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Sez. di Napoli

SOCIETÀ SPELEOLOGICA ITALIANA

3RD INTERNATIONAL SYMPOSIUM ON UNDERGROUND QUARRIES

Napoli
Castel dell'Ovo
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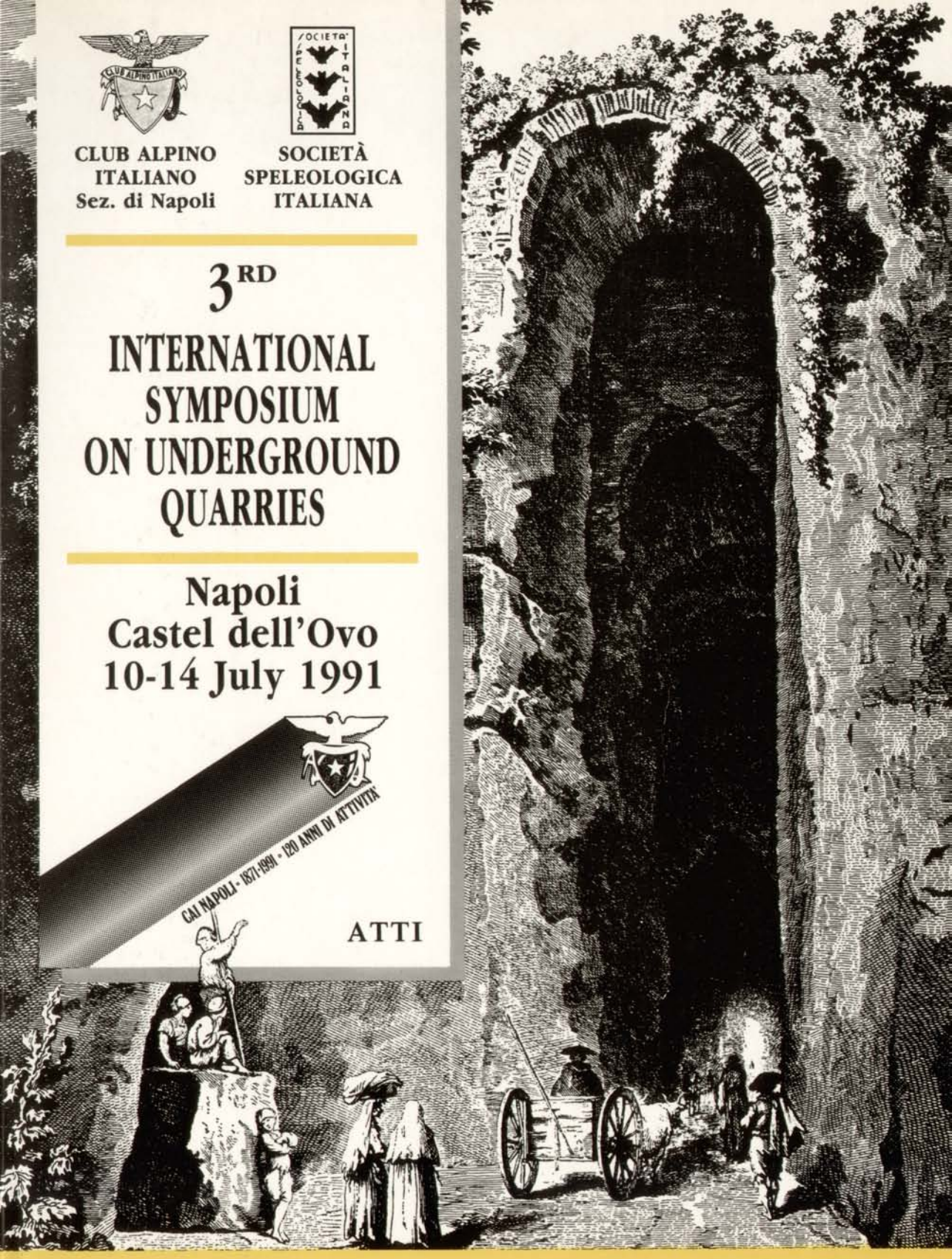

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A T T I

a cura di R. Paone e C. Piciocchi

Napoli - Castel dell'Ovo - 10/14 July 1991

NOTE ON THE ANCIENT EMISSARY OF LAKE NEMI

V. Caloi - V. Castellani***

Riassunto

Noi presentiamo e discutiamo la prova recente dell'origine e della evoluzione dell'antico emissario del Lago di Nemi, sui colli Albani presso Roma. Come risultato di venti anni di studi, molti nuovi particolari sono stati scoperti, gettando luce sulla storia del tunnel, sebbene abbiamo sollevato ulteriori problemi irrisolti.

Le nostre osservazioni non confermano la credenza diffusa della esistenza di sfiatatoi lungo il tunnel, suggerendo una tecnica comune al vicino emissario del Lago Albano. Infine discuteremo alcune prove dell'uso di una tecnica di pianificazione già adottata da Eupalino, nell'Isola di Samo, nel VI secolo A. C.

Introduction

The extension and the quality of human intervention on the territory operated, at least since the VI century BC, by the populations inhabiting Latium, appears impressive indeed. We refer in particular to those works aiming at the control of the water regime in lakes, ponds, valleys, together with the capture of springs, to be attributed very likely to a time well before the construction of the first Roman acqueduct. The macroscopic consequences on the territory can be appreciated in Figure 1, where the present day distribution of water basins is compared with the distribution before this ancient human intervention.

The amount of work accomplished suggests the presence of a dense population, trying to occupy all the niches of the territory; a population technically well prepared and confident in its own capacities, with a not negligeable degree of social and political cohesion on a large scale. In fact, it would be difficult to think that works of the dimensions of the artificial emissary of Lake Nemi, that we shall discuss in this paper, may have been planned and performed just by the small community in the nearby town of Ariccia or by some other small community along the course of the newborn river.

