THE DRAINAGE TUNNEL OF LAKE ALBANO (ROME, ITALY) AND THE 3-YEARS STUDY PROGRAM "PROJECT ALBANUS": A PROGRESS REPORT

Carla Galeazzi [1-2], Carlo Germani [1-2], Luigi Casciotti [1-3]
[1] *Egeria Centro Ricerche Sotterranee (Roma)*
[2] *Hypogea Ricerca e Valorizzazione Cavità Artificiali*
[3] *Architect naturalist*

Corresponding Author: Carla Galeazzi - Via degli Opimiani 21, 00174 Roma, Italy - carla.galeazzi3@alice.it

Abstract
The artificial drainage tunnels are drain systems of lakes with no natural outlet. To date, 20 underground structures of this kind have been identified and registered in Italy, 12 of them only in Lazio. The main emissaries of the Alban Hills, that is of the Vulcano Laziale, located only a few kilometers south of Rome, have been dug to regularize the level of the lakes Albano and Nemi. Both basins have no natural outlet and for this reason were affected by variations in the water level, especially as a consequence of heavy rain falls. Differently from the lesser water basins in the region, the lakes of Albano and Nemi have not been completely drained, both because of their depth (respectively, 170 m at the Albano lake, and 33 m at the Nemi lake) and in order to maintain a large water reservoir, with the possibility of using it for irrigation and for mills and factories functioning. The period of realization, the technical problems encountered during the digging, solved with limited means, the good functioning conditions until the years 60's, each of these characteristics place these works among the most important historical testimonies of our past. The emissary of the Alban Lake is the best known from historical sources. Since 2013, the Federation Hypogea for Research and Valorization of Artificial Cavities has been conducting a study (Project Albanus), aimed at exploring, investigating and documenting the ancient emissary, to obtain its precise topography and to examine the excavation techniques. The study has been conducted in cooperation with the Superintendence for Archaeological Heritage of Lazio, the Regional Park of the "Castelli Romani" and the Town of Castel Gandolfo. The project is dedicated to the memory of professor Vittorio Castellani, eminent scholar and speleologist (Egeria CRS). This contribution studies in detail the historical sources, the ancient and modern reports, the geological investigations and presents the preliminary results of the Project Albanus.
Keywords: artificial cavities, artificial underground outlets, Alban Lake, Alban Hills, Latium, Italy.

Riassunto
Gli emissari artificiali sono canali di drenaggio dei laghi privi di sbocchi naturali. In Italia sono state individuate e censite sino ad oggi 20 strutture sotterranee di questo tipo, delle quali 12 nel solo Lazio. Gli emissari maggiori dei Colli Albani, cioè dell'edificio del Vulcano Laziale, situato pochi km a sud di Roma, furono scavati per regolarizzare il livello dei laghi di Albano e Nemi, bacini privi di emissari naturali e quindi soggetti a variazioni di livello, soprattutto a seconda delle precipitazioni atmosferiche. Contrariamente a quanto avvenuto per gli specchi d'acqua minori, i laghi di Albano e Nemi non furono completamente prosciugati sia in ragione della profondità (170 m per il lago Albano e 33 m per il lago di Nemi), sia per mantenere un'ampia conserva d'acqua con possibilità di sfruttamento del rivo ottenuto per l'irrigazione o per il funzionamento di mulini, opifici, etc. L'epoca di realizzazione, le difficoltà tecniche incontrate nello scavo e risolte con mezzi limitati, la funzionalità rimasta intatta sino agli anni '60 del secolo scorso collocano queste opere tra le più importanti testimonianze del nostro passato. L'emissario del lago Albano è il più noto alle fonti storiche. Dal 2013 è in corso uno studio condotto dalla Federazione Hypogea Ricerca e Valorizzazione Cavità Artificiali, denominato Progetto Albanus che ha l'obiettivo di riesplorare, studiare e documentare l'antico emissario, acquisire la topografia completa della struttura e analizzare le tecniche di scavo e realizzazione. Lo studio è condotto in collaborazione con la Soprintendenza per i Beni Archeologici del Lazio, il Parco Regionale dei Castelli Romani ed il Comune di Castel Gandolfo. Il progetto è dedicato alla memoria del professor Vittorio Castellani, insigne accademico e speleologo (Egeria CRS). Il contributo analizza dettagliatamente le fonti storiche, le relazioni antiche e moderne, gli studi geologici condotti sulla struttura e presenta i risultati preliminari del Progetto Albanus.
Parole chiave: *cavità artificiali, emissari artificiali sotterranei, Colli Albani, Lazio, Italia.*

Introduction
The Alban Hills, placed 20 km SE of Rome, are the remains of a big volcanic complex known as the "*Vulcano Laziale*". The favourable climate, the presence of water and the morphology of the Alban Hills favoured human settlements since prehistoric ages. Here the Latium Civilization was born, that gave origin to Rome itself.
The *Vulcano Laziale* is the last and southernmost of a volcanic chain (Volsinii, Vico, Sabatino) lined up along the Tyrrhenian coast of central Italy. When the

