Supporting the under touristic development Poliphimos cave in Maronia, Thrace

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Abstract. Poliphimos Cave is an under development site for touristic purposes. The cave is full of beautiful stalactites and stalagmites and it is of great palaeontological and touristic interest. In the present paper the stability conditions were studied regarding to wedge and planar failures. For this purpose, all the tectonic data were determined and recorded separately for each site in the cave and tectonic and stability diagrams were elaborated, in order to determine stability factors. The main purpose, after determining any type of potential failure, was to propose the more appropriate stability methods. It is obvious that all the ordinary methods, used in underground construction, are not appropriate for use in caves. Supporting methods have to be adapted, taking into account the already existing natural stability conditions, the safety of visitors and the monumental character of the cave.

Keywords. Heritage, Poliphimos cave, Cave support

1. Background and History of Maronia Cave

The cave is located in a distance of 5 km from Maronia Town, near Komotini City, in Thrace – Eastern Greece. It is considered as an important natural monument which unfortunately has not already developed. According to the Greek mythology, Cyclope Poliphimos is considered that was living in the cave.   According to the archaeological research, the cave was used as living and religious site, from the Neolithic until the Byzantine period. The cave is 2000 m long and covers an area of 10.000 m^2, according to Petrohilou, A. (1984), who investigated the cave for first time. The present study was a part of a bigger project, included in the 3rd EU Framework Program. The aim of the project was the touristic and scientific development of the cave. For this purpose, the tectonic features of the cave were studied in order to determine the stability conditions and propose the proper retaining and protection measures (Christaras et al. 2004[1]).

2. Geological and geotechnical conditions

The area, geologically, consists of compact coarse-grained karstic limestone and tectonically it is traversed mainly by faults of NNW-SSE to NW-SE and E-W directions. The cave is formed in low depth and the width of the upper layers appears to be small as roots of plants are visible on the ceiling of the cave. The stability of the cave is mainly determined by the tectonic regime of the area. Field measurements were made, statistically interpreted and the results were plotted in stereographic projections. The main directions of the discontinuities are kl1: 089/68, kl2: 344/80, kl3: 246/75 and kl4: 041/77 (Fig. 1) while the bedding is almost horizontal.

As mentioned previously, the rock mass is traversed by at least three major sets of discontinuities. The spacing between the discontinuities changes from 20 to 100 cm, their length appears to be more than 1 m and their dip is close to vertical. The majority of the discontinuities are opened and filled with calcite carbonate which formed as calcite precipitates in a limestone cavern. The above mentioned geometrical features in conjunction to the practically horizontal dip of the bedding of the limestone form rectangular blocks that appear to be unstable on the roof of the natural cave (Fig. 1).
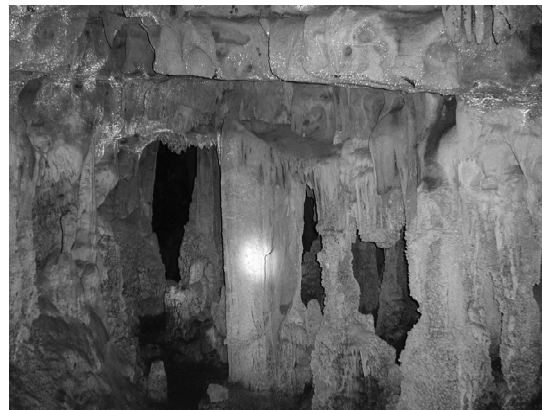

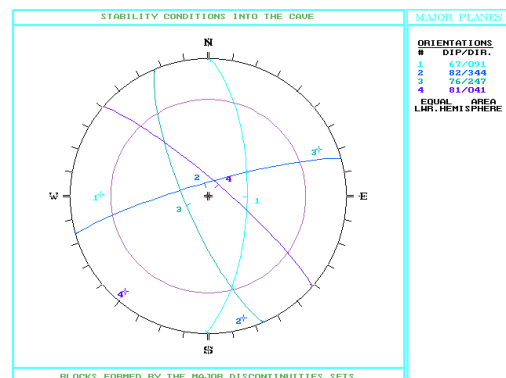**Fig. 1** Failure on the roof along the bedding plane

Fig. 1 Stability of representative blocks (combination of discontinuities 1,2,3,4). Block 123: Falling, Block 124: Sliding, Block 134: Falling, Block 234: Sliding