Historic and archeological sources suggest a strong increase in the population in the "Campagna Romana" in the VII and VI centuries, with "densities that will be be found again only in the imperial age, and the formation and consolidation of that system of urban centers and road network that will remain pratically unchanged as far as present time" (Quilici Gigli 1980). It is therefore possible that large scale works of drainage and water exploitation went together with the population expansion on both sides of the Tiber valley.

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Some general considerations on the historical and technical aspects of the cunicular work in Latium Vetus have been already presented elsewhere (Castellani and Dragoni 1989, 1991); in the following we shall concentrate on the Nemi emissary, which we have been studying for years, still discovering new details at every visit. The present paper gives a progress report, in which we intend to present and discuss the numerous problems brought to light during this long investigation.

1. The main features

In Figure 2 a map is shown of the Nemi-Ariccia cunicular system, together with the ancient emissary of Lake Albano. While for the digging of the Albano emissary we have the traditional date of 396 B.C. (see Coarelli 1981; the tunnel may be older, anyway), there is no mention of the tunnels at Nemi and at Ariccia in the known ancient literature. A widely accepted term "ante quem" is the construction of the temple of Diana Ericina, one of the great Latin sanctuaries, about the end of the VI century (Lanciani 1885; Coarelli 1981). The foundations of the temple lie on a small plane very close to the border of the lake, suggesting that the works for the temple began only after the regulation of the lake water regime made the place safe from floods.

The emissary was the subject of intensive studies in occasion of the works of reactivation in the year 1928, when the level of the Lake Nemi was lowered to allow the recovery of two Roman ships (Ucelli 1940). Notwithstanding this (supposedly) thorough examination, twenty years of visits to the tunnel have convinced us that many aspects of the manufact have to be carefully reconsidered, and many conclusions changed.

In Figure 3 the plan of the tunnel as given by Ucelli (1940) is shown. A curious fact is immediately evident: while no shafts have been mapped in the central part of the cuniculus, the text by Ucelli (and the corresponding plastic at the "Museum of the Ships") reports the presence of many of them. Careful inspections of the cuniculus confirmed beyond any doubts that no shafts are actually present in the main body of the tunnel. The origin of the diffuse belief in the need for shafts throughout the tunnel has to be attributed on the one side to ancient texts such as those by Vitruvius, Frontinus and Pliny, and on the other to the evidence from the later Roman acqueducts and from the Claudius emissary of Lake Fucino. The interesting point is that, on the basis of such a belief, a series of unexisting shafts has been attributed in the literature not only to the Nemi emissary, but also to the similar tunnel draining Lake Albano.

With respect to another important point we disagree with the conclusions by Ucelli. He stated that the two deviations from the straight line in the main body of the tunnel ("bypasses") were due to the presence of lava lenses, that the diggers had to avoid. But various pieces of evidence contradict this statement: first of all, the entire last part of the cuniculus is entirely dug in lava, so that a lava lens should not have bothered the ancient diggers. Moreover, the first bypass evidently coincides with a region of crumbling rocks, to the point that in the works of reactivation, this portion of the tunnel was completely rebuilt, and the old structure was covered with a new strengthening one. Also the second bypass does not confirm Ucelli's speculations: behind a well visible

wall that deviates the route, we found the ancient cuniculus (see later). In the following we shall enter in some detail into the structure of the Nemi tunnel, always keeping in mind that, as mentioned before, many misteries are still to be solved and many important aspects of the construction are still likely to be noticed.

2 The overall planning

Figure 4 gives a schematic plan of the cuniculus, reporting our main observations (direction of the digging, junction points, direction of air flows...). With reference to this figure, we shall make some comments.

2.1 The active branch

The water entered the tunnel through the side branch a1 - c1; the shape of the intersection indicates that this active branch was dug from the two end points, with meeting point at c2. On the whole, this section of the tunnel gives the impression of a working technique much less accurate than what generally found in the enterprise. The intersection has been reached with evident errors and difficulties. The cross section of the tunnel appears smaller and of roughly ovoidal shape, contrasting with the beautiful square section of the main body of the tunnel. Moreover, Ucelli's map shows (correctly) an evident error in the ground level of this branch, which results too low in its central part. This has been confirmed in a recent visit, when we found this branch flooded owing to a leak from the modern pipeline that runs along the cuniculus (Photo 1).

The occurrence of two shafts (Pa1 and Pa2) presents other problems. One shaft could be justified by the need of controlling the digging direction, though the short distances involved do not appear to require necessarily such a procedure. Pa1 was evidently used for some sort of bulkhead (Photo 2). It may be that Pa2 was built to fix the direction and, after that, Pa1 has been built to manoeuvre the bulkhead: however, the question is still open.

2.2 The winze

The entrance to the main body of the cuniculus by the lake border consists of an upper tunnel sloping down sensitively for about 30 meters. The cross section is almost square and very regular (Photo 3). At the end of this first section one finds a shaft (Pb) and, on the left, a cuniculus sloping down and progressively filled with earth. After this point, the tunnel goes on with a gentle slope, till the crossing with the active branch. The ceiling of the tunnel does not show any discontinuity across this point, while the floor makes a sudden step of about two meters. A small staircase of unknown epoch connects the two sections (Photo 4).

In our opinion, this situation gives convincing evidence that originally after the shaft Pb the tunnel ran continously through the mountain, and that only successively the level was lowered to allow a connection with the active branch (Figure 5).

As a whole, the characteristics of this section suggest quite naturally the following procedure: from the border of the lake a sloping tunnel was dug down to reach the planned level of the lake waters. Here a shaft was dug to connect the tunnel to the outside and so to transport inside the planned direction, as defined at the surface. The cuniculus to the left has a straightforward motivation: to allow the collection of the water (rain or other) entering either the winze or the shaft. If this hypothesis is true, we think that the cuniculus is a blind one, dug as long as the water table was reached; it could also be used to obtain information on the level of the water table, in order to dig safely the following section.

All this suggests that the original plan was to eventually (that is, after the completion of the tunnel) lower the winze down to the lake level, to capture progressively the water into the tunnel. Evidence for such a procedure has been already found in the Albano emissary (Castellani and Dragoni 1991). For unknown reasons, this plan was abandoned and changed into the already described by-pass to the lake.