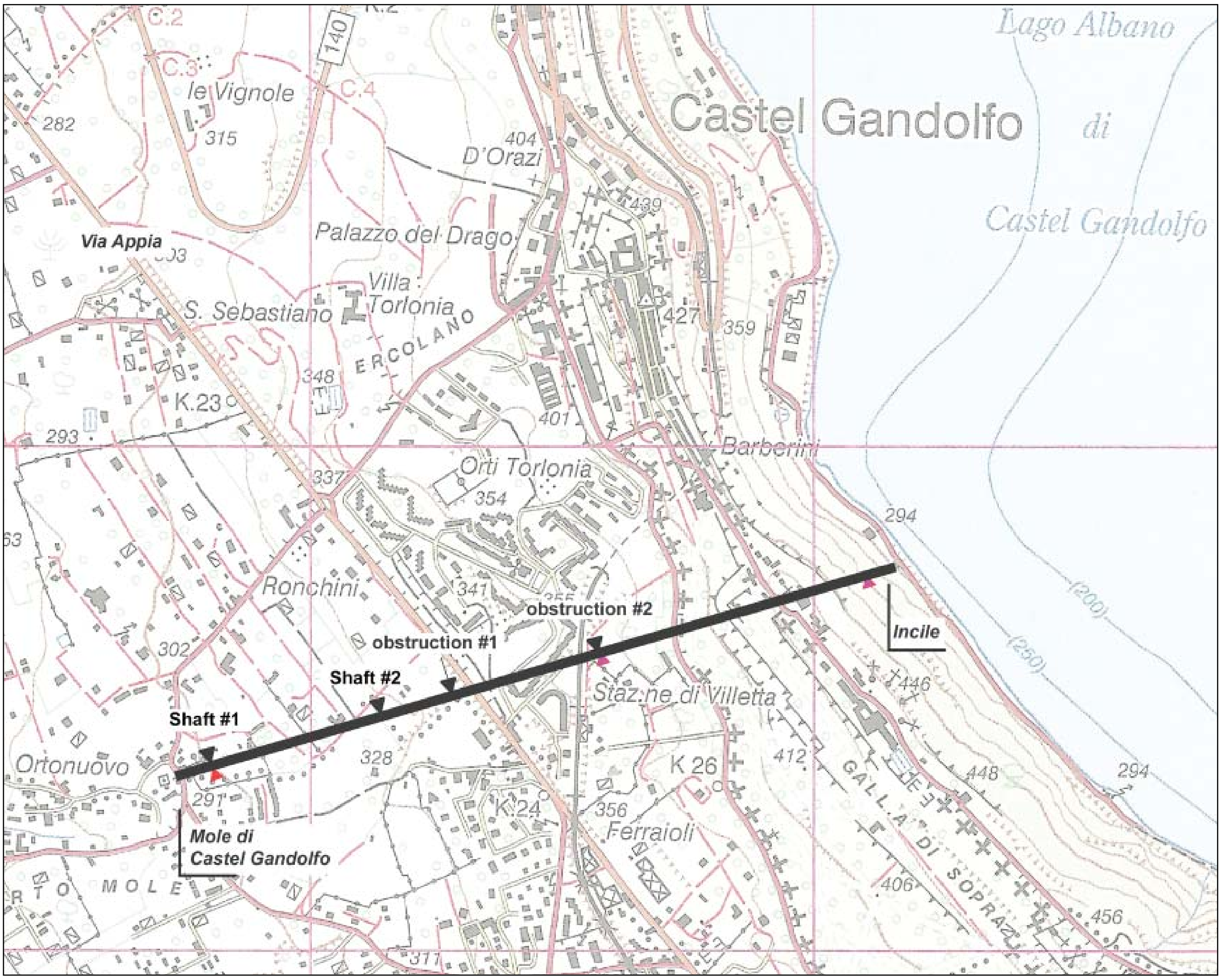

Fig. 1: Path of the Albano drainage tunnel, on topographic map from the Italian Geographical Military Institute.
Fig. 1: Il tracciato dell'emissario Albano su carta topografica dell'Istituto Geografico Militare.

volcanic activity ceased, approximately 40000 years ago, the craters were filled with water, giving origin to a number of volcanic lakes. This situation was deeply altered by human action since the sixth century b.P.E., when first the Latin populations, likely with the help of Greek and Etruscan workers, and then the Romans started a complex work of control and drainage of the land between the Alban Hills and the Tyrrhenian sea. Probably some of the most interesting and less known Roman structures are the drainage tunnels built to control the level of the various craters and of karst areas in central Italy (Castellani & Dragoni, 1990). To date, 20 underground structures of this kind have been identified and registered in Italy, of which 12 only in Lazio (Galeazzi et al., 2012).

The main emissaries of the Alban Hills have been dug to regulate the water level of the Alban and Nemi lakes, since they have no natural outlets and therefore were subject to variations in the water level, according to rainfalls (Fig. 1). They were not completely dried up, both because of their depth (respectively, 170 m at the Alban lake and 33 m at the Nemi lake), and in order to maintain a large water reservoir with the possibility of using the outcoming stream for irrigation or to operate mills and factories (Germani et al., 2012).

On the contrary, most of the smaller craters were dried up, in different moments, by means of underground and surface outlets (Castellani, 1999). These minor emissaries were intended to thoroughly drain the lakes, a function they still perform at present, in order to gain cultivable land. In these cases, the starting point of the drainage tunnel or emissary *(incile)* is necessarily located in the deepest hollow, and does not offer, unavoidably, any architectural feature (Germani et al., 2012).

Instead, the emissaries of the Alban and Nemi lakes regulate the water level by a complex system of filters and gates, so that the lakes become major water supplies, located upstream of partially artificial basins, to be added to the natural ones (Germani & Parise, 2009) (Fig. 2).

The Alban emissary

Ancient Sources

The historical tradition places the emissary among the most ancient documented underground Roman undertakings, second in time only to the Cloaca Massima[1]. It has an extraordinary archaeological,

1) There are hypotheses according to which the making of the

Fig. 2: The crater of lake Albano (photo C. Germani).
Fig. 2: Il cratere del lago Albano (foto C. Germani).

geological and speleological importance, to date still poorly investigated for the objective difficulty of going through the channel, almost completely filled up with water. To understand its importance, we have to consider that the Romans began building aqueducts, pride of their civilization, only a century after the construction of the emissary, probably at the beginning of the 4th century b.P.E.

Livy[2] relates the construction of the emissary to the problems of the never ending war between Rome and Veio. The Romans, already in trouble for a long siege to Veio without results, in 398 b.P.E. had to suffer also for unusual meteorological conditions. A cold and snowy winter made the roads impassable and the river Tiber not navigable. A sudden season change followed, and the summer brought a pestilence that affected all the fauna in the area. This plague induced the Romans to try to appease Gods' wrath with various sacrifices. Shortly afterwards, puzzling prodigies took place, which could not be properly interpreted, being Rome in war with the Etruscans, and no haruspex could be consulted. But great interest was aroused by what happened to the Alban lake. In absence of rainfall or other clear cause, the level of the lake raised unexpectedly. It is possible that the sudden change in temperature caused snow melting on the nearby hills or a landslide (Nisio, 2008). In both cases there followed a sudden and turbulent increase in the water level.

The Romans sent ambassadors to Delphi, in Greece, to seek the help of the horacle. While waiting for the response, an old man in Veio predicted "in the fashion of a haruspex" that the Romans would never conquer Veio unless, in case of an overflow of the Alban lake, they manage to collect and carry away the water in a ritual way. The Senators did not pay much attention to the old man, and preferred to wait for the ambassador's return. The oracle prediction was substantially the same as the one by the old man: the Romans should not let the water from the Alban lake flow toward the sea by its natural path, but they should collect it and carry it to the fields, divided in streams[3].

Cicero (106 - 43 b.P.E.)[4], Diodoro Siculo (about 80 - 20 b.P.E.), Dionigi d'Alicarnasso (about 60 - after 7 b.P.E.), Valerio Massimo (I sec. b.P.E. - I sec. P.E.)[5] and Plutarch (50 - 120 P.E.) report the same events[6] in a way similar to Livy, with little differences on the period of the flood. According to Dionigi, between 23 July and 24 August of 398 b.P.E., according to Plutarch[7] at the beginning of autumn, when the water supply is at minimum. Beside, Cicero quotes the "wonderful emissary realized by the ancestors". Given that he liked to stay in his villa in the nearby Tuscolo, it is possible that he actually visited the site.

The fact that an Etruscan (haruspex) and a Greek (oracle) had given detailed and identical information on how to drain a basin without natural outlets supports the notion diffuse among scholars that the Romans started their hydraulic works on the basis of the knowledge handed down by the Etruscans and the Greeks, who had acquired the necessary techniques long before the Roman epoch. The old man of the legend may not have simply suggested the excavation of the tunnel, but rather he may have supervised the recovery of a pre-existent structure known to him (Castellani & Dragoni, 1991). Veio was conquered a few years later after a long siege, and, as it is well known, the Romans entered the Veio fortress through underground passages.

During the Middle Ages the stream from the Alban lake was, in the neighborhood of Le Mole (Fundus Molas), a stable source of energy to operate the mill located

emissary could date back to an even earlier epoch (Castellani, 1999).

2) Livy (59 b.P.E.-17 P.E.) History of Rome from its foundation, V (13-19).

3) *"Romans, do not let the Alban water stay in the lake, do not let it reach the sea with its own flow, but make it get out to water the fields, and divide it into streamslets..."* (Livy, by Perelli 1970-79).

