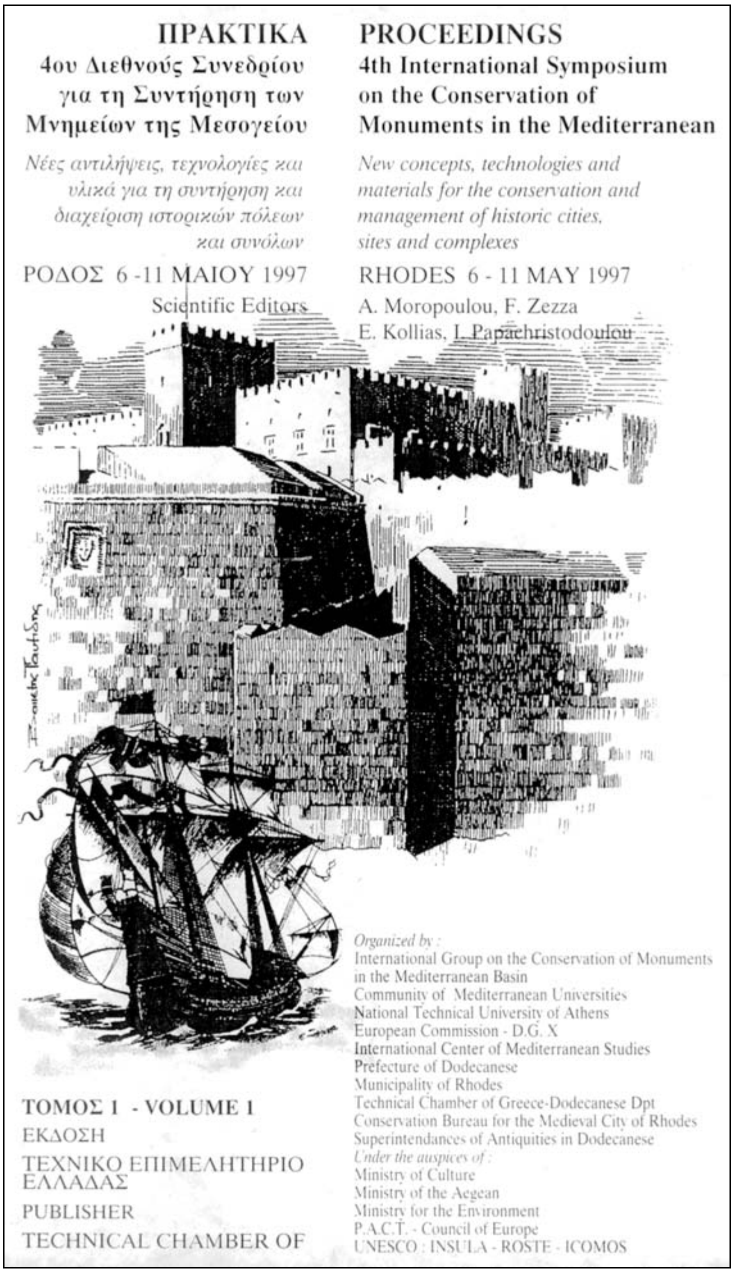
ΔΗΜΟΣΙΕΥΣΗ No 43



CRHISTARAS, B., MARIOLAKOS, I., FOUNTOULIS, I., ATHANASIAS, S., DIMITRIOU, A., (1997). **-** Geotechnical input for the protection of some Macedonian tombs in northern Greece. *In Proceed. Of IVth Intern. Symposium on the conservation of monuments in the Mediterranean basin.*(Rhodes 6-11 May, 1997), v. **1**, 125-132.

