EVIDENCES FOR HYDROGEOLOGICAL PLANNING IN ANCIENT CAPPADOCIA

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Riassunto

L'ispezione del territorio di Göreme ha posto in evidenza che gran parte delle strette valli incise nei tufi appaiono regolate da sistemi cunicolari scavati in epoca imprecisata. È stato in particolare rilevato e studiato il sistema che regola la valle di Meskendir, procedendo ad una topografia del fondovalle nella quale è stato infine riportato l'andamento dei condotti sotterranei. Si constata che il fondovalle è stato liberato dalle acque di scorrimento e reso disponibile per le attuali intense coltivazioni grazie ad un lungo cunicolo che si sviluppa lungo il bordo della valle raccogliendo le acque che provengono dai sovrastanti rilievi per trasportarle, con un percorso di circa 3,5 Km, nella piana del villaggio di Çavusin. Tale condotto, indicato come "collettore principale", appare come il risultato della intensa erosione di un cunicolo originale che ha prodotto al presente gallerie dell'ordine di 3-4 m di diametro. Le tracce di scavo del cunicolo originale mostrano che il lavoro fu condotto a partire da diversi punti di attacco, portando i cunicoli ad incontrarsi nel sottosuolo. Questo sistema appare integrato da una numerosa serie di corti cunicoli inoltrati nella parete della valle sino a raggiungere ed emungere la falda acquifera. Piccoli sbarramenti all'imbocco di tali cunicoli creano all'interno delle riserve d'acqua distribuite con continuità lungo tutta la valle, utilizzate per le coltivazioni. Precise evidenze documentano che lo scavo di alcuni cunicoli presuppone uno scenario orografico profondamente diverso, indicando una antica ma non precisabile data per l'esecuzione di tali opere.

1. Introduction

The territory of ancient (and modern) Cappadocia is largely covered by rocks of volcanic origin. The extended banks of tuffs have been submitted to the natural erosion which gave origin to a well known peculiar landscape characterized by plateau, calanques and rocky pinnacles. In addition, along the course of history, these soft rocks have been submitted to an intense human activity directed to produce several kinds of underground rooms. Rocky churches and monasteries dating back to the Byzantine period are well known over the world; moreover in several places the cliffs of the plateau are scattered with the entrances of underground habitations which remained in use till very recent times.

In the last years, the attention has been driven to the occurrence of peculiar underground structures, whose origin is still under debate. One is dealing with surprisingly extended subterranean networks which, as in the well known case of Derinkuyu, can contain a hundred rooms scattered over eight levels, connected by a tangle of passages and with wells which take water some 80 m below the surface. Till now, no clear evidence has been found about the origin of these "underground towns", so that current evaluations range from the Byzantine era back to the II millennium B.C., if not earlier.

Since many years, the Commissione Nazionale Cavità Artificiali della Società Speleologica Italiana have programmed a series of missions in central Anatolia, devoted to the study of these "underground towns". During these missions, evidences have been collected for the occurrence of a further type of ancient underground structures, as given by the openings of small tunnels one may find scattered in the field, far from present or ancient inhabited centers. From a morphological point of view, these structures closely recall the ancient "cuniculi" which characterize a large portion of the volcanic terrain in central Italy, and which have been, and are still submitted to careful studies (see, e.g., Castellani & Dragoni 1990, 1992 and references therein). According to such an evidence, in the framework of the mission 1993 a special program was devoted to the study of these cuniculi, in order to gain information about their function and, possibly, about their origin, aiming to add a further example to the history of the development of tunneling in the ancient world.

According to a preliminary discussion with the colleagues of the Museum of Nevsehir, the occurrence of cunicolar systems in the region was strongly supported. With the help and under the guide of the local archaeologist Murat Gülyaz we performed a one-day quick look along the territory east of Göreme, collecting evidence that the valleys are all interested by extended cunicolar systems. According to such an evidence, we finally decided to take as a sample a suitable portion of the territory to be submitted to a careful investigation concerning the distribution, the function and the origin of these structures. To this purpose, we choose the upper portion of the Meskendir Valley, whose location is shown in Fig.1.

In the following sections we will report the results of such an investigation, discussing the evidence for an ancient and surprisingly developed system for the hydrogeological control of the territory.