4) The dates of birth and death of ancient historians are often uncertain. Here we report the data found in the site Treccani.it.

5) (I,6,3) "*...the immortal gods opened the way to the craved victory with a wonderful prodigy: in fact, the Alban lake, without being fed by rainfalls or rivers, suddenly overflew its usual level*".

6) Dionigi, XII,11; Cicero, De Divinatione I,XLIV,100; Valerio Massimo, I,6,3; Plutarch, Parallel Lives, Cam., III,1-4; Diodoro, III,10-11.

7) "...*Not much afterwards, at the peak of the war (between the Romans and the Falerii-Capenates), there took place the cataclysm of the Alban lake, made the more terrifying by the absence of a customary cause and of a physical explanation. The summer just over had not been particularly rainy or affected by hot and wet winds. Some of the many lakes dried up completely (…). On the contrary, the Alban lake, which is without inlet or outlet being surrounded by fertile mountains, without reason, if not a divine will, grew and swelled, touched the hillsides, and rose to reach uniformly the highest peaks, without stirring and ruffling in the process. At the beginning the phenomenon surprised the shepherds and the cowherds who pastured their animals; but afterwards the heavy water mass broke a sort of dam that prevented it from falling down into the underlying region, and a huge flood poured itself over the fields and the farms toward the sea. Not only the Romans were terrified, but to everybody the phenomenon appeared as the sign of an important event to come*".

Fig. 3: The entrance (incile) of the Albano emissary, as it appears today (photo C. Germani), and in two postcards dating to 1800.
Fig. 3: L'incile dell'emissario Albano oggi (foto C. Germani) e in due cartoline dell'800.

near the extant tower, the centre of a settlement rich in fountains, channels, dams and at least two other mills (Giannini, 2006). Also for these reasons the settlements concentrated in the area.

The emissary flows into the *Fosso della Mola* (Ditch of the Grindstone), which flows into the *Fosso della Torre* (Ditch of the Tower) that along the route changes its name first in *Rio Petroso* (Stony Brook) and then in *Fosso di Vallerano* (Ditch of Vallerano), finally flowing into the Tiber.

At the exit of the underground Alban stream, in the 18th century were built the washing-basins still in site. It is possible that two further underground channels, recently observed, carried at least partially the "*rivus aquae albanae*" into the "*lacus Turni*" (Turnus' lake), a crater next to present-day Pavona (Giannini, 2006), a basin in turn drained by an artificial emissary (Germani et al., 2012). It is likely that the emissary of the lacus Turni has been put in operation by Pope Paul V in 1611 using a pre-existing Roman structure, with the aim of preventing or of relieving the risk of malaria caused by backwater.

So it appears possible that also the basin of Pavona may be put in relation with the "integrated system" of the Alban Lake Emissary, which is the subject of the "Albanus Project". If so, we would have a situation similar to that of the Nemi lake, where a proper "integrated system" has been identified (Dobosz et al., 2003).

The historic "explorations"

In the 18th century Piranesi figured the emissary in beautiful engravings rich of technical details[8], which largely contributed to make this work famous. Nevertheless, it is known that he drew more shafts than those really existing.

Between 1700 and 1800, the emissary arose a great interest, but the descriptions show that nobody really advanced beyond the first few metres from the entrance (*incile*). This is an imposing structure, one of the major attractions for the travellers of the Grand Tour in the surroundings of Rome (Fig. 3).

"In the morning, after having ordered your meal, [...] take with you the man with the key to the emissary of the Alban lake, which at present is named Castello lake after the name of the overlying village. [...] As for the emissary, I have no doubt that you will be pleased in seeing such a wonderful work"[9] (Dalmazzoni, 1806).

Fea analyses in detail the hypotheses, surely incorrect but at the time largely debated, according to which there was a connection between the lakes of Albano

8) Dimostrazioni dell'emissario del Lago Albano, 1764. (Illustrations of the Alban Lake, 1764).

9) "*La mattina, dopo aver ordinato che il vostro pranzo sia pronto (…) prendete con voi l'uomo che ha la chiave dell'emissario del lago Albano, che ora dal villaggio, che è sopra il medesimo, si chiama il Lago di Castello. (…) Quanto al detto emissario, io non dubito che avrete piacere di vedere un'opera sì maravigliosa*".

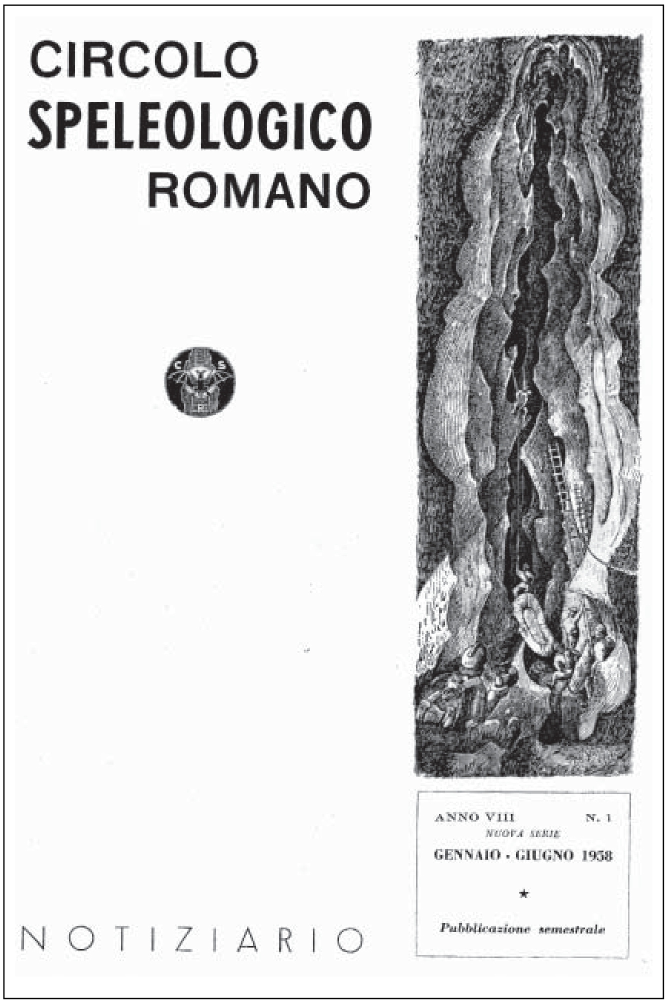

Fig. 4: The first speleological exploration (Dolci, 1958; Chimenti & Consolini, 1958).
Fig. 4: Relazione della prima esplorazione speleologica (Dolci, 1958; Chimenti & Consolini, 1958).

and Nemi (Fea, 1820).
In the light of recent researches it is conceivable that they were misled by the presence of integrated structures (Albano-Pavona and Nemi-Vallericcia-Fountain of Pope), at the time misunderstood as a connection between the two major basins. Fea himself mentions a possible "previous" exit of the emissary under the convent of the Cappuccini or at the Fountain of Marino, called on a plaque "*rivus aquae Albanae*". Confusing the aqueduct of Malaffitto located near the monastery of Palazzola, close to the Cappuccini fathers, with the open air stream effectively called *"rivus aquae Albanae"*.
Fea mentions 358 b.P.E. as the year of construction of the emissary, Dalmazzoni puts it in 357 b.P.E. and Raggi (1879) quotes 356 b.P.E., instead that between 398 and 397, as generally supposed.
Fea also asks himself (correctly?) the reason for appealing to oracles for a situation already dealt with by the realization of the Nemi emissary. Perhaps to "make it an object of religious and civic admiration, accomplishing in a year a exploit that appeared incredible even to *Cicero?* [10]"

Nibby assigned to the emissary as many as 62 shafts, while up to date only two[11] have been found (Nibby, 1849). This mistake was repeated by Raggi (1879). Pellati (1940) asserted that the whole conduct was completely coated, while it is clearly dug in the bare rock. Lanciani quoted the Alban emissary as an example of the presence of inclined shafts *("discenderie")* "as described and drawn by Canina", though, after consideration, they appear simply as the hypotheses already advanced by Piranesi (Canina, 1848-56; Lanciani, 1879).
Essentially, it is clear that none of the mentioned authors has ever explored the whole emissary.