In addition to that wedge failure type could be presented as recorded from in situ observations. The RQD of the rock mass is estimated 75-90 and the unconfined compressive strength 35-60 MPa using a Schmidt hammer (Hoek & Bray, 1997). The rock mass quality can be characterized as good (RMR= 61-70) according to RMR method (Bieniawski, 1989).
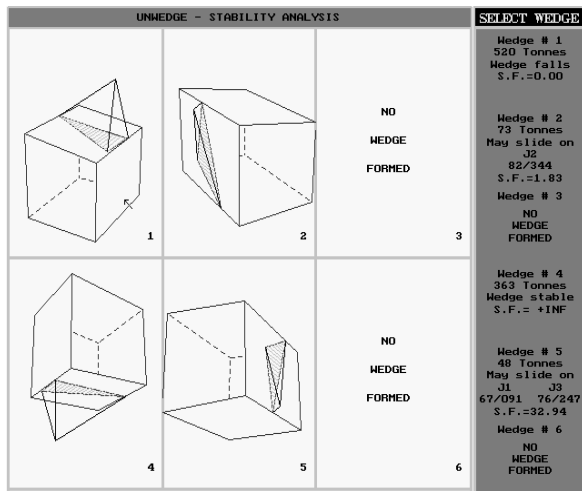
Fig. 2 Block 123 (c=16 t/m^2, φ=30°)

Table 1: Proposed support measures

| Section	Potential wedges	Arrangement and length of rockbolts	Safety Factors after bolting
152-151	kl1-kl3-ss2	2,0 x 2,5m – L=3m	2,24
	kl1-kl2-ss2	2,0 x 2,5m – L=3m	2,04
154-153	kl1-kl2-ss2	2,0 x 2,0m – L=3m	3,32
	kl1-kl3-ss2	2,0 x 2,0m – L=3m	2,00
156-155	kl1-kl3-ss2	2,0 x 2,0m – L=3m	2,33
158-157	kl1-kl3-ss2	2,0 x 2,0m – L=5m	2,21
	Kl2-kl3-ss2	2,0 x 2,0m – L=5m	2,51
160-159	kl1-kl3-ss2	2,0 x 2,0m – L=5m	2,31
	Kl1-kl2-ss2	2,0 x 2,0m – L=5m	2,14
162-161	kl1-kl3-ss2	2,0 x 2,0m – L=5m	1,97
151-150	kl1-kl3-ss2	2,0 x 2,5m – L=3m	2,45
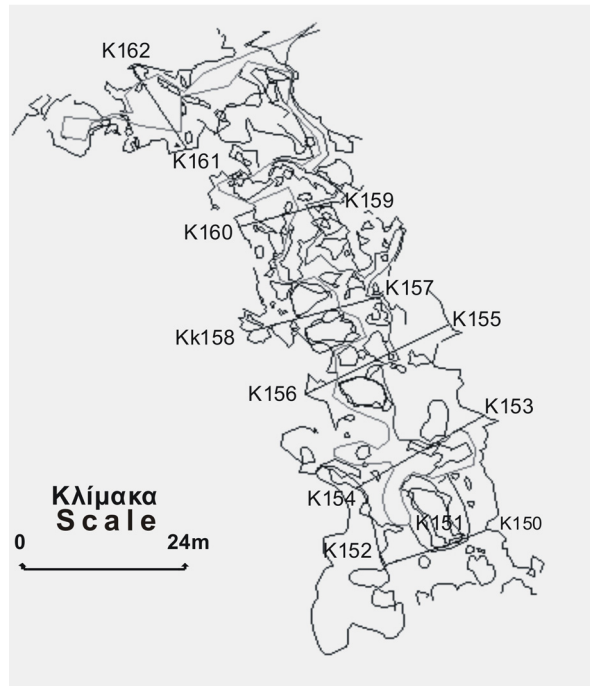
Fig. 3 Topographic sketch including studded cross-sections ("Geographein Co", Komotini City, Greece)

The stability conditions are variable and different stability problems occur along the visiting route. Therefore each stability problem should be dealt separately. The tectonic data were elaborated, using UNWEDGE software, in order to determine the unstable wedges or blocks in each room of the cave. In order to determine the safety factors and the maximum volumes of the potential falling blocks, the following pairs of values were used: a) c = 10 t/m^2, φ = 30° b) c = 16 t/m^2, φ = 30°.
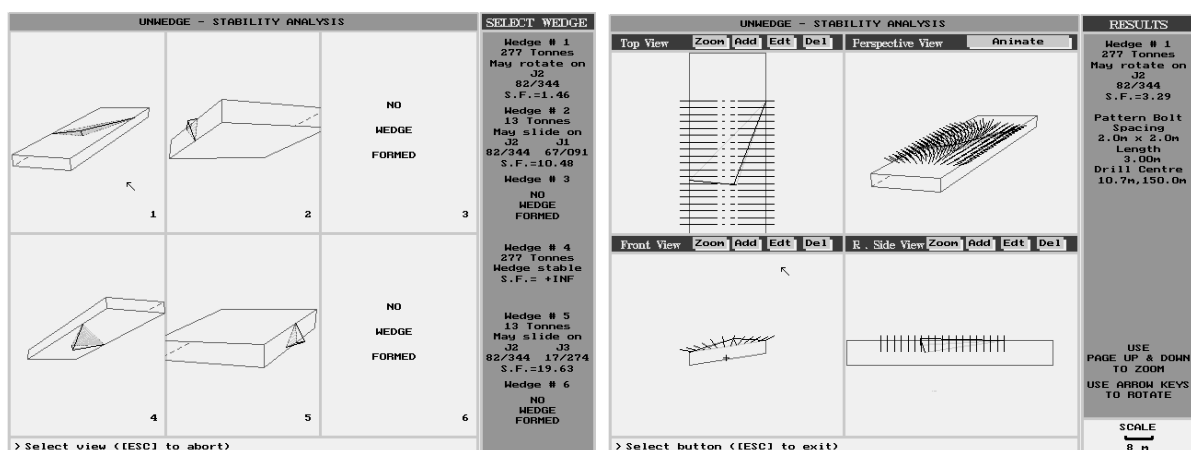