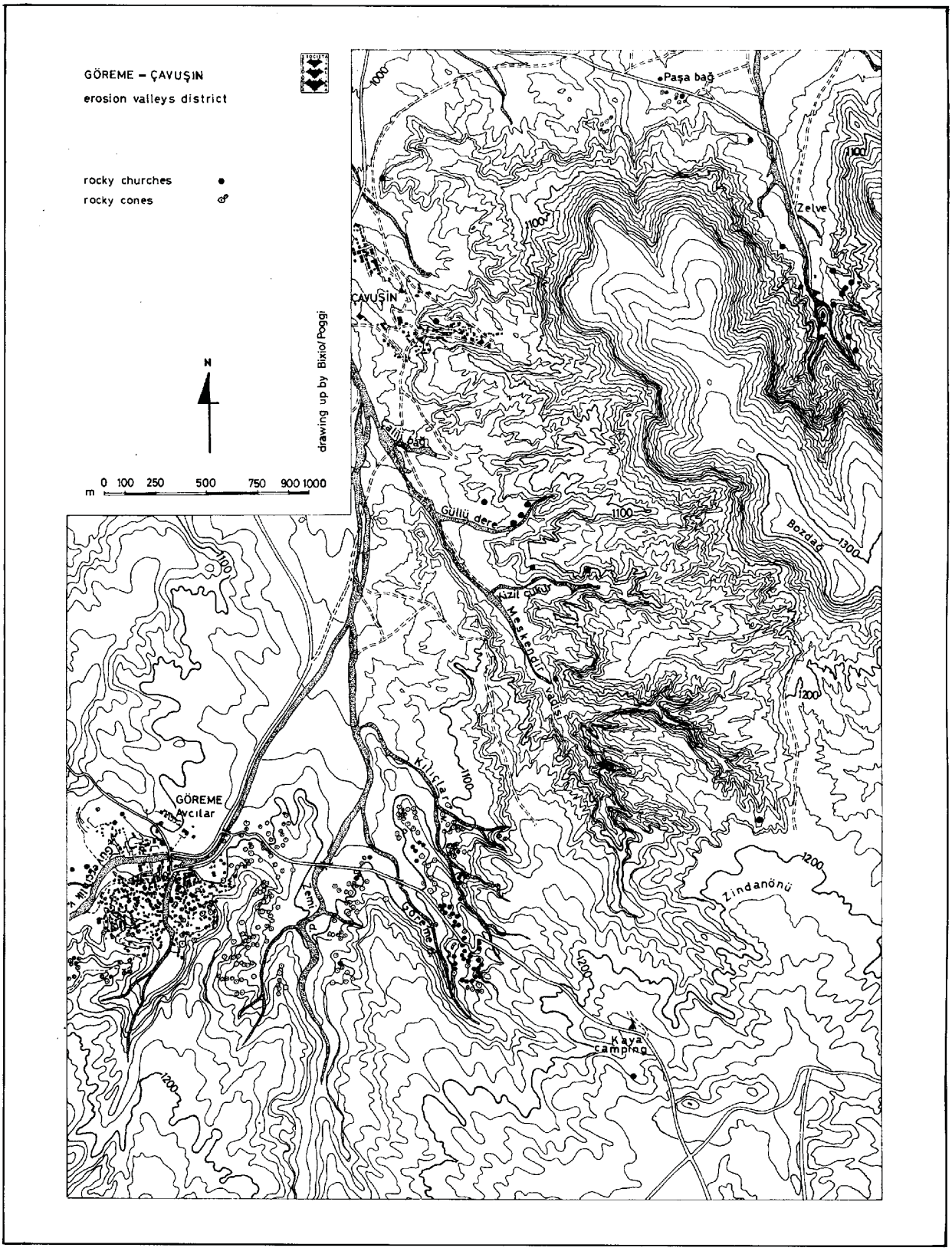

Fig. 1
Overall view of erosion valleys district and location of Meskendir Vadisi. Çiliklar Vadisi and Göreme Deresi in Avcilar (Göreme) and Çavusin regions (Nevsehir province).
Vista generale del distretto delle valli di erosione e ubicazione delle valli di Meskendir, Kiliçlar e Göreme nella regione tra Avcilar (Göreme) e Çavusin (Provincia di Nevsehir).

2. The cunicolar systems of Meskendir

In its upper portion the valley of Meskendir appears as a deep canyon excavated by the water in the overlaying bank of white tuffs. The center of the valley is made up of small flat fields, intensively cultivated with fruit trees (mainly apricots) and vegetables, progressively rising North to South through a series of artificial terraces. These fields are in general immediately bordered by the high cliffs of the surrounding banks of tuffs, deeply channeled by the action of meteoric water. No watercourse is present during the summer, nor evidences can be found for a central torrent bed. The inspection of the area revealed that water for farming is derived from numerous cuniculi tunneling the cliff just along the borders of the central fields; the mouths of a large (dry) tunnel appears from time to time at the foot of the cliff.

To put order in the observations and to investigate the role of the many cuniculi scattered along the valley , one needs to locate the cuniculi in the framework of the local orography. According to such an evidence, as a preliminary step of the investigation we produced a topographic survey of a selected portion of the area. By means of the polygonal network we have reconstructed the contour of the valley, as defined by the border of cultivated fields. With reference to this topography, Fig.2 gives a general picture of the water regulation system present in the area.