Modern Explorations

The underground channel was partially explored for the first time in 1955 by speleologists of the Circolo Speleologico Romano (Dolci, 1958; Chimenti & Consolini, 1958), who made a preliminary planimetry of the tunnel. There are no photographs of this first exploration, but we have its detailed description, attesting the tremendous difficulty encountered, together with the opinion that "the structure presents a poor archaeological interest" (Fig. 4). This statement, so far from truth, must not surprise since speleology in artificial cavities began in Italy only in the 60's.
We have to wait until 1978 to have a first reliable topographic description of the tunnel, after various demanding explorations (Cardinale et al., 1978).
On the basis of that experience and of subsequent explorations, Vittorio Castellani in the volume "Civilization of water" gives a sufficiently complete description of the tunnel and of its conditions, together with some elements of the techniques used for planning the structure and digging it (Castellani, 1999).
The pictures taken in the 70's of past century by Castellani show the water still flowing into the tunnel. From the middle of the 80's the level of the lake has been decreasing constantly, reaching the present level of three metres lower than the entrance; here is present only a small quantity of backwater correlated with rainfalls[12].
At the beginning of present century a malfunction of the water depurator (in service of Castel Gandolfo) caused a substantial pollution of the water in the tunnel, such as to require the closing of every access to the emissary, in order to prevent the leaking of unpleasant smells at Le Mole of Castel Gandolfo[13].
The substantial lowering of the lake level during the

10) "*Illa admirabilis a maioribus Albanae aquae facta deductio*". (That wonderful conveyance of the Alban water made by our ancestors).

11) A manoeuvre room, looking like a shaft, can be seen inside the entrance at a few meters from the beginning of the underground channel; it was likely used to operate the bulkheads.

12) Between the years 1980 and 1996 the lake lost about 160cm (data from the Province of Rome); another 90cm are lost between the years 1996 and 2000 (data WWF).

13) The situation has been solved, at least officially, in 2009 when a sewage collector was build all around the lake. In any case, according to appropriate analyses the water inside the emissary appears unpolluted.

Fig. 5.1: Albano lake emissary: the arrow points to the furrows in the bulkheads. Figs. 5.2 e 5.3: the double stone filter at the entrance of the underground channel of Albano lake (photo C. Germani and P. Bersani).
Fig. 5.1: emissario del lago Albano, la freccia indica le scanalature delle paratie. Figg. 5.2 e 5.3: il doppio filtro in pietra all'ingresso del canale emissario del Lago Albano (foto C. Germani e P. Bersani).

past few years is surely due to human exploitation, but it is not a completely new phenomenon. In fact, there is evidence of strong fluctuations in the lake level in the past, also before the construction of the emissary (Bersani & Castellani, 2005).
At present the remains of proto-historical structures, once deep in the water, are visible on the lake shore, manifesting a past lake dropping below the emissary level. Other strong reductions in the water level are mentioned by Eschinardi for the year 1683, and by Giorni for the year 1834 (Bersani & Castellani, 2005).
Starting from 2005, the Centre for Underground Research Egeria of Rome has been monitoring the accessible zone of the entrance (*incile*)[14]; in 2008 the researchers have observed the total absence of water in the underground channel, and in 2009 the "reappearance" of water, with a puzzling inversion of the stream flow toward the lake (Caloi et al., 2012).
The presence of a substantial backward flow suggested that the emissary was completely filled with rain water and dripping water, whose outflow was hampered by internal obstructions.
During inspections preliminary to the present investigation (2013), we noticed that the dam at the entrance (a dam that did not exist in the past) had been raised; as a consequence, the water level in the channel had suffered a further increase with respect to 2009, producing problems in the hydraulic equilibrium of the structure and greatly complicating the conditions of exploration. It is not a surprise that a small intervention can change substantially the functioning of the emissary, for the difference in level between entrance and exit is of about two metres.

Geological studies

The connection between the emissary construction and the sudden rise of the lake level during the war between Veio and Rome has been studied also from a geological point of view.
Funiciello and co-authors suggested that, between 7500 and 4100 years ago, various phenomena of volcanism and overflowing took place in the Alban lake, and that the present crater may have been formed in that period (Funiciello et al., 2002).
This theory, nowadays rejected, was based on archaeological findings of the beginning of 1800 (Fea,

14) A few attempts to go forward into the tunnel have been blocked after few meters by the evident and heavy pollution and, above all, by the amount of mud.

Fig. 6: the stone filter at the entrance of the underground channel of Nemi lake (photo C. Germani).
Fig. 6: il filtro in pietra all'ingresso dell'emissario del Lago di Nemi (foto C. Germani).

1820), which consisted of earthenwares found under peperino rocks, and on findings of the second half of 1800 (Ponzi, 1868) of tombs of the 10th century b.P.E., buried under the most recent volcanic deposits of the Alban peperino[15].

These facts suggested that the last volcanic episode in the Alban crater took place no more than 3000 years ago, and not 40000 years ago, as commonly assumed. On the basis of this hypothesis Funiciello and co-authors (2002) give an unusual interpretation of the legend told by Livy, that is, that the Alban emissary may have been made to prevent the risk of sudden floods from the crater, caused by volcanic eruptions and/or gas emission, with ensuing mudslides.

According to Drusiani et al. (2007) the presence of bulkheads at the entrance of the Alban emissary (Fig. 5.1) would clearly indicate the necessity of stabilising the lake level in case of heavy rainfalls, rather than the necessity of the quick disposal of a flood, as supposed by the previous authors; besides, the emissary would have supplied downstream a very useful water system (Drusiani et al., 2007).

D'Ambrosio et al. (2009) agree that there is no evidence of either volcanic activity or of floods after 36000 years ago, as confirmed by the multi-discipinary studies by the "Istituto Nazionale di Geofisica e Vulcanologia" (D'Ambrosio et al., 2009).

Structure and dating of the emissary

The entrance (*incile*) of the emissary is located on the W shore of the Alban lake (or lake of Castel Gandolfo). It consists of a wide room in *opus quadratum* for the operation of the bulkheads, from which the tunnel begins. At present it is hard to notice it from the road along the lake and its level is at about three meters above the water level.

When were the Alban emissaries made?

Until today many researchers have tried to answer this question, and we among them, starting from the technical analysis of the work and attempting a comparison with similar structures, like the emissary of the Nemi lake (Castellani et al., 2003).