2.3 The first bypass

The reason for this first bypass appears rather clear when one considers the map of this side tunnel. A similar structure was already found in the Fucino tunnel (Giovannoni 1906), suggesting a straightforward explanation. At a certain moment after the completion of the work, there was a landslide that obstructed the water flow (remember that we are in the region of crumbling rocks, where the tunnel has been rebuilt in 1928). Apparently, the initial part of the duct was thus filled with water. The ancient curators of the emissary were obliged to the dramatic effort of starting a reconnaisance from the valley side.

The plan of the bypass shows all the precautions with which the contact with water was reached: the approach could be done only through solid rock, so that various attempts were performed at increasing distance from the original cuniculus, and at a safe height over the new water level. Eventually, they succeeded in digging the tunnel in solid rock, catching the flooded section just near the original ceiling. After that, the excavation was deepened and water progressively removed from the main cuniculus. As a consequence of this procedure, the cross section of the bypass when approaching the main tunnel appears like a deep cut in the rock, more than 3 meters high. The eventual entrance in the main tunnel has the same height of the tunnel itself; the threshold is, however, at about 40 cm over the floor, since the purpose of the bypass was not to empty completely the emissary, but simply to allow the work of cleaning of the passage.

2.4 Closed side entrances

Just before and after the first bypass, one finds two low entrances on the opposite wall, closed with cemented stones (d1 and d2). The purpose and the epoch of these structures are unknown, though there should be a relation with the collapse of the tunnel; one may speculate about a previous bypass, opened to help in a risky region, that eventually collapsed.

2.5 *The second bypass*

A thorough exploration of this section has brought up many problems, for which we do not have even a partial explanation. The only clear thing is that the present bypass was dug from both sides, in such a way that the cuniculus from e5 eventually intercepted the one from e1. It is not possible to ascertain how far the branch from e5 is going on, since it is filled up with earth.

In this section we find two bona fide winzes (e6 and e7), inclined upwards and still connected with the exterior, as proven by the air flow through them; they appear filled up almost to the ceiling with stones not of local origin (see Photo 5: the stones look like lava fragments, while the surroundings are made of tufa). A similar system of obstructed winzes that, at the completion of the work, have become dangerous for the good maintenance of the main tunnel, has been found in the acqueduct at Palestrina (Castellani et al. 1990). There the side tunnels were isolated from the exterior with walls of stones, which filtered the intruding material, without blocking the water. We do not know whether the final walls blocking the discenderie in the Nemi emissary are the original or modern ones. Also in the Palestrina acqueduct the winzes are found in couples, for unclear reasons.

The outline of the ducts in the region of the second bypass is difficult to understand. Behind the wall in e1 one finds the continuation of the main tunnel (Photo 6); here the ground level increases due to loose material, but also the ceiling gets higher in two steps; the cuniculus ends in a well defined digging front. On the left, an aperture leads down for two meters to intercept a lower cuniculus, which connects in e5 with the main tunnel; it goes in the opposite direction, getting filled with earth. Both in e1 and e5 the tunnel appears continuous through the (later) obstructions; also the winze e6 and the branch e4 of the bypass looks well aligned (see Figure 6).

This complex scheme seems to require digging from both e1 and e5. From e7 to the meeting point, the digging was surely from the lake direction. So one is induced to think that a third front was opened in the enterprise, through e6 (and/or e7?), achieving the noticeable result of getting the right level and direction: a conclusion unexpected and difficult to accept.

The situation is complicated by other features: in the branch e4, there is a stone wall, with in front the end of a blind duct, suggesting that a cuniculus was dug from somewhere in that direction. In e2 we have a wall, behind which there is a small room, without clear continuations. Finally, just after this, a short abandoned bypass (see Figure 4), perhaps because of the bad quality of the rock. This feature has been sometime interpreted as the interception of a pre-existing cuniculus; such a hypothesis is unacceptable on observational ground; moreover, an older cuniculus at the very center of the mountain would imply an older emissary! Photo 7 shows the beautiful section of the tunnel beyond the second bypass.

2.6 *The meeting point*

The emissary was built with the technique of starting at the two opposite ends, trying to meet underground with the least mismatch. At the meeting point, in a hard lava flow,

one has a lateral mismatch of about 3 meters and an errror in height of about 2 meters (see Castellani and Dragoni 1991 for a discussion on the planning methods). In this region, the digging was performed through hard rocks with a special apparatus, discussed in Castellani and Dragoni, resembling techniques used till very recently for the construction of railroad tunnels.

An important fact that recently caught our attention is that in the vicinity of the junction, both branches deviate from the straight line and the height of the tunnel increases. This suggests us the application of the method supposedly used by Eupalinos in his famous acqueduct in Samos in 520 BC (see the thorough discussion by Kienast 1983). In Figure 7 we sketch the basic idea: in order to increase the probabilities of meeting, both branches bend in the same direction (to overcome errors in direction) and increase in height (to enlarge the cross section in case of errors in level).

Curiously enough, we find in Nemi a situation that resembles the one in Samos: at the meeting point, one of the two branches behaves "canonically" as expected, with one clear bending (Photo 8); the other branch instead shows a less clear behaviour, with "s" curves and a final abrupt connection with the other duct. Let us note that a meeting procedure in the Eupalinos' style is found also in the Palestrina acqueduct, suggesting strongly that the technique was of general use.

2.7 Pre-existing cuniculus

In g1 (see Figure 4) the emissary intercepts a pre-existing cuniculus (this time in reality!). This shows that, at the epoch of the realization of the tunnel, the techniques relative to water control through subterranean ducts were already developed in the region.

3. Discussion

As mentioned before, the shafts are found only at the two ends (as in the Albano emissary), in our opinion for the reason of getting the correct direction for the digging. One needs shafts to this purpose because of the impossibility of using the poles of the "coltellatio" below or at the level of the two entrances in the situation in Nemi. On one side, one had the lake; on the other, a not very gentle hillside. As pointed out to us by Dr. Kienast (private communication), if the slope is gentle enough, as at the northern entrance of the Samo tunnel, the "coltellatio" beyond the tunnel entrance can be easily used to give the underground direction.