One recognizes the occurrence of the two main systems we will discuss below, a first one devoted to collect the natural flux of meteoric water, diverting the water either along the foot of the cliff or into a large underground tunnel transporting the water down in the valley. A second system is formed by numerous short tunnels opening at the foot of the cliff devoted to reach the watertable to supply water for farming. One find both active and old dry tunnels. As a general rule, the active ones at their opening have a wall (a dam) about 1 meter high, thus producing an internal water basin which provides a water reservoir attained through a small aperture at the foot of the wall, easily closed with a bung when not in use.

On the whole, when one takes into account not only the two quoted networks of tunnels but also the terracing and the dry walls reported in the same Fig. 2, one reaches the conclusion that the possibility of farming in the valley is due only to the human intervention, which diverted the water stream from the bed of the valley in order to leave room for cultivation. Doubtless, the natural bed of the original torrent had to be rearranged in order to obtain cultivable fields. Interestingly enough, we found that modern farmers are still excavating small tunnels at the foot of the cliff just in order to spread the resulting soil on the fields, because of its fertility. One may suspect a similar procedure also at the time of the original water regulation, for which the soil obtained by digging the tunnels was utilized to rearrange the bed of the valley in a terraced sequence of cultivable fields.

As for the age of such a system, the situation appears rather intricate. Some of the small drainage tunnels could be of a rather recent origin, though we collected from local people information about their maintenance but no information about their original excavation. However, as we will discuss later on, some dry drainage tunnels show the effects of such an impressive erosion which cannot be the result of a short period of time. Such a (qualitative) conclusion is reinforced by the evidence that the large tunnel which now acts as primary collector of the main stream was in origin a cuniculus with a cross section of the order of 70x180 cm. How much time was needed to transform the original cuniculus in a gallery 4x4 m wide?

3. The main collector

Inspection of the previous Fig. 2 shows how all the branches of the valley have been cleared from streaming water by means of a network of main collecting channels diverting the water on the border or below the border of the valley. A small branch West of the main branches appears regulated by a tunnel (coordinates A9 in Fig.2) which directly takes the water away from the branch to flow it into the collector of the nearest branch. The origin of this system is a short canalization, shown in Fig.2, which collect the water directly at the foot of a deep natural channel driving meteoric water down along the cliff.

As a first important point, let us notice here that the situation shown in Fig. 2 can be taken as a fully representative sample of the works existing all along the valley, which runs northward for about 3.5 km in the direction of the village of Çavusin. As a matter of fact, we followed the main collector all along the valley, along a dirty road which - in the lower portion of the valley- often uses the collector as a practicable tunnel. This may give an idea of the amount of work that was applied to turn the original valley in a fertile territory.

As already mentioned, the tunnels of the main collectors appear in general rather large, with transversal dimensions of the order of 4-5 meters, both in width and in height, and with a shape governed by erosion processes, giving to the tunnel the typical form of a natural gallery. However, one