GEOTECHNICAL INPUT FOR THE PROTECTION OF SOME MACEDONIAN TOMBS IN NORTHERN GREECE

By Christaras B.[1], Mariolakos I.[2], Foundoulis J.[2], Athanasias S.[1] & Dimitriou A[1]
1. School of Geology, Aristotle University of Thessaloniki, Greece
2. School of Geology, Kapodistrian University of Athens, Greece

Abstract

The present paper is a preliminary approach to the geotechnical and hydrogeological problems observed in three Macedonian Tombs of Lefkadia area, located in the County of Imathia (N. Greece). In the study area, the damages are related to a) the presence of an important aquifer, which overflows the floors of the monuments, mainly during summer, and b) differential settlement phenomena. Weathering phenomena of the walls are also observed, due to the inside humidity. In this paper the present geotechnical conditions are described and some preliminary ideas are proposed, as a contribution to the effort of preservation and protection of these monuments.

Introduction

The present paper deals with the investigation of the high humidity conditions and the differential settlement phenomena observed in the Krisis, Anthemion and Lysson & Kallikles Macedonian Tombs (Petsas[1]), located between Kopanos and Lefkadia villages, on the national road connecting Naoussa with Skidra and Edessa Cities, in Northern Greece (Figure 1). These monuments are of the 3rd c. B.C. and contain interesting frescos; they are not collapsed but they present important damages.

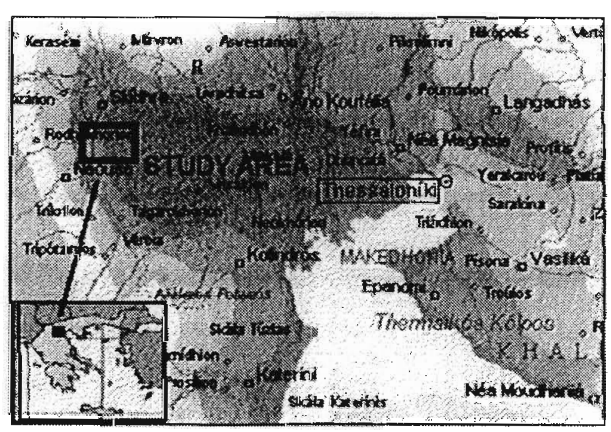


Figure 1. Location map of the study area

The damages are related mainly to the groundwater, which, very often covers, the floor of the monuments. Differential settlements and humidity are related to the influence of the groundwater in the area. The aim of this study was to investigate the cause of damage and propose methods for the drainage and protection of the monument.

The Toms

The Macedonian Tombs of the area, (found outside the walls of the ancient city Mieza) were located along the road connecting Pella, the capital of Macedonia, to Mieza, which was one of the important commercial cities during the period of the 4^{th} - 2^{nd} c. B.C. This kind of Tombs, was not used for burying ordinary people but only members of the King family or other important members of the Macedonian Kingdom of that period. The Tombs are now, buried in the soil, because of the sedimentation. All these monuments are constructed using big blocks of travertine that is very abundant in the area (Figure 1).

In our investigation, the Tombs of Krisis, Anthemion and Lysson & Kallikles were investigated by geotechnical point of view.

-The Krisis Tomb (early 3^{rd} c. B.C.). It is one of the more important Macedonian Tombs, by architectural point of view, presenting a principal facade of two floors (Figure 2). On this facade the Ionian style is alternated by the Doric one. The monument is constructed with big blocks of travertine (Figure 3) and the facade is covered by exceptional frescos of war subjects. The construction is not collapsed, however the facade and the other parts present weathering and