As already mentioned, the original layout appears to have been the following: a short winze to reach the desired level, a shaft (Pb) to mark the direction, and digging of the main body of the tunnel as far as the intersection. The same at the opposite side with the shaft Pg. At the completion of the digging, the diaphragm toward the lake should have been cut and the lake water channeled into the emissary, as in Albano.

Instead, a lateral tunnel was open in cl, built with a much inferior technique both in the digging and in the planning (see the difficulty of meeting over such a short distance, the small and rough section of the cuniculus, and the imprecise level, as evident

from Ucelli's plan and Figure 5). Besides, the level of the main part of the tunnel was lowered noticeably. The reasons for this change in the original plan are unknown. One may speculate about a sudden decrease in the lake level; alternatively, there could have been an interruption in the work, when, as we saw, the portion near the lake was almost finished, perhaps for political or technical reasons. When the work started again, we had likely a change in technical direction.

If we compare the Nemi emissary with the other known tunnels of similar planning and size, we see that it reminds very much of the Albano emissary, as for the planning of the technical procedure. There are also elements in common with the acqueduct at Palestrina and the Fucino emissary, perhaps simply because similar difficulties require similar technical solutions, but likely also because of a common tradition.

At this regard, let us finally mention a possible scenario proposed by Coarelli (1991), that takes into account the political events at the epoch of construction of the Nemi emissary. The town of Aricia was at war against the Etruscans of Arrunte, son of Porsenna, who at the time was in some way the ruler in Rome. Aristodemus, tyrant of Cuma, came to help Aricia — and Cuma is a labyrinth dug in tufa. The Cumans came from Euboea, and their immediate neighbours were the Puteolans, originating from Samos, where Eupalinos dug in 520 BC his acqueduct. Arrunte was eventually defeated, but the Latin League took power only for a short period, till the battle at Lake Regillo. It may be that the Cumans were at the origin of the experienced diggers of the main body of the tunnel.

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Figure captions:

Fig. 1 - The area of the Alban Hills before the ancient lake regulation (a) and in present time (b).
Fig. 2 - The Nemi-Ariccia cunicular system and the emissary of Lake Albano.
Fig. 3 - The plan and the section of the Nemi tunnel as presented by Ucelli (1940).
Fig. 4 - A schematic plan of the Nemi tunnel reporting the main points discussed in the text.
Fig. 5 - A sketch of the suggested evolution of the enterprise.
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Fig. 7 - Kienast's suggestion on Eupalino's procedure when approaching the meeting point.

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2 - The shaft Pa1 at the beginning of the active branch as seen from the cuniculus.
3 - The tunnel in the upper part of the winze. A line of candles marks the axis of the tunnel. We feel that a similar procedure has been of help during the ancient digging.
4 - The staircase connecting the main tunnel to the winze, as seen from the main tunnel.
5 - The winze in e6, filled by stony rocks.
6 - The original tunnel beyond the wall in e1.
7 - The tunnel just beyond the second bypass. On the back the wall closing the original tunnel, e4 on the left and e6 on the right.
8 - The clear deviation of the tunnel when approaching the meeting point.