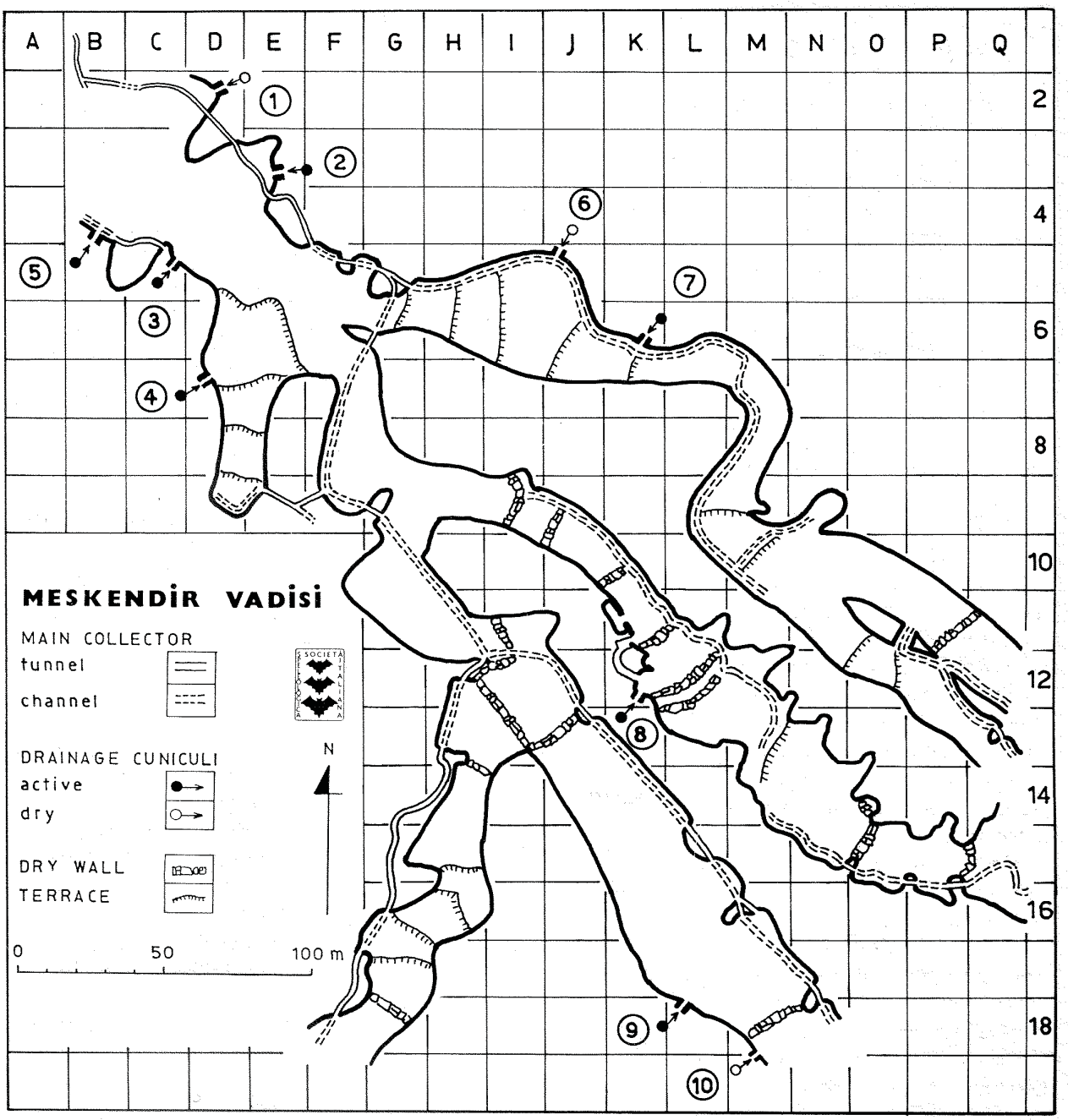

fig. 2

Map of the surveyed area of the Meskendir valley, with the hydraulic network. The numbers show the position of the draining tunnels.

Mappa del settore studiato della valle di Meskendir, con la relativa rete idrica. I numeri corrispondono ai cunicoli di emunzione della falda acquifera: 1) Albicocco, 2) Lucerna, 3) Tronchetto, 4) Albicocco II, 5) Passerotto, 6) Ginepro, 7) Maggiociondolo, 8) Turco, 9) Scala, 10) Zanzare.

knows that natural galleries are a rare and peculiar occurrence in tufaceous terrains, nor one may expect a natural gallery following closely a valley for some kilometers. Thus an artificial origin appear beyond any reasonable doubt. As a matter of fact, in many portions of the tunnel one clearly recognizes on the roof the remains of the original cuniculus, whose inferior portion has been deeply excavated and enlarged by water erosion.

For unknown reasons (but probably for a peculiar local hardness of the rock), one may find the original cuniculus well preserved at coordinates H14, where one finds the further evidence that the cuniculus was excavated from opposite sides, the point of junction being marked by the sudden variation in the direction of the cuniculus just at the quoted coordinates. However, the rather erratic direction of the tunnel in the previous portion (G14-15) seems to suggest that the dig was based on a temptative procedure guided by a rough perception of the digging direction rather than on precise topographical planning. As a whole, one derives the feeling for people already experienced in tunneling cuniculi, knowing that the sound of the stroke of a digging hammer does propagate across the rock, allowing the connection if the two cuniculi to be intersected are not too far from each other.

As a further relevant point, one finds precise evidences that the present structure of the main collecting system is only the very degraded remain of the original structure. As an example, the morphology of the open channel connecting the mouth of the tunnel in G5 with the cuniculus of the "Ginepro" and, further on, with the cuniculus of the "Maggiociondolo" strongly suggests that we are in presence of an ancient cuniculus whose external wall has been disrupted by erosion, finally producing a open channel running along the border of the cliff, but still below the present surface of the field.

Such an indication for a deep modification of the original hydrogeological and orographical situation is supported and confirmed by the evidence that in several locations, as in G5 and in H13, one finds along the present cliff the marks of excavation a few meters above the present surface, indicating that we are in presence of the residual inner wall of an ancient conduct, now completely disrupted and obliterated by water erosion. Similar evidences tell us that where there is now a border channel, there was at the origin a rock massive enough to allow and to justify a tunneling. No doubts this implies that the dimension of the missing rock was much larger than the dimension of the tunnel. One easily concludes that the original orography was sensitively different from the actual situation which, in turn, appears largely to be the result of the peculiar erosion induced by the artificial tunneling of the territory.