Unfortunately, it is not easy to assign a reasonable dating to a hydraulic work examining the excavation techniques, especially in absence of literary and epigraphic sources. The fact is that digging techniques have not changed much over the centuries, and a strict archaeological analysis of a tunnel dug into the bare rock does not offer unambiguous answers.

Some characteristics are common to the emissaries of Albano and Nemi. The water from the Alban lake was filtered by a double grid of stone slabs with holes (Figg. 5.2-5.3) which, similarly to the Nemi lake emissary (Fig. 6), let the water flow in preventing at the same time the incoming of floating stuff (such as tree trunks or other material), which could clog the tunnel. The use of bulkheads to regulate the flow of the lake water, bulkheads no more visible, is attested by the vertical grooves where the stone or wooden slabs slided[16], again as found in the Nemi emissary.

In both cases the digging began from the two opposite sides: in the case of Nemi the work began at the two ends and the teams met halfway, after an excavation of 1650 m with no external point of reference (blind excavation); the case of Albano shows some differences, that are being put in evidence by the present study.

First, in the Alban emissary the digging was surely made between two opposite points from the exit to shaft 1 (Fig. 7.1), but not between shaft 1 and shaft 2, that was reached from shaft 1 (Figs 7.2, 7.3). This occurrence suggests that shaft 1, closer to the exit (and about 3 m deep), was of importance for the work of excavation, like the entrance of the working teams, while shaft 2, farther away and 35 m deep, was useful for a correct alignment. At the present stage of the investigation we have no data for other parts of the tunnel, either because not reachable or because covered

15) This hypothesis has been disproved by the finding that the remains were not under the tufa rock, but had been dug into the pre-existing tufa layer.

16) The metallic bulkheads now at the entrance (incile) have been made in the first years of the 20th cen.

Fig. 7.1: part of the present map: path between exit and first shaft (survey and drawing C. Germani, Albanus Project).
Fig. 7.1: stralcio della planimetria attuale: tratto tra uscita e primo pozzo (rilievo e restituzione grafica C. Germani, Progetto Albanus).

by concretions which hide the digging marks.
The similarity, even if not complete, of the techniques employed has suggested to a few researchers.
(Drusiani et al., 2007) that both the emissaries could be reasonably dated to (at least) the 6th century b.P.E.
Coarelli, even though agreeing on the possible dating of the 6th century, believes that the Alban emissary had to be older than the one in Nemi, and that it may have been made for "ritual" reasons beside practical ones (Coarelli, 1991). That is, he thinks that the floods from the Alban lake were due to the bad functioning of a channel already existing at the time of the phenomenon described by Livy, and that the restoration of this channel, urged by the oracle and the

Fig. 7.2: part of the present map: path between first shaft and progressive no. 100 (survey and drawing C. Germani, Albanus Project).
Fig. 7.2: stralcio della planimetria attuale: tratto tra primo pozzo e la progressiva 100 (ril. e rest. grafica C. Germani, Progetto Albanus).

Fig. 7.3: part of the present map: path along the progressives nos. 150 and 200 (survey and drawing C. Germani, Albanus Project).
Fig. 7.3: stralcio della planimetria attuale: tratto fra le progressive 150 e 200 (rilievo e restituzione grafica C. Germani, Progetto Albanus).

haruspex, may have symbolized the renewed stability of the pact between Rome and the Latin League.

This opinion is shared in part by Castellani and co-workers, according to whom the puzzling increase of the water level may have been caused by the sudden accidental interruption of a well known pre-existent hydraulic system (Castellani et al., 1991).

The three functions of a draining system can be outlined as follows:

1 - Regulation and control of the variations in a lake level (spillway). The underground outlet is built starting from the lake level to dispose of the water excess in case of strong rainfalls. The artificial flow may be led to the nearest ditch.

2 - Regulation obtained by an underground outlet starting below the lake level, in order to draw from the surface water table which feeds the lake basin. In this way a permanent water reservoir is secured for the lands and the factories located downstream of the outlet. The making of such an emissary requires an advanced stage both in knowledge and technology.

3 - Complete emptying of the lake. The underground channel is dug starting from the deepest point of the basin, so that all the water is drained and the recovered land may be used for agriculture.

The emissaries of Albano and Nemi, as they appear today, belong surely to the second function: the water from the outlets, suitably canalized and split up, was used for agriculture and to operate factories. A travertine block close to the exit may have been part of a divider of the outflowing water.

However, the lake may well have been regulated previously by a pre-existent system which did not manage to cope with the sudden raise in the water level, so to require a subsequent readjustment. If so, the preceding system should lie two or three meters above the level of the present emissary.

The authors suggest that the classical sources refer to an ancient system which regulated the variations in the lake level (spillway), a system disappeared during the making of the present emissary. The major Alban emissaries appear as daring enterprises, the result of a complex and coherent planning which involved the employment of a large manpower and of noticeable financial resources. From this point of view they appear very different from the archaic systems, also considering the use of sophisticated techniques and the building of imposing structures in *opus quadratum* at the entrances (especially in the case of the Alban emissary).

Analysis of the technical characteristics of the emissary

The entrance of the Alban emissary is characterised by an imposing structure in *opus quadratum* which, according to Castellani (1999), can be ascribed to a remake under Silla (Lucio Cornelio, 138-78 b.P.E.). In recent time the wall surrounding the large internal room for the operation of the bulkheads has been raised, so that it is no more visible from the outside the imposing arch in *opus quadratum* located where the stream from the lake enters into the mountain, a sort of celebration of the successful work (imposing structures were generally built in Rome at the distribution point of the water of an aqueduct).

The tunnel has been completely flooded for many years, even if the lake level is, as already mentioned, three meters below the *incile* level. The flow of the abundant dripping water is hampered by internal landslides dating back to an undetermined epoch, by earth

Fig.8: the impressive speleothems that create an obstacle to the water flow in the Albano drainage tunnel (photo S. Barbaresi).
Fig. 8: le imponenti concrezioni che ostacolano il flusso dell'acqua nell'emissario albano (foto S. Barbaresi).

Figs. 9.1 - 9.2: the "ledge" (photo M. Mazzoli e V. Puggini).
Figg. 9.1 - 9.2: le "cornici" (foto M. Mazzoli e V. Puggini).

deposits under the two shafts, by a large earth mass close to the exit and by two massive concretions (Fig.8), all obstacles that have altered the tunnel altimetry, causing the flooding. The presence of internal waters may be also due to a water table.

At present the tunnel is only passable using techniques typical of speleo-underwater exploration. The studies previously quoted give for the tunnel a length of 1450m, an average width of 1,20 m and a maximum height of 2,50 m. The slope gradient is about 0,14 per thousand.

The planning of the structure was performed using the method of the "*coltellatio*", very common in ancient times, which determined the altitude of the two ends and the external direction transferred inside by means of shafts opened close to the two ends. In the case of Albano, we have in fact two shafts close to the exit, one very close (at a distance of 70 m) for an approximate estimate of the digging direction, and one toward the interior (at a distance of 420 m), to reduce the error. The waving in the tunnel direction appears to have ensured a high precision during the excavation, by further limiting the size of the light beam entering the tunnel (Castellani, 1999). We are at present checking whether other explanations are possible for these changes in direction.