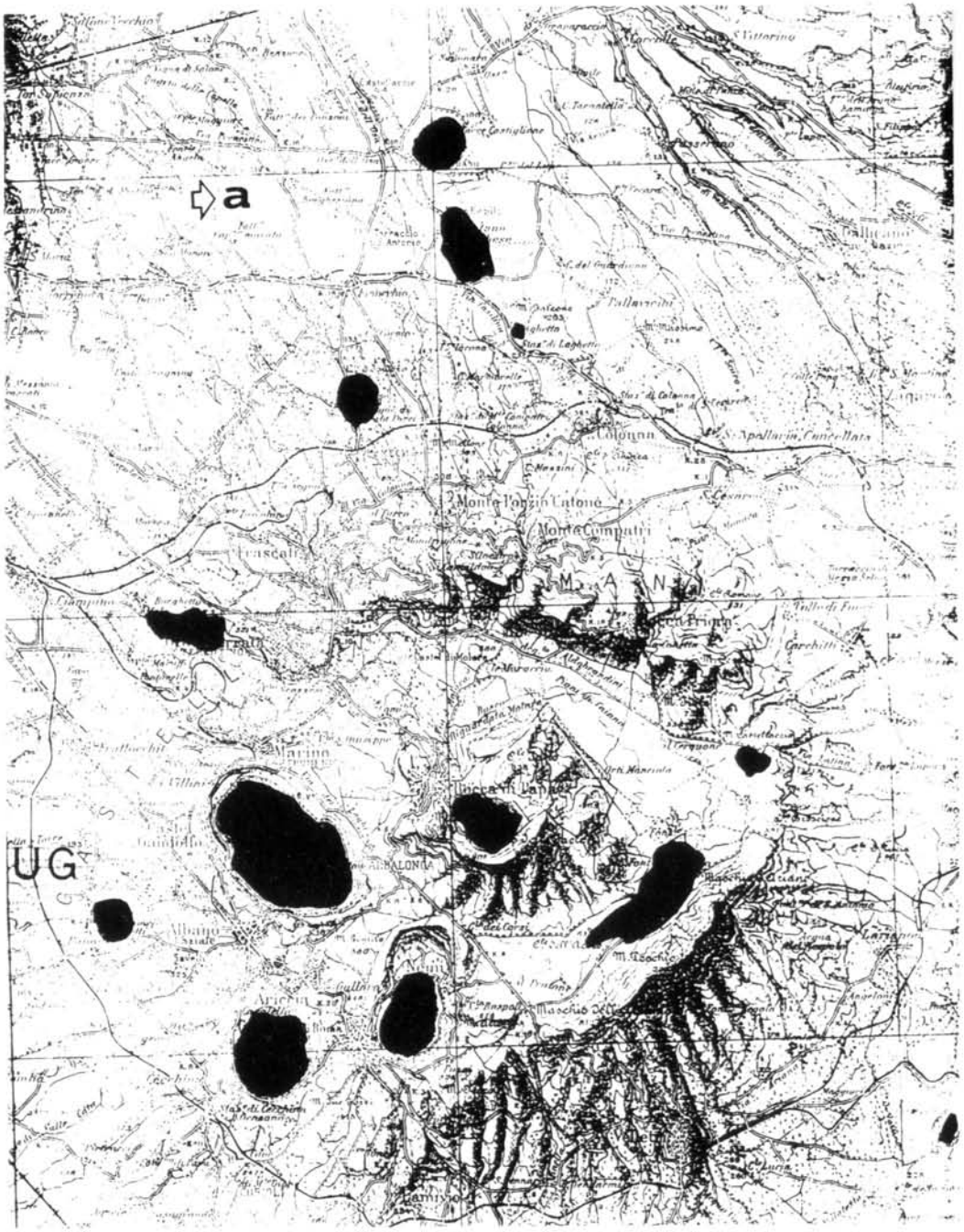


Fig. 1 (a)

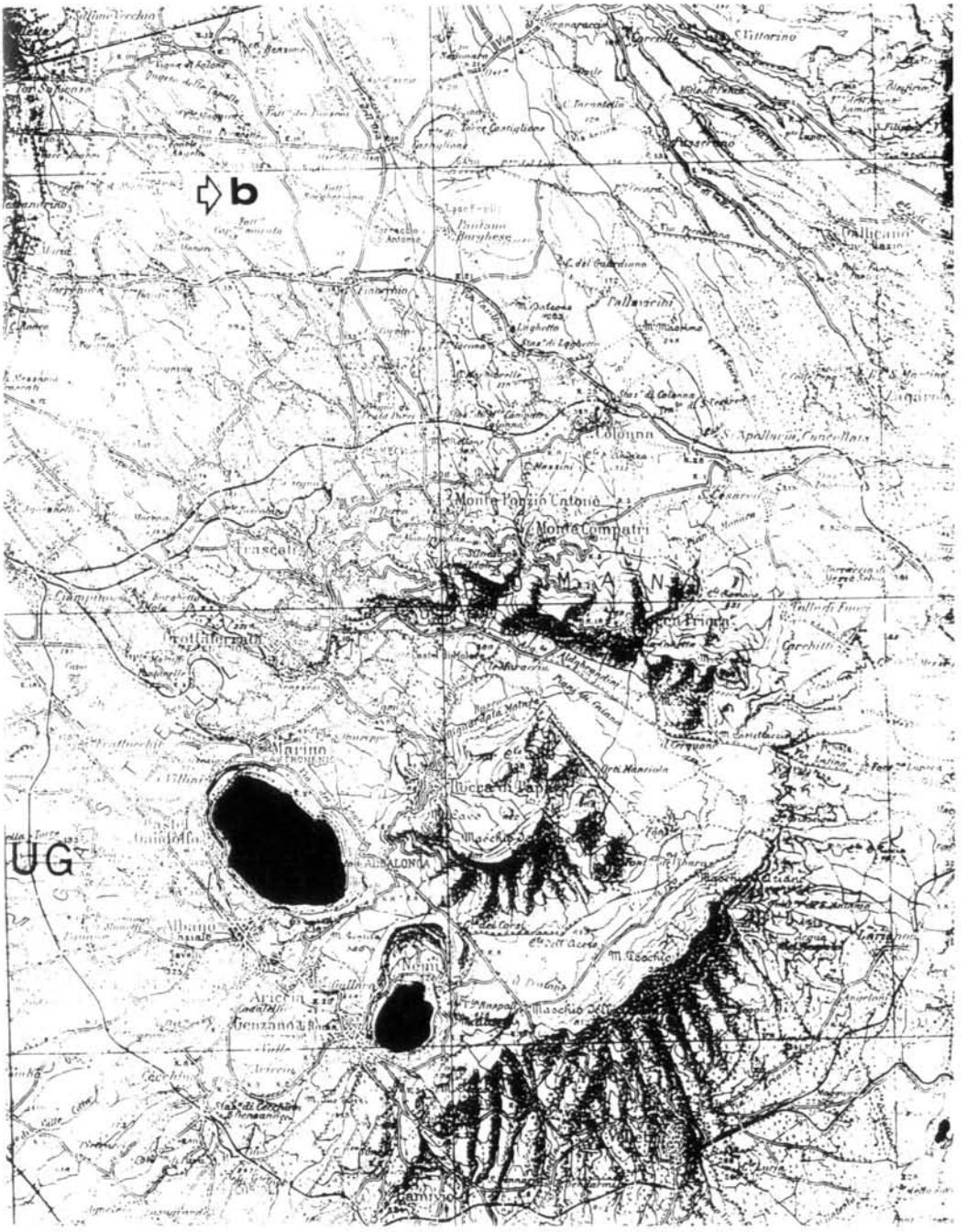


Fig. 1 (b)