One may finally notice that a cuniculus with the reduced dimension quoted above could hardly support the flux of water collected during heavy rains by the system of valleys. As a matter of fact, one finds evidences that in some locations the original cuniculus has been submitted to further enlargements. This is particularly evident in the rocky bridge in G6, where on the roof and on the walls one finds evidences for two subsequent interventions, the first one enlarging the original cuniculus to a width of about 1.3 m, followed by a further enlargement bringing the cuniculus to the actual transversal size of about 2 m.

4. The draining tunnels

As already indicated, along the border of the valleys one finds a series of draining tunnels whose locations have been reported in Fig.2. To better distinguish and identify the various cuniculi, we found helpful to name the cuniculi according to some characteristics, in general from the name of the tree growing near the opening of the cuniculus. According to such a nomenclature, Fig.3 reports the maps of the internal developments of the cuniculi. As a general rule, one finds that all the cuniculi have been dug to reach the water below the surrounding hills, producing in such a way a reservoir of water to be used for farming. The rather sinuous course of the typical tunnels shows that this has been done following more or less evident underground streams. It is also probable, and in same case evident, that the actual tunnels are the result of subsequent excavations, suggested by the need of reinforcing a dwindling stream.

In the following we will briefly describe the characteristic of the various cuniculi. As a whole, one finds that rather short tunnels have been able to supply the required amount of water, an occurrence that in our feeling did play an important role in the history of the valley.

1) Cuniculus of the "Albicocco" (=Apricot). One finds an apricot tree right at the entrance of the cuniculus. The tunnel is dry and soon filled by soil. For the first 6 meter the roof is sloping down. If the floor follows a similar slope, the cuniculus could drain the play toward an unknown collector rather than draining the watertable toward the plain. However, we have no real information on the matter. The cuniculus is well preserved, with scarce evidence of erosion.

2) C. of the "Lucerna" (=oil lamp). This is the most extended cuniculus we found in the area. The