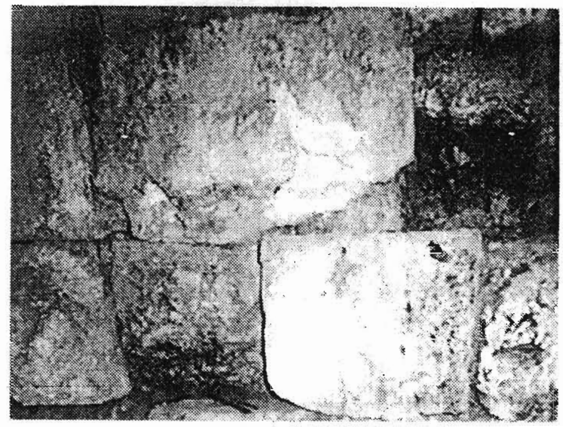


Figure 2. All the Tombs are constructed with travertine

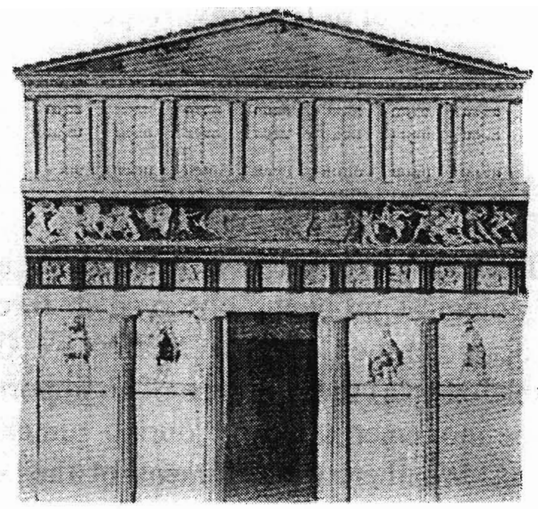


Figure 3. The Krisis Tomb (Alamani[2])

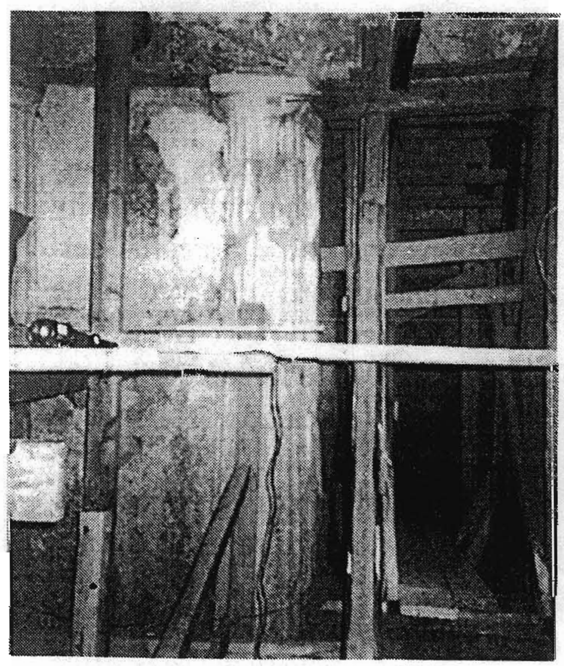


Figure 4. The facade of the Krisis Tomb presents significant damages

stability problems (Figure 4).

-<u>The Anthemion Tomb (3rd c. B.C.)</u>. The Tomb consists of two rooms and presents Ionian style architecture. The principal facade and the inside walls are covered by frescos, the colors of which are in rather good condition The monument presents important weathering and static damages (Figure 5). The front door of the monument is of marble (Figure 6)

-<u>The Lysson & Kallikles Tomb (200 B.C.)</u>. This Tomb is considered as an exceptional architectural sample of that period. In the monument, 22 cavities, containing ash-pans were located on the wall. The Tomb is still buried in the soil and contains frescos of significant importance (Figure 7).