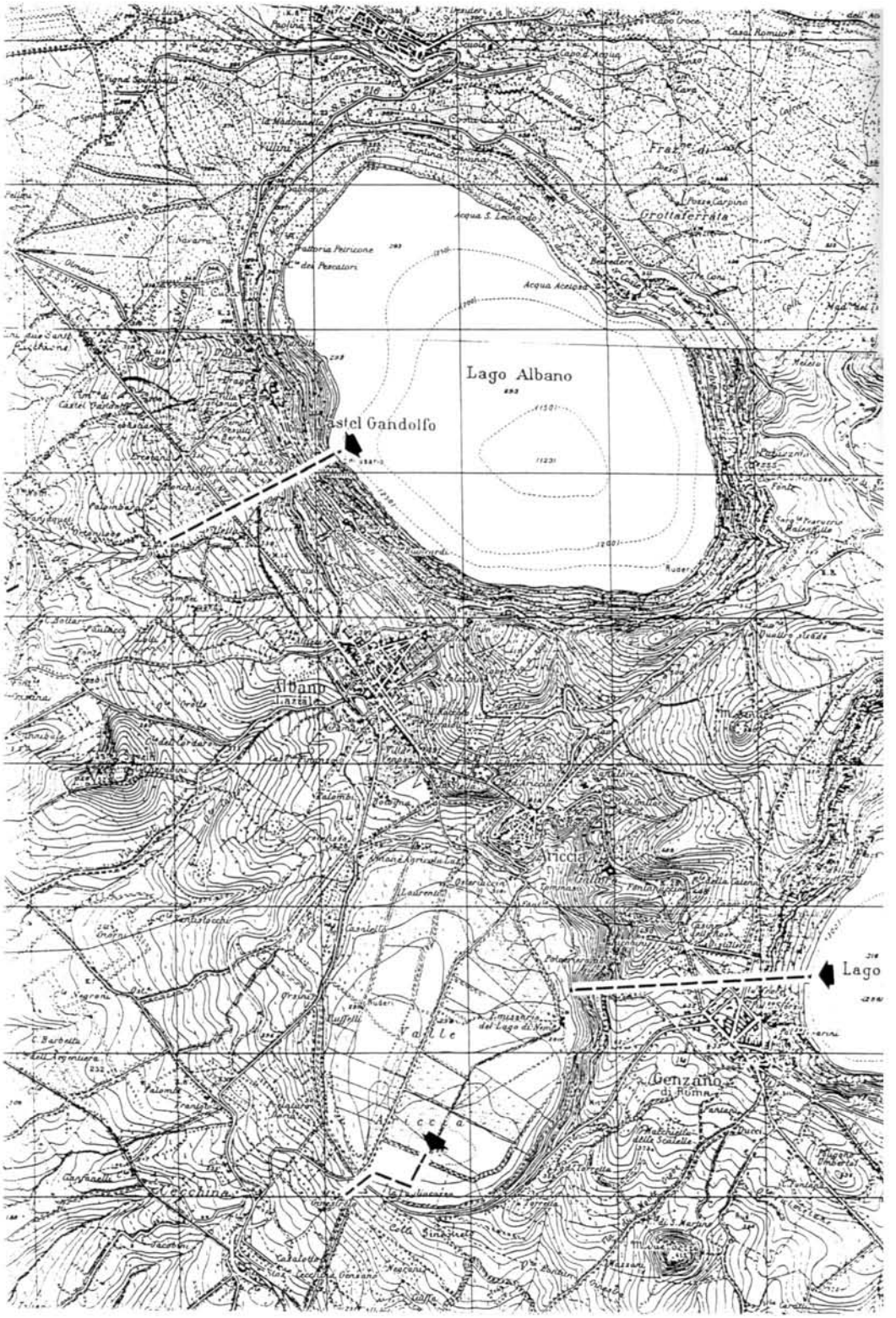


Fig. 2

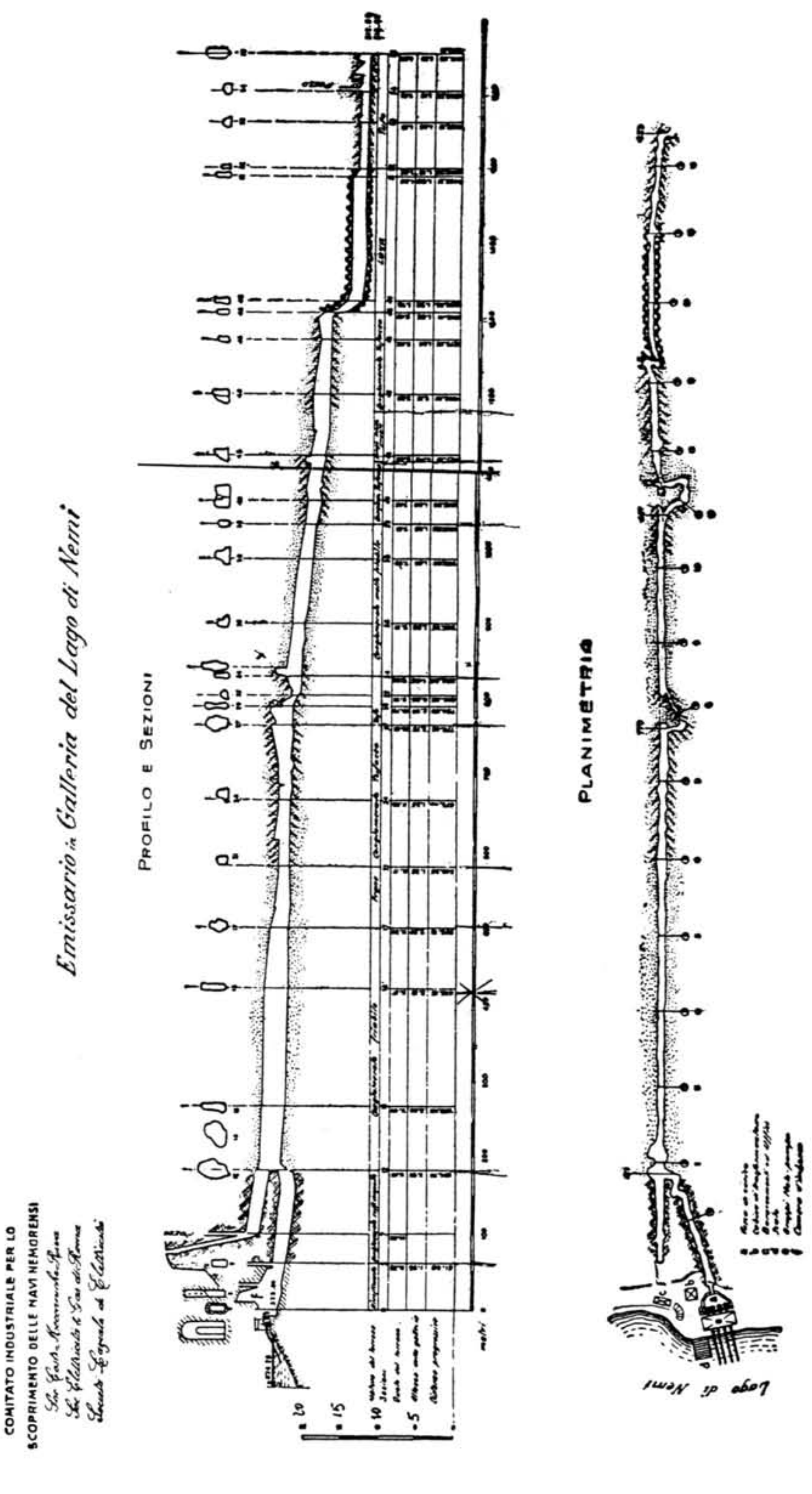


Fig. 3

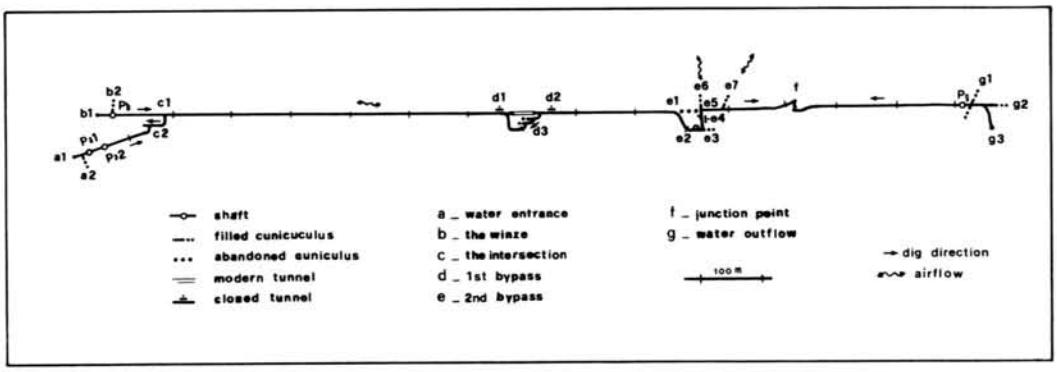


Fig. 4

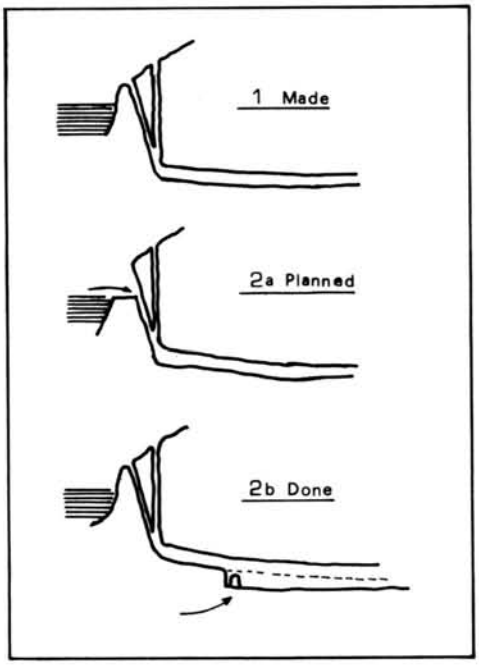
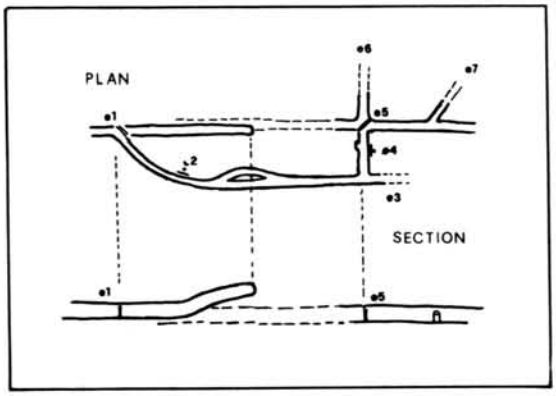