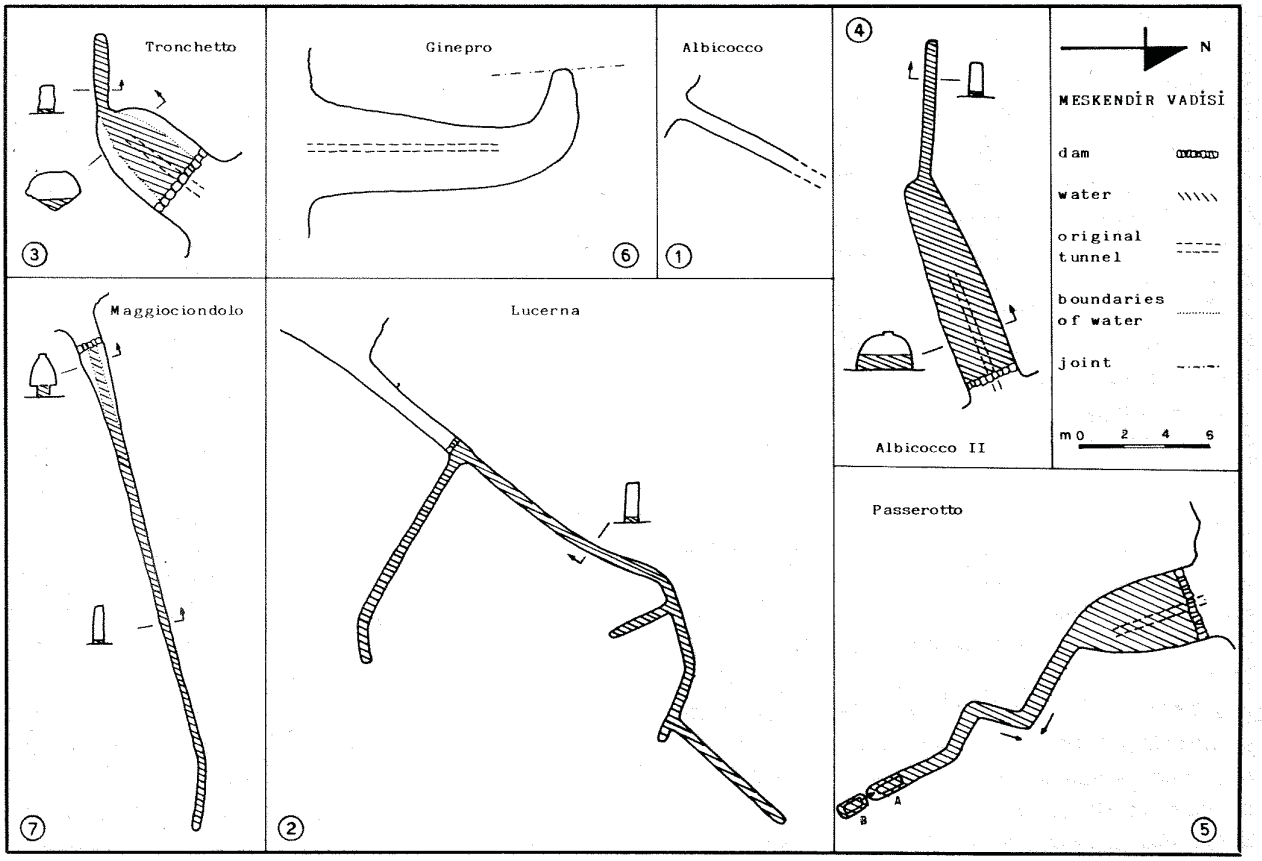

Fig. 3
Maps of the drainage cuniculi. - *Planimetrie dei cunicoli di emunzione.*

first portion, till the dam, appears largely eroded. Beyond the dam a network of cuniculi well preserved, following two main branches and a small water basin, mainly supplied by the right branches. The path of the cuniculus can be easily understood in term of various subsequent attempt to catch water. On a niche near the dam, a small metallic lamp, covered by rust. A local farmer told us that the system was recently reactivated by his family. Near the entrance of this cuniculus, one finds a short cuniculus crossing the rocky promontory immediately South the cuniculus (E4). Nearly in the same location a further cuniculus is draining the field into the underlying collector.

3) C. of the "Tronchetto" (little log) and

4) C. of the "Albicocco II". Both these cuniculi have a quite similar shape and, presumably, a quite similar history. An external dam is followed by a first room a few meters large. However, on the roof one finds the trace of the original cuniculus which was not larger than, about, 70 cm. At the bottom of this room, a new, well preserved cuniculus, evidently done in a later time to improve the water supply.

5) C. of the "Passerotto" (=sparrow). In its external portion this system appears quite similar to the previous two cuniculi. However, this system has been connected with a more internal system formed by two adjacent wells from which a cuniculus has been conducted till reaching the more external branch. Curiously enough, the two parallel wells are separated by a continuous diaphragm with only a small communication about 1 m above the floor. One may attempt the following explanation: the first system was made by more external room and, separately, by the well A in Fig.3 devoted to serve the overlaying fields. Because of the decreasing amount of water in the cuniculus, this was connected with the well. However, following the connection the well became useless because of the decreased water level. Thus well B was dug, allowing a connection with the previous system only for water level larger than about 1 m.

6) C. of the "Ginepro" (=juniper). This is an old drainage cuniculus now completely dry. A large gallery is turning left after about 12 m to reach a joint in the rock, were evidently water was coming from. This suggests that when talking about underground water we cannot properly refer always to a watertable. As usual, on the roof the clear track of the original cuniculus. The problem again arises of how much time was needed to enlarge a cuniculus

70 cm wide in a cave of about 4 m ?

7) C. of the "Maggiociondolo" (=laburnum). A rather long drainage cuniculus, not wider than about 50 cm, turning right in its last portion. The final wall, where the work was stopped, tells us how the digging was done: a vertical strip about 10 cm wide and with a similar depth was first excavated on one side of the tunnel. Then the remaining front was disrupted taking advantage of the previous strip. One finds that such a digging procedure was quite general, since we found very similar evidences in other tunnel and in some underground rooms (the pigeon-houses) excavated along the cliff. Erosion at the mouth of the cuniculus is in a very first stage. It appears that erosion is at work essentially on the portion of the cuniculus above the water level and near the entrance. As a matter of fact, the submerged portion of the cuniculus appears always well preserved, whereas both walls in the corresponding upper portion appear near the entrance eroded up to a further 50 cm. Such an evidence strongly suggests to us that weathering should play a relevant role in the evolution of the tunnels, according also with the very low temperatures (more than 10 degrees below zero) reached during the winter in this high altitude land. In this case, it would follows that the degree of weathering would be fairly proportional to the time elapsed from the digging, with little dependence on the raining regime.

8) C. of the "Turco" (=Turk). A typical dam at the border of the cliff closes a room of about 5 meters of diameter with a water basin a bit less than 2 meters deep. On the bottom left, a small tunnel, like the one already found in the cuniculi of the "Tronchetto" or "Albicocco II". On the roof at the bottom of this tunnel a small passage in connection with an irregular room again opened to the surface. A few meters North of the mouth of the cuniculus, the opening of further underground rooms whose floor lies about 2 meters below the floor of the previous basin. The evidence for the lack of water in these last rooms convincingly demonstrates the impermeability of the rock and thus, the lack of a real watertable in the area.