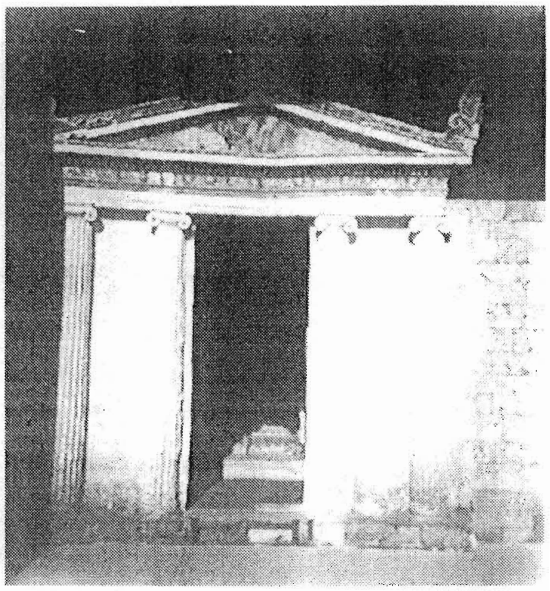


Figure 7. The Anthemion Tomb

Figure 5. The marble front door in Anthemion Tomb

Geological settings

Geologically, the area is located in the western part of Almopia zone (Kilias & Moundrakis[3]). The surrounding area of the Tombs, is consisted of recent alluvial deposits with fans and telus cones as well as pleistocene lacustrine and continental deposits, with clay, loam, sand, conglomerates and travertine (IGME[4]).

The absolute thickness of these deposits is difficult to be determined, in the area, but it is estimated to about 100 m. The thickness of these deposits increases to the East (about 200-300 m).

Mount Vermio, located to the West of the Tombs, is consisted of serpentinite and Upper Cretaceous limestones.

Hydrogeological settings and geotechnical conditions

The mountainous limestone masse located to the West of the Tombs (Vermio mountain) is considered to be the reservoir of the rivers and aquifers of the study area (Athanasias & Soulios[5]) . The significant permeability of the soil also contributes to the enrichment of the aquifers.