Fig. 5



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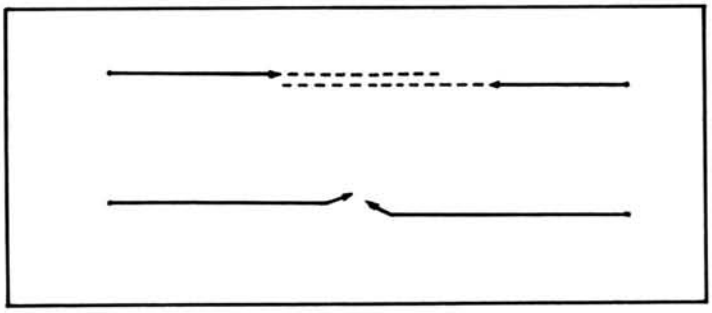


Fig. 7

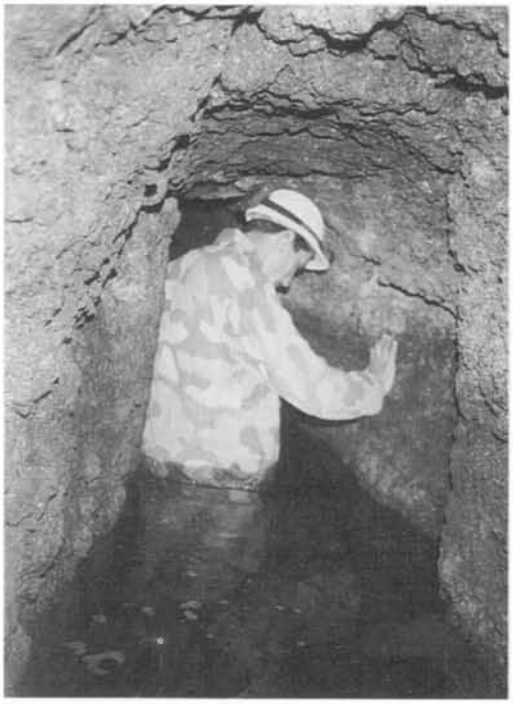
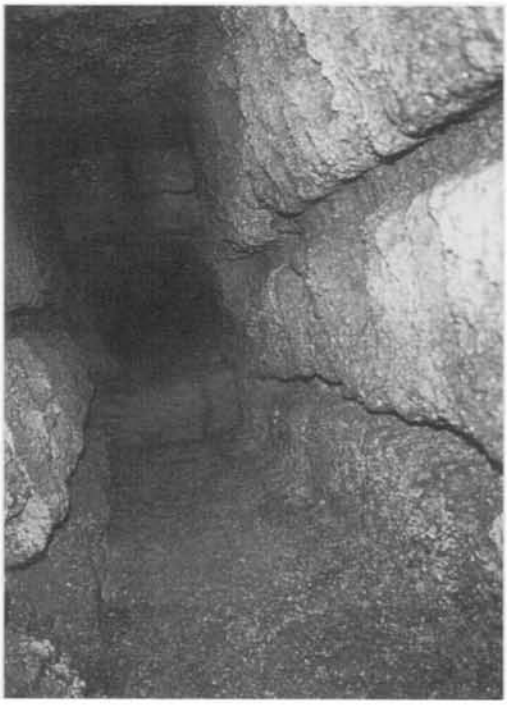