5.Discussion and conclusions

Collecting the results reported in the previous sections, one finds the evidences that Meskendir valley , in its present status, is the result of a heavy

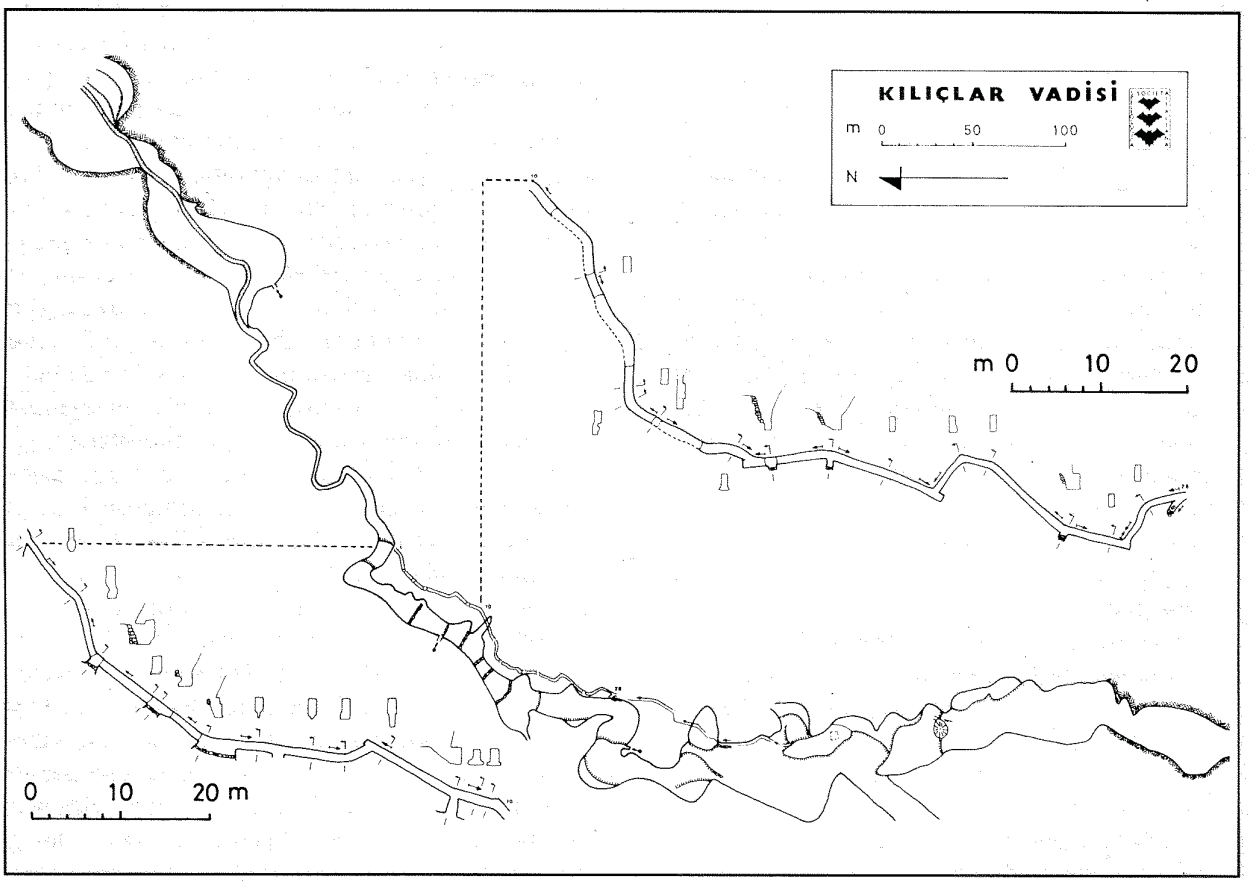

Fig. 4

Map of Kiliçlar valley, with plan and cross sections of the main collector (segments 1-28).

Planimetria della valle delle spade (Kiliçlar), con la pianta e le sezioni trasversali del collettore principale (segmenti da 1 a 28).