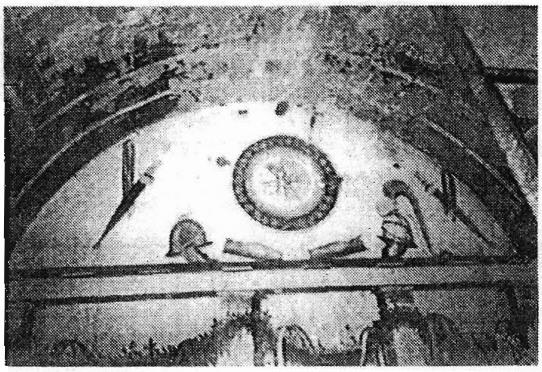


Figure 6. Lysson & Kallikles Tomb

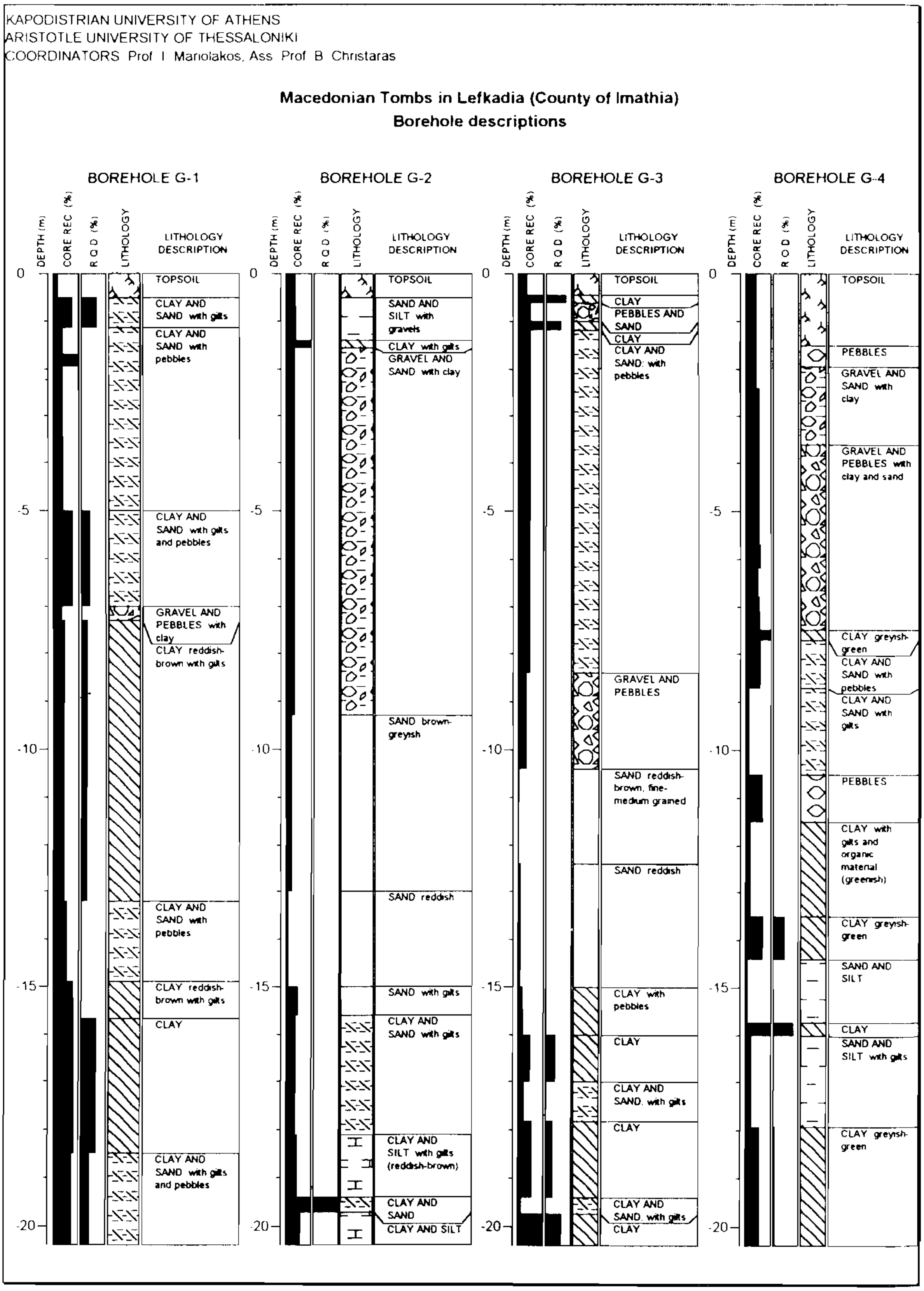


Figure 8. Borehole cross sections at the sites of the Tombs

Four boreholes (G1-G4, depth: 20 m) were constructed, in order to investigate the geotechnical and hydrogeological features of the soil (Krisis Tomb: G1, G2, Anthemion Tomb: G3 and Lysson & Kallikles Tomb: G4). The data of this investigation are given in the borehole sections of Figure 8.

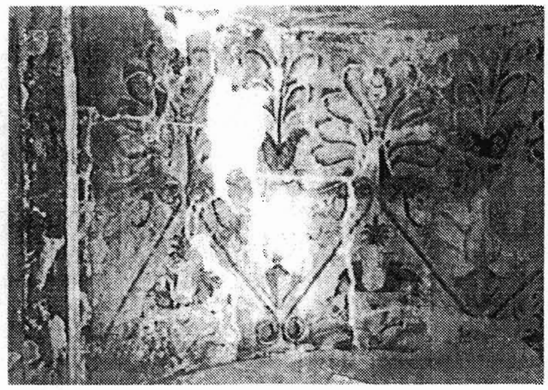


Figure 9. Paint on the upper part of the arc in front of the entrance in the second room of the Anthemion **Tomb**

According to the borehole data, the formations in which the Tombs are buried, are consisted of alluvial deposits with clay, sand, gravel and conglomerates. These materials were accumulated in the area by the activity of Arapitsa and Siasaki rivers which cross the area in very short distance from the Tombs.

Figure 10. Krisis Tomb. The differential settlement caused failures and displacements on the front wall

The soil materials are generally loose and coarse grained, presenting, active porosity and permeability that vary depending on the grain size distribution of the soil. The core recovery and the rock quality designation (RQD) values also vary regarding to the grain size and the cohesion of the soil materials.

