Symposium "Quaternary stratigraphy in volcanic areas," September 20–22, 1993, p. 2.

Nappi, G., De Casa, G., and Volponi, E., 1979, Geologiae caratteristiche tecniche del "tufo giallo della Via Tiberina": Bollettino Società Geologica Italiana, v. 98, p. 431–445.

Penta, F., 1956, Materiali da costruzione del Lazio: La Ricerca Scientifica, v. 26, p. 11–201.

Rosa C., 1995, Evoluzione geologica Quaternaria delle aree vulcaniche laziali: Confronto tra il settore dei Monti Sabatini e quello dei Colli Albani [Tesi di Dottorato di ricerca in Scienze della Terra]: La Sapienza, Università degli studi di Roma La Sapienza, VII ciclo.

Manuscript Accepted by the Society 29 December 2005