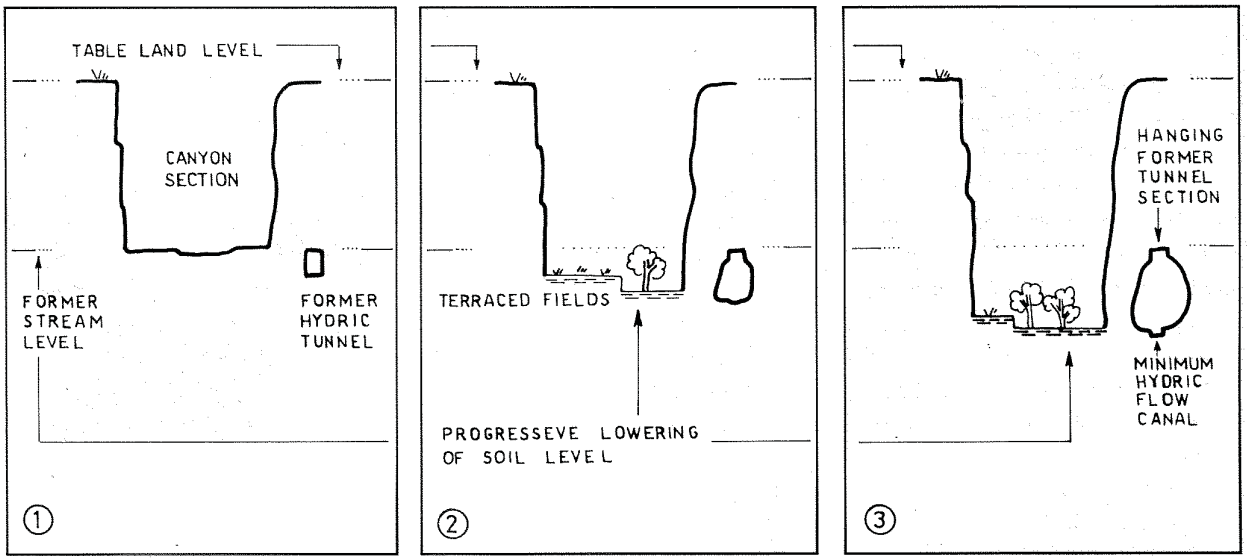

fig 5
Morphological evolution scheme of an hydric installation into a canyon (Avcilar: erosion valleys district).
Schema dello sviluppo morfologico di un sistema idrico in un canyon (Avcilar: distetto delle valli d'erosione).

work performed in unknown times. As a result of these works, an underground collector underpassing the valley was used to capture the natural torrents, clearing in such a way the fields from water streams and making them available for farming. Moreover, during the survey of the collector we found the recurrent evidences that -as expected- the tunnel was reached by a series of small cuniculi devoted to clear the fields from the surplus of rain water.

The problem arises of what is justifying such a heavy work. In our feeling the answer is likely to be found in the drainage cuniculi. As a matter of fact, the Cappadocian plane during the summer is far from being rich of water. An occurrence which makes difficult the growing of trees and/or vegetables, allowing mainly cereals and dry farming (see, e.g., Ballatore 1974). On the contrary, it was realized that the canyon valleys cut in the white tuffs gave access, with small effort, to valuable reservoir of water to be used for farming. Thus these valleys, when cleared from the torrents, could be transformed in the garden of Cappadocia, providing quite a lot of valuable and precious food.

Who and when performed this work? We have no answer to this question. We can only notice that not only our valley but, as far as we know, practically the totality of neighbouring valleys has been submitted to similar modifications (for example, see Fig.4: Kiliçlar vadisi). This tells us that the job was not a sporadic episode, but the goal of a people owning the territory for a not small number of generations. A people which were organized enough, and maybe free enough, to devote its efforts for a long time to such a major intervention on its territory. Historians could tell us if and when a similar scenario has been realized.

We already found that the evidence for deep erosion tells us that we are in presence of an ancient job, though it appears difficult to better precise the meaning of "ancient". However, in order -at the least- to promote a discussion on the matter let us in the following advance some working hypotheses. The lack of memory about the excavation of the draining tunnels, if confirmed, should indicate that the last excavations were conducted not later than - at least- a century ago. If this is the case, and if the erosion is fairly proportional to the elapsed time, the comparison between the cuniculi of the "Maggiociondolo" and of the "Ginepro" could indicate that the latter is much older, with an age that one may guess not lower than several centuries.

Much more impressive has been to us the evidence that the collectors show to have been excavated within a orographic scenario quite different from the present one. In addition to the discussion already given, let us discuss the evidence from the bridge at G6 and the following portion of the collector in G5. It appears that this system, that now transports the water flowing on the surface, has been underescavated by water by no less than 2.5 m with respect to the original floor of the tunnel. As a consequence, one has to admit that at the origin the surface of the fields was locally higher by no less than 2.5 meters. Adding this evidence to the quoted evidence for the disappearance of the large masses of rocks originally containing the cuniculi now found in open air, one

may conclude that this could be the work of millennia rather than centuries (Fig.5).

As a further point, the dimensions reached by the collector again tell us of a long period of time. We already found similar phenomena in the volcanic tuffs of central Italy, where the original cuniculi have been enlarged by water erosion to form caves roughly as large as the Meskendir collector. In all cases (see Castellani 1975) we were in presence of underground conducts where water has been continuously flowing since the VII century B.C., i.e. for more than 2500 years. Naturally, we have no clear idea how far the differences in rocks and/or the difference in the hydrogeological regime can affect this time. However, let us conclude that we would be extremely surprised if the system would be later than the Byzantine era. On the contrary we would be not surprised if the system would be even much earlier.

Acknowledgment: it is a pleasure to thank here Stefano Rubuano who cooperated with us in surveying a portion of the valley.

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