There is no trace of all the other shafts mentioned in the literature, starting from Piranesi, who in any case quotes them as a hypothesis: the two zones filled up by concretions are the only sites where a "*discenderia*" (inclined tunnel leading outside) can be hidden.

Along the tunnel one finds variations in the section, sort of ledges in the rock of the size of a few cm.

Livy (V, 19), as an aside in the report of the events in Albano, tells that the Roman army was taken to Veio and was employed also in works of fortification and diggings. The most important and the most tiresome of these undertakings was the excavation of a tunnel under the enemy lines. The work had to be without breaks, and in order not to fatigue too much the workers, the operation was organized on the basis of six teams with shifts of six hours, alternating night and day.

Since the geologic conditions at Veio and Albano are similar - we have in both cases rather soft tuff rocks - Castellani (1999) made the hypothesis that the ledges on the wall were meant to mark the progress accomplished by a team during its shift. Given that the distance between two successive ledges lies between 0,70 m and 2 m, each team in six hours supposedly advanced of 1,35 m. Therefore, if the work proceeded without interruptions for 24 hours (four shifts), the full length of 1450 m of the Alban emissary would have been completed in about 8-9 months, rather than in one/two years as reported by ancient sources. This period would have been halved if the digging proceeded from the two ends.

Up to date, ledges similar to those in the Alban emissary have been investigated only in the *Praeneste* aqueduct (Casciotti & Castellani, 2001).

The present study suggests that the digging was not completely performed by hand, but with the help of a (man powered) machine, as hypothesized also in the case of the Nemi emissary. It is possible that the ledges (that in the Alban tunnel are found on one wall only) do not correspond to the end of a shift, but to different positions of the machine while digging (Figs. 9.1-9.2). If so, the time for carrying out the work would be difficult to estimate.

Another interesting feature under investigation is given by vertical symmetric grooves on both walls of the tunnel, which could be due either to bulkheads or to the quoted digging equipment.

The "Albanus Project"

In 2013 the Roman speleological groups with the strongest activity in the study of artificial cavities decided to tackle the problem presented by the Alban emissary in a systematic way and by means of advanced techniques. The purpose is to investigate the structure, to get some insight into its scientific and cultural heritage, trying also to regain some of its functions. So the Project Albanus was born, promoted and carried out by the Hypogea Federation[17], with the authorization of the Superintendence for Archaeological Heritage of Lazio, in cooperation with the municipality of Castel Gandolfo and the Regional Park of Castelli Romani.

A preliminary chemical and bacteriological analysis was made on water samples from the two ends of the

17) Hypogea Research and Valorisation of Artificial Cavities is the Speleological Federation of Lazio which includes the groups A.S.S.O, EGERIA centre for underground research and Underground Rome.

tunnel: no impurity was found. In the summer of 2013 the exploration began.
At the entrance (*incile*) the underground channel was found completely awash, so that since the beginning experts in underwater speleology had to come into play. However, even these advanced techniques were not sufficient to make any progress. Three attempts were made to get over the stretch, at about 36 m from the entrance, where the vault lowers to touch the water; here underwater explorations showed that between bottom and vault there was 1,10 m of slime and mud, plus only 20 cm of water at the surface. In these conditions any further attempt was suspended for safety reasons. So the researchers moved to the tunnel exit, at Le Mole (Millstones) of Castel Gandolfo, where it was possible to get into the underground channel through a narrow passage in the wall closing the exit. This first stretch was filled up with rubbish, mainly glass and waste materials from recent roadwork. Besides, the narrow size of the passage made it difficult to carry inside the necessary equipment.
Most of the rubbish was cleaned up to allow a safe passage to the speleologists, who in any case had to stop again after 70 m, under the first shaft, where a heap of earth and material from the overlying fields (plastic nets, building waste, rubbish, roots) prevented further progress.
In the spring of 2014 only 36 m at the entrance and 70 m at the exit were accessible, and with difficulty, against a total of 1450 m.
In the summer of 2014 it was decided to work by starting from the first shaft. Part of the obstruction was removed and the water flow to the exit was restored, allowing to partially drain the channel and to lower the internal overall water level to 0,9 m, making the passage accessible. As a consequence, the water disappeared from the entrance, but not the mud, which is the main obstacle to go on.
After the disappearance of the water, colonies of very small shellfishes came to the surface (Fig. 10); they belong to at least two families, the most common being *Lymnaea stagnalis,* typical of cold waters rich in oxygen and abundant in macrophytic vegetation and submerged algal (Audisio, 2014, pers. comm.). The term macrophytes indicates the primary productive macroscopic component of water systems. The presence and the distribution of macrophytes in a

Fig. 10: small mollusks in the emissary water (photo C. Germani).
Fig. 10: i piccoli molluschi presenti nell'acqua dell'emissario (foto C. Germani).

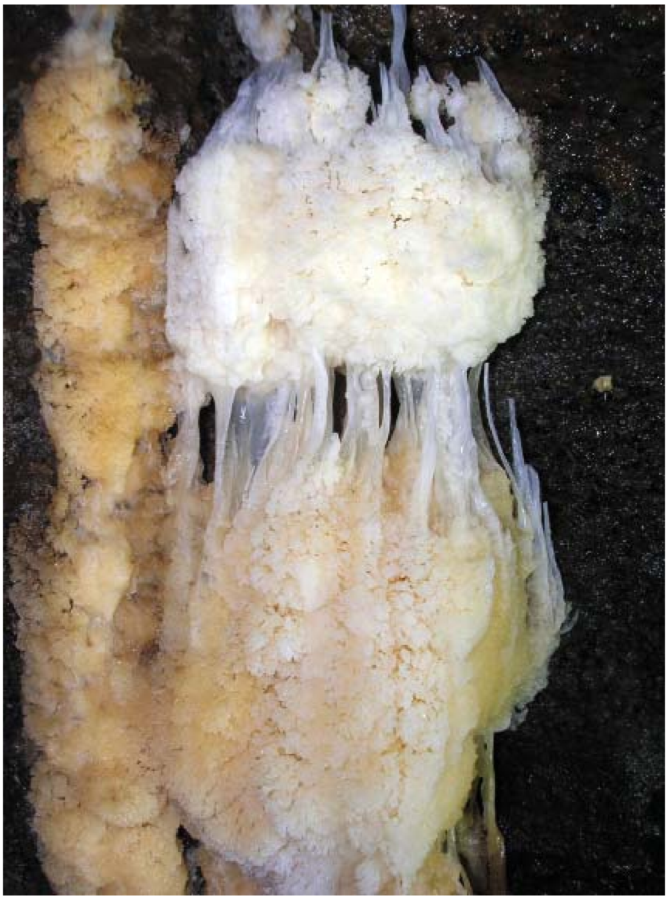

Fig. 11: the peculiar speleothems of the Albano emissary (photo M. Vitelli).
Fig. 11: particolari speleotemi dell'emissario Albano (foto M. Vitelli).

volcanic lake basin depends on various environmental parameters specific of the basin or of anthropogenic origin. For this reason they can be used as indications for understanding the characteristics of the lake environment (Azzella, 2012).
After the drop of the water level, the exploration on the side of Le Mole became easier and the cavers succeeded to go beyond the second large concretion, reaching a distance of 920 m. The conditions of the underground channel appear perfect, with the exception of a few stretches showing anomalous enlargements due to collapses occurred in undetermined epochs, a feature already described by the explorers at the end of the 50's.
In September 2014, even if the tunnel has not been completely explored, we began the work of documenting, surveying and detailing the structure. We are particularly interested in the results of the analysis of the concretions, since the abundance of stalactites, calcite blades, "angel's hairs" is unusual in a volcanic structure (Fig. 11).
The water, extremely clear, sometimes is higher than 2 m; it is very cold due to the steady drip. The calcite concretions present at 575 and 840 m from the entrance make the progress through the tunnel highly suggestive, but at the same time they partly block the tunnel section, possibly hiding shafts or "*discenderie*", no more visible nowadays from the outside.
The concentration of concretions in two sites

suggests that here is located most of the seepage, in correspondence to fractures in the rocks, or that shafts or "*discenderie*" are hidden in the walls .