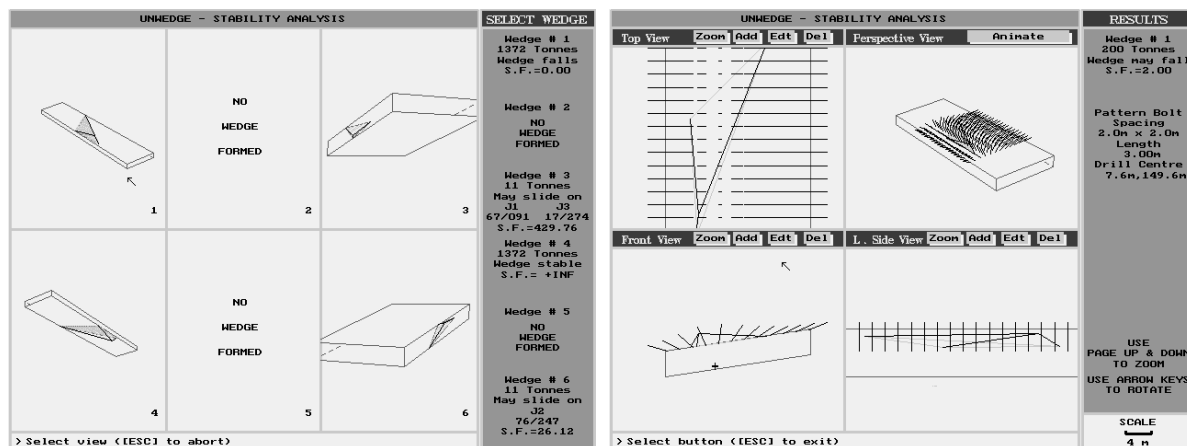**Fig. 5** Section K154-K153 (kl$_1$-kl$_2$-ss$_2$)

Fig. 6 Section K154-K153 (kl1-kl3-ss2)

In Figs. 2 and 3, representative unstable wedge blocks are given, creating falling and sliding failures. The geometry of the blocks formed by the combination of the vertical discontinuities sets with the horizontal bedding creates potential instability conditions, which are mainly related to unstable blocks falling from the roof (Fig. 3)

3. Data elaboration

The main purpose, after determining any type of potential failure, was to propose the more appropriate stability methods. It is obvious that all the ordinary methods, used in underground construction, are not appropriate for use in caves. Supporting methods have to be adapted, taking into account the already existing natural stability conditions, the safety of visitors and the monumental character of the cave.

According to the stability analysis of the cave, the main failure mechanism is the falling of wedges from the roof. The sides of the cave seem to be stable. For the reinforcement support of the roof, an arrangement of stainless pre-tensioned self-drilling rockbolts is suggested (2X2m and 2X2.5m, length 3m and 5m [Table 1]) as the optimum scenario of intervention, giving safety factors >2 . In Figs. 5 and 6, representative stability analyses with proposed support measures are given

4. Conclusions

According to our investigation, we arrived to the following conclusions:

1. As the thickness of the overlying layers is small, the stability analysis inside the cave is only based on the probable creation of unstable wedges due to the tectonic system of the area and not to a stress pattern due to the load of the overlaying layers.

The probable unstable wedges are mainly observed at the roof of the cave, creating either falling or sliding blocks

2. The proposed support measures take into account the specific conditions and the monumental character of the cave.
3. The safety factors, after the application of the proposed support measures, are generally enough high (SF>2), having using relatively moderate admissions and mechanical characteristics for the rock mass.
4. For the reinforcement support of the roof, an arrangement of stainless pre-tensioned self-drilling rockbolts is suggested (2X2m and 2X2.5m, length 3m and 5m [Table 1]) as the optimum scenario of intervention, giving safety factors >2.
5. It is recommended to determine the exact places of interventions and bolting application, during the phase of the application study.

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