So, in the borehole G1 (placed at the north side of the Krisis Tomb), with the exception of a gravel zone, at the depth from 7 to 7.3 m, the material can be generally characterized as clay or clay and sand with more or less clayey composition, depending on the depth. The RQD values depend from 25 to 75 % in these zones, but decreases to 0 % in the loose parts of the column. The permeability varies from 10^{-2} m/s (high), in the gravel zone, to 10^{-4}-10^{-5} m/s (intermediate to low) and 10^{-6}-10^{-7} m/s (low to very low) in the clayey sand and clayey zones respectively.

In the borehole G2 (placed at the south side of the Krisis Tomb), the grain size distribution of the soil is not similar to that of the G1. An upper silty-sandy part (depth 0.5-1.4 m) overlyes to an impermeable clay zone, of 10 cm thick, and a high permeability ($\cong 10^{-2}$) thick gravel zone follows, until the depth of 9.3 m. An also permeable sandy zone follows, until the depth of 15.6 m, where a lower permeability zone with clay and sand starts.

In the borehole G3 (placed at the west side of the Anthemion Tomb, which is located at about 200 m to the East of the Krisis Tomb) a gravel zone of 50 cm is found just bellow a topsoil bed of 0.5 m and an underlying clayey zone of 20 cm. This gravel is stopped by an impermeable clayey zone of 20 cm, underlayed by a thick zone of clay and sand, until the depth of 8.4 m. This zone is totally broken presenting intermediate permeability. Just bellow this zone a high permeability gravel zone starts again until the depth of 15 m, where an impermeable clayey zone starts.

The borehole G4, is located in some distance (900 m) to the west of Krisis and Anthemion Tombs, near the The Tomb of Lysson and Kallikles. It is placed at the west side of the Tomb, which is still buried in the soil and only a small opening at the roof is used for entering inside. According to the borehole data, the ground materials in the area consist mainly of gravel interrupted by thin layers of clay or clay and sand.

The depths of the groundwater level in these four boreholes, measured once a month, give the following mean values: G1: 7.513 (7.3-7.6), G2: 7.123 (7-7.215), G3: 7.011 (6.965-7.075) and G4: 4.698 (4.575-4.925). The ground level is practically horizontal. The difference of the water levels in the above boreholes, determines an eastward water flow direction, related to the limestone of Vermio mountain, located to the West of the study area. The higher elevation of the water level, in the borehole G4, is also related to the vicinity of Arapitsa river.

The foundation levels of the Tombs are lower than the water table in the area. So, the water overflows the floors of the monuments, causing damages related to a) the weathering of the walls and frescos (Figure 9) and b) differential settlements and instability of the construction (Figure 10). The depth of the groundwater table is not constant during the year but decreases during summer, when irrigation activities start. During this period a big quantity of surface water enrich the aquifer rising the water table. For this purpose the main problem of our study is to find out a reasonable way to drainage the tombs in order to protect them.

Suggested measures

According to the constructed borehole profiles (G-1, G-2, G-3 & G-4), the groundwater level in the area it is not connected with a single aquifer layer. If that was the case, then, depending on its depth, the layer could be probably isolated in order to protect the tomb monuments. On the contrary, the groundwater table in the area is an outcome of different overlaid aquifers, met in various depths in every borehole (G-1: 0.5-7.3 m, 13.2-14.9 m, 18.5-20.4 m; G-2: the hole borehole consists of water-bearing formations; G-3: 1.2-15 m, 17-17.8 m, 19.4-19.75 m; G-4: 1.5-7.5 m, 7.7-11.5 m, 14.4-15.75 m, 16-17.9 m). Considering the above-mentioned facts, the suggested solutions should aim to the isolation and water-resistance of the tombs themselves and must reach a depth below the depth of tombs' floor.

1) Construction of drainage trenches.

According to this solution, a peripheral drainage trench will be excavating around every Macedonian tomb, in order to collect the groundwater and carry it to the pumping area. From this area, using pumping equipment, the water will be shifted to the surface drainage or irrigation network.