In present conditions, the mud wall about 470 m long, that lies between the entrance (*incile*) and the closest point to the *incile* reached in the exploration, is the major obstacle to get over respecting environmental safety and regulations in force: the mud cannot be shed into the lake, cannot be removed by hand, and cannot be passed through.

The next steps in the project foresee the involvement of experts in various disciplines and the establishment of an international scientific committee that should guarantee the continuation of technical and scientific investigations, also after the end of the Project Albanus.

Acknowledgements

The Authors express their gratitude to Prof. Walter Dragoni (Hydrogeology at the Department of Earth Sciences, University of Perugia, Italy) for his availability and collaboration, and for helpful comments and constructive suggestions; Dr. Franco Medici (Department of Chemical Engineering, Materials and Environmental, Sapienza Rome University, Italy) for the bacteriological analysis of the underground water; Prof. Paolo Audisio (Full Professor, Zoology, Dept. of Biology and Biotechnologies "C. Darwin" Sapienza Rome University, Italy) for the analysis of the small underground clams.

References

Ashby T., 1982, *La Campagna romana nell'età classica*. Longanesi ed., Milano, p. 99.

Azzella M. M., 2012, *Flora, vegetazione e indicatori macrofitici dei laghi vulcanici d'Italia,* Pubblicazioni digitali aperte de La Sapienza - PADIS (http://hdl.handle.net/10805/1440).

Bersani P., Castellani V., 2005, *Considerations on water flow regulation in ancient times in the Alban Hills. Considerazioni sulla regolazione delle acque in epoca antica nell'area dei Colli Albani*, T&A Gennaio/Marzo 2005.

Bersani P., 2004, *Ripristino del lago della Doganella nei Colli Albani in provincia di Roma*. Tevere n. 28, Rivista quadr. dell'Autorità di bacino del fiume Tevere.

Caloi V., Cappa G., Castellani V., 1994, *Antichi emissari nei Colli Albani*. Atti XVII Congresso Naz. di Speleologia, Castelnuovo Garfagnana, 1994, pp. 299-307.

Caloi V., Galeazzi C., Germani C., 2012, *Gli emissari maggiori dei Colli Albani*. Opera Ipogea 1-2012, pp. 29-40.

Canina L., 1848-56, *Gli edifici di Roma antica e sua campagna*, Vol. VI, Roma.

Cardinale M., Castellani V., Vignati A., 1978, *L'emissario del Lago di Albano, 2000 anni dopo*. Quaderni Museo Speleologico "V. Rivera", IV, 17.

Casciotti L., Castellani V., 2002, *L'antico acquedotto delle Cannucceta* suppl. ad Opera Ipogea 2/2001.

Castellani V., 1999, *Civiltà dell'acqua*. Editorial Service System, Roma.

Castellani V., Dragoni W., 1989, *Opere idrauliche ipogee Romane: origine, sviluppo ed impatto sul territorio* in L'Universo, Ist. Geog. Mil., 69, 2.

Castellani V., Dragoni W., 1990, *Contribution to the history of underground structures: ancient Roma tunnels in central Italy*, Proceedings of Intern. Simp. on Unique Underground Structures, Denver (colorado-Usa; June 12-15,1990).

Castellani V., Dragoni W., 1991, *Opere arcaiche per il controllo del territorio: gli emissari sotterranei artificiali dei laghi albani*. Gli Etruschi maestri di idraulica, Ed. Electa, Perugia.

Castellani V., Dragoni W., 2003, *Gli Emissari dei Laghi Albani. Aggiornamenti e prospettive*. In Lazio e Sabina vol. II a cura di Giuseppina Ghini, Lavori e Studi della Soprintendenza per i Beni Archeologici del Lazio, De Luca Editori d'Arte, pp. 215-220.

Chimenti M., Consolini F., 1958, *Relazione tecnica sull'esplorazione dell'emissario del lago di Albano*. Not. Circ. Spel. Rom. Anno VIII, n. 1, p. 20.

Coarelli F., 1991, *Gli emissari del laghi laziali tra mito e storia*. Gli Etruschi maestri di idraulica, Ed. Electa, Perugia.

Castellani V., Caloi V., Dobosz T., Galeazzi C., Galeazzi S., Germani G., 2003, *L'emissario del Lago di Nemi indagine topografico-strutturale*, Opera Ipogea 2/3-2003, Società Speleologica Italiana.

Dalmazzoni A., 1804, *L'Emissario del lago Albano* in L'Antiquario o sia la guida de' forestieri pel giro delle antichità di Roma, pp. 321-323.

D'ambrosio E., Giaccio B., Lombardi L., Marra F., Rolfo M.F., Sposato A., 2009, *L'attività recente del centro eruttivo di Albano tra scienza e mito: un'analisi critica del rapporto tra il vulcano laziale e la storia dell'area albana*. Atti VI Incontro di studi sul Lazio e la Sabina, Ed. Quasar, Roma, 2009.

Dobosz T., Filippi G., Galeazzi C., Galeazzi S., Germani C., *Gli ipogei aricini, nemorensi e del lago Albano* in Opera Ipogea 2-3/2003 pp. 77-144.

Dolci M., 1958, *Esplorazioni dell'emissario del lago di Albano in comune di Castel Gandolfo*. Not. Circ. Spel. Rom. Anno VIII, n. 1, pp. 17-19.

Drusiani r., Bersani P., Penta P., 2007, *L'Antico emissario del Lago di Albano, ipotesi sulle origini ed il suo ruolo nel tempo* in L'Acqua, Rivista dell'Ass. Idrotecnica Italiana, n. 4/2007 Sezione 1 Memorie.

Eschinardi F., 1750, *Descrizione di Roma e dell'Agro Romano*, p. 208 (ristampa A. Forni, Bologna, 1973).

Fea C., 1820, *Lettera a S. Ecc. Rma Monsig. Frosini, Maggiordono di S.S., e Prefetto de' Sacri Palazzi, relativa a Castel Gandolfo, e suoi contorni (19 Luglio 1818)* in Varietà di notizie economiche, fisiche, antiquarie sopra Castel Gandolfo, Albano, Ariccia, Nemi, loro laghi ed emissarii, Ed. F. Bourlié, pp. 1-12.

Ferri Ricchi L., 2001, *Oltre l'avventura*, Ed. Ireco.

Funiciello R., Giordano G., De Rita D., Carapezza M.L., Barbieri F., 2002, *L'attività recente del cratere del Lago di Albano di Castelgandolfo*, Rend. Fis. Accademia dei Lincei, Roma).