Photo 1



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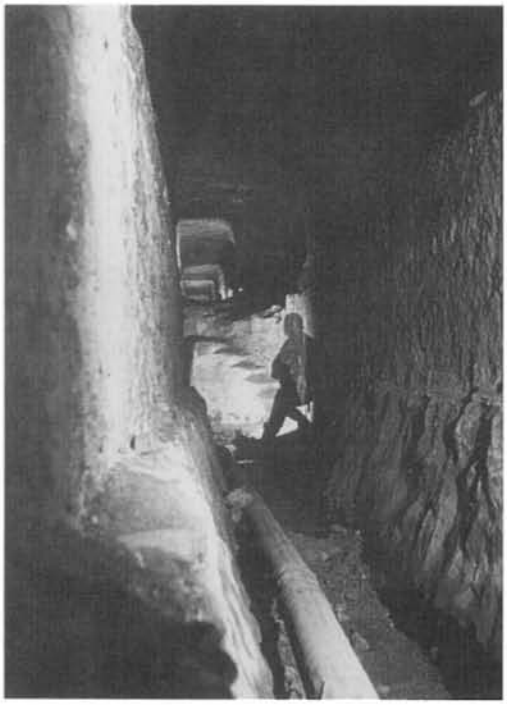

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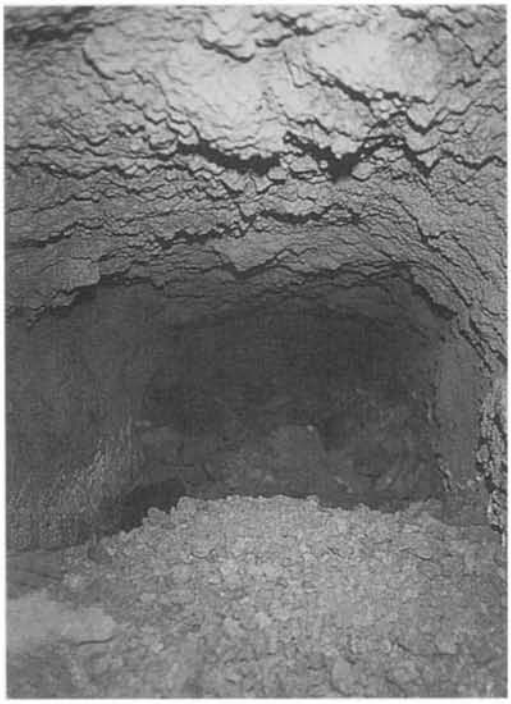

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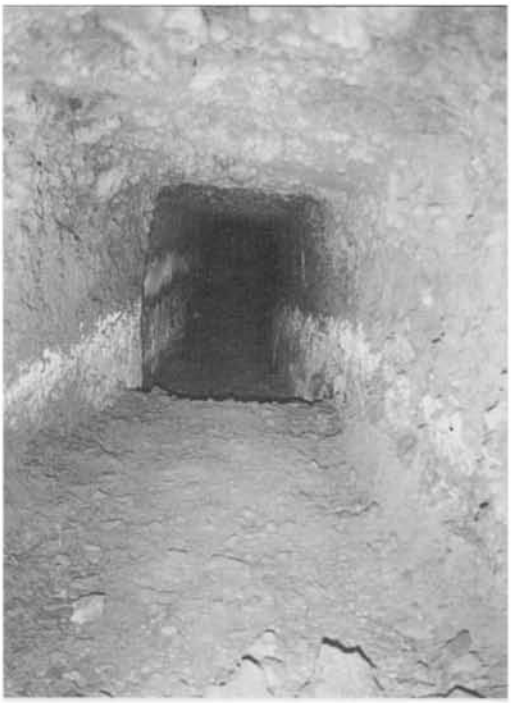

Photo 6

Photo 7

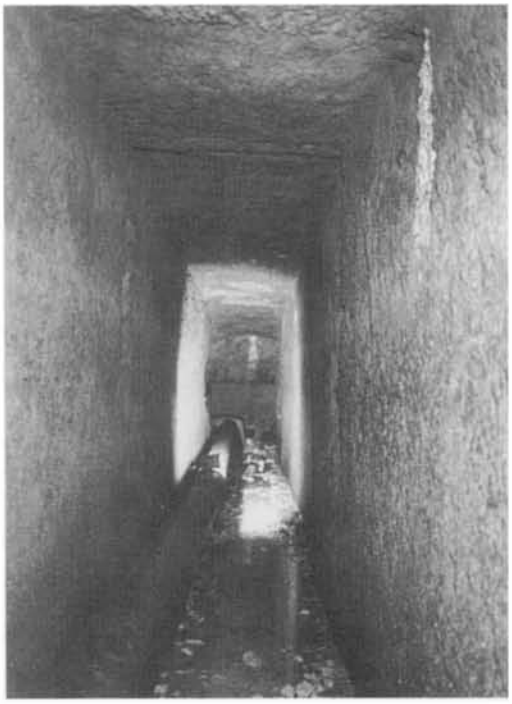

Photo 8