The depth of the trench must be at least 1-1.5 m bigger than the depth of the tomb's floor and its width should be approximately 1 m. The side of the trench that is closer to the tomb must become water-proof (with the use of concrete, geo-fabrics or any other water-proof material), while its interior will be filled with a high permeability material (using a sand and gravel mixture). The floor of the trench should be constructed with an inclination, in order to assist the transport of the collected groundwater. Its inclination grade must be proportional to the amount of water that needs to be drained out (1-3% inclination should be adequate). The material that fills the trench, working as a filter, will increase the water velocity in the interior of the trench and, with the assistance of the inclined floor, it will drive the groundwater to the pumping area.

A pumping machine placed in the pumping area, will automatically begin to operate when the water level inside the trench exceeds a certain security depth (app. 0.5-1 m below the depth of the tomb's floor).

The advantage of this method is the very limited maintenance cost which practically concerns only the pumping equipment, while the rest of the construction does not require any kind of maintenance. The major disadvantage is the high excavation cost for the construction of the trenches.

2) Construction of pumping boreholes.

According to this solution, a series of boreholes will be drilled around every tomb. The use of these boreholes for pumping out the groundwater, will have as a result the decrease of the water level, at least locally. The number and the diameter of the boreholes must be proportional to the amount of water that needs to be pumped out, in order to keep the water level below the desired depth (app. 0.5-1 m below the depth of the tomb's floor). The necessary amount of water that needs to be pumped out can be determined with a pumping test performed in a borehole drilled especially for that purpose. In that test, a correlation will be made between the water discharge of the borehole and the resulting draw-down of the water level. From the pumping boreholes, the water will be shifted to the surface drainage or irrigation network.

Depending on the groundwater flow direction, the boreholes network must have higher density towards the flow direction and lower density towards the opposite direction. The pumping boreholes will automatically begin to operate when the water level exceeds a certain security depth (app. 0.5-1 m below the depth of the tomb's floor). The number of the boreholes needed, taking into account and the above-mentioned presuppositions, it is estimated to 3-5 boreholes per tomb, with a certain number of back-up units (which will be used in a case of failure or maintenance of the major ones) included.

The great advantage of this method, compared to the previous one, is the low cost that is needed for the construction of a series of small-depth (12-15 m) boreholes. On the contrary, the disadvantage is the maintenance cost of the boreholes and the pumping equipment which, combined with their large number, it will be much higher than the one of the previous proposed method.

Conclusions

The conclusions of our investigation can be summarized as follows:

1. The studied Macedonian Tombs present important weathering and settlement problems.
2. The damages are related to the presence of an important aquifer near the foundation level of the Tombs. In some periods the groundwater covers the floors of the Tombs.
3. The soil where these Tombs are buried is highly permeable, consisting mainly of gravel and clayey sand, alternated, in some cases, with thin layers of clay.
4. Two methods are suggested for the drainage of the Tombs. The first refers to the construction of drainage trenches around the Tombs while the second refers to the construction of pumping boreholes. The second method is too much chipper than the first.

References

1. Petsas, F. (1966). The Tomb of Lefkadia. Archaeological Society, Athens, 179p.
2. Alamani, V. (1995). The ancient Mieza. Kopanos, Lefkadia, Naousa. Municipality of Naousa & IZ Ephoriate of Prehistoric & Classic Antiquities, Thessaloniki, 24p.
3. Kilias A. and Moundrakis D. (1989). The tectonic Pelagonian nape. Tectonic, Metamorphose and Magmatism, Proc. 4^{th} Congr. Geol. Soc. Gr., Bull. Geol. Soc. Gr. XXIII, 1, Athens, pp. 29-46.
4. IGME (1982). Geological map of Greece, sheet Veria, 1:50.000.
5. Athanasias S. and Soulios G. (1995). Study of the discharge in the karst ground water system of St. Nicolas springs, in Naousa. Proc. 3^{rd} Hell. Hydrogeol. Congr., Iraklio (in press).