Galeazzi C., Germani C., Parise M., 2012. *Gli antichi emissari artificiali dei bacini endoreici*. Opera Ipogea

1-2012, pp. 3-10.
Germani C., Galeazzi C., Caloi V., Dobosz T., 2012. *Gli emissari minori dell'edificio vulcanico Albano: laghetto di Monte Compatri, Pantano Secco, Pavona, Giulianello*. Opera Ipogea 1-2012, pp. 29-40.
Germani C., Galeazzi C., Parise M., Sammarco M., 2007. *Gli antichi acquedotti sotterranei: esempi di uso sostenibile delle risorse idriche*. Atti del Convegno "La crisi dei sistemi idrici: approvvigionamento agro-industriale e civile", Accademia Nazionale dei Lincei, Roma, 2009.
Germani C., Parise M., 2009, *Interventi antropici nel bacino idrografico del Fiume Tevere: gli antichi emissari sotterranei*. Atti Convegno "Il Bacino del Tevere", Accademia Nazionale dei Lincei, Roma.
Giannini N., 2006. *Canalizzazioni sotterranee e mulini altomedievali in un'area campione dei Colli Albani tra il Nemus Dianae e l'Albanum*. In Tecnica di idraulica antica. SIGEA.
Lanciani R., 1879, *Di alcune opere di risanamento nell'Agro Romano eseguite dagli antichi*. Atti Acc. Dei Lincei, s. II, vol. II, Roma.
Nibby A., 1849, *Analisi storico topografica antiquaria della carta dei dintorni di Roma,* Roma, pp. 98-106.
Nisio G., 2008, *Dalla leggendaria Alba Longa a Castel Gandolfo*, A.P.T. Castel Gandolfo.
Pellati F., 1940, *L'ingegneria idraulica ai tempi dell'impero romano*. Ist. Studi Roma, ed.
Perelli L., 1970-79: *Livio. La prima deca*, Torino.
Ponzi G., 1868, *Lettera a Pigorini sul modo di seppellimento di sotto uno strato litoide di peperino dell'intera necropoli Albana nel Lazio e dell'età cui debbesi riferire.* In Gazzetta Ufficiale del Regno, n. 326.
Raggi, 1879, *I Colli Albani e Tuscolani,* Ristampa Anastatica Arnaldo Forni Editore, 2005.

Other works consulted in drawing up this contribution

Andreatta D., Voltaggio M., 1988, *La cronologia recente del vulcanismo dei Colli Albani*. Le Scienze, n. 243, pp. 26-36.
Bersani P., Piotti A., 2001, *Ricarica artificiale della falda acquifera presente nel Vulcano Laziale in provincia di Roma.* L'Acqua, rivista dell'Ass. Idrotecnica Italiana, n. 3-2001, Roma.
Capelli G., Cecili A., De Rita D., Giordano, G., Mazza R., 1998, *La conoscenza idrogeologica del territorio quale presupposto alla gestione delle risorse idriche: il caso Colli Albani*. Giornata di Studio Regione Lazio Ordine dei Geologi, "Uso e Tutela delle Acque sotterranee". Viterbo, Aprile 1998, pp. 109 – 161.
Caputo C., Funiciello R., La Manica G.B., Lupia Palmieri E., Parlotto M., 1974, *Geomorphological features of the latian volcano (Alban Hill, Italy)*. Geologica Romana XIII.
De Angeli D'Ossat G., 1910, *Di alcune opere idrauliche romane*. Ann. Soc. Ingegn. Archit. Italiani, vol. X, pp. 225 sg.
De Angeli D'Ossat G., 1933, *Antiche opere di risanamento idraulico nelle terre di Roma*. Roma, p. 69, Da Vinci Ed., Roma.
De Francesco D., 1991, *S. Eufemia e il lacus Turni presso Albano dall'età tardoantica al basso medioevo* in Mèlanges de l'Ecole française de Rome. Moyen-Age, Temps Modernes T. 103, N. 1, pp. 83-108.
De La Blanchère M. R., 1889, *Un chapitre d'histoire Pontine*, Parigi.
De La Blanchère R., 1882, *La malaria de Roma et le drainage antique*. Melange de l'ecole française de Roma, vol. II, n.1, pp. 94-106.
Del Pelo Pardi G., 1943, *Bonifiche antichissime. La malaria ed i Cunicoli del Lazio*. Atti R. Acc. Georgofili, Firenze.
Fraccaro P., 1919, *Di alcuni antichissimi lavori idraulici di Roma e della Campagna*. Boll. Soc. Geogr. It, Serie V, p. 8, p. 186. 1957 ristampa con aggiunte Opuscola, Tipografia del Libro, Pavia.
Frederiksen M.W., Ward Perkins J.B., 1957, *The ancient road system of the central and mothern Ager Faliscus*. Pap. British Sch. Rome, 25, p. 67.
Frutaz A.P., 1972, *Le carte del Lazio,* Voll. II e III, Istituto di Studi Romani, Roma.
Judson S., Kahane A., 1963, *Underground drainageways in southern Etruria and northern Lazio*. Pap. British Sch. Rome, 31, pp. 74-99.
Lanciani R., 1879, *Di alcune opere di risanamento nell'Agro Romano eseguite dagli antichi*. Atti Acc. Dei Lincei, s.II, vol.II, Roma.
Lucidi E., 1796, *Memorie storiche dell'antichissimo municipio ora terra dell'Ariccia e sue colonie Genzano e Nemi*. I Lazzarini, Roma.
Medici F., 2005, *Laghi Albano e Nemi: carenza idrica e alterazione della qualità delle acque*, Geologia dell'Ambiente, SIGEA, Anno XIII, pp. 8 –11.
Medici F., 2007, *Laghi Albano e di Bracciano: bilancio idrico e valutazione dei prelievi*, Geologia dell'Ambiente, SIGEA, Anno XV, 2 – 2007.
Nibby A., 1819, *Viaggio antiquario ne' contorni di Roma,* Roma,
Nibby A., 1849, *Analisi storico topografica antiquaria della carta dei dintorni di Roma,* Roma.
Quilici L., 1974, *Forma Italiae, Regio I, Volumen Decimum, Collatia* De Luca Editore, Roma.
Ravelli F., Howart P.J., 1988, *I cunicoli etrusco-latini: tunnel per la captazione di acqua pura. Irrigazione e drenaggio* 35, p. 57.
Ricciardi R., 1940, *Le modificazioni apportate dall'uomo al suolo del Lazio*. Boll. R. Soc. Geogr. It., s VIII, vol. V, p. 445, Roma.
Secchi P., 1876, *Intorno ad alcune opere idrauliche antiche rinvenute nella Campagna di Roma*. Atti Acc. Pontificia dei nuovi Lincei, XXIX, p. 300.
Tomassetti G., 1910-1926, *La Campagna Romana*, Vol. II, p. 175 e Vol. III pag. 502 (ristampa A. Forni, Bologna).
Ventriglia U., 1989, *Idrogeologia della Provincia di Roma: Regione Vulcanica Sabatina*. Amministrazione Provinciale di Roma, Assessorato LLPP Viabilità a Trasporti, p. 480.
Ventriglia U., 2002, *Geologia del territorio del Comune di Roma*, Amministrazione Provinciale di Roma.