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32nd INTERNATIONAL
GEOLOGICAL CONGRESS

GEOLOGICAL AND GEOTECHNICAL HAZARDS OF MAJOR NATURAL AND ARCHAEOLOGICAL MONUMENTS

Conveners:
I. Bruchev, G. Frangov, N. Dobrev, A. Lakov

Post-Congress **PW06**

The scientific content of this guide is under the total responsibility of the Authors

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Series Editors:
Luca Guerrieri, Irene Rischia and Leonello Serva (APAT, Roma)

English Desk-copy Editors:
Paul Mazza (Università di Firenze), Jessica Ann Thonn (Università di Firenze), Nathalie Marléne Adams (Università di Firenze), Miriam Friedman (Università di Firenze), Kate Eadie (Freelance indipendent professional)

Field Trip Committee:
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I. Bruchev, G. Frangov, N. Dobrev, A. Lakov
(Geological Institute, Bulgarian Academy of Sciences, Sofia - Bulgaria)

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Front Cover:
Rock relief of the Madara Horseman

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This field workshop will start at the biggest city in NE Bulgaria – Varna (Figure 1). The total field trip distance is estimated at about 800 km. Roads are in good condition. The program will take place over 3 days. Attention will be paid to the natural (seismicity, erosion, landslides, and rockfalls) and human-induced hazards endangering important natural and archeological monuments.

Program

Arrival day, 29.08.2004: Arrival of participants (max 30 persons) at the airport of Varna and accommodation in the town of Varna, Bulgaria.

First day, 30.08.2004: Trip by bus between Varna and Veliko Tarnovo. The following sites will be visited: the archeological remains of the first old Bulgarian capital Pliska, and the Madara Horseman rock relief monument, which has been affected by earthquakes, weathering, and slope processes. Accommodation in Veliko Tarnovo.

Second day, 31.08.2004: Trip by bus between Veliko Tarnovo and Rousse. In the morning the participants will see the sights of the mediaeval capital, Veliko Turnovo, and the nearby Transfiguration Monastery, affected by earthquakes and slope processes. In the afternoon, Ivanovo rock-hewn churches near the mediaeval town of Cherven, along the river Rousenski Lom, which are threatened by natural hazards, will be observed. Accommodation in Rousse.

Third day, 01.09.2004: Trip by bus between Rousse and Varna. The first stop during the trip is the Thracian Tomb at Sveshtari. The next observation locality is the Aladja Rock Monastery, near the city of Varna. The last stop is Chirakman Cape, affected by strong earthquakes in the 3rd Century BC. Accommodation in Varna.

Departure day, 02.09.2004: Departure from Varna Airport.

Introduction

Covering a central position in the Balkan Peninsula, and being a crossroad between three continents, the territory of Bulgaria is marked by vestiges and monuments from ancient times till nowadays. The oldest gold treasure (~4000 years B.C.) was found in the city of Varna.

The main goal of the field trip is to present some selected monuments of culture from different historical periods; the geological conditions in which they are located; the consequences caused on them by damaging geological processes (landslides, rockfalls, earthquakes, weathering), and to look at the measures taken to prevent such damage.

The motives for choosing the suggested route are:

- In the northeastern part of Bulgaria there are situated historical, cultural, and natural monuments included in the World Heritage List of UNESCO - the Madara horseman, the Ivanovo rock-hewn churches, the Sveshtari Thracian tumuli, and the natural reserve - Srebarna Lake.
- There are many unique geological and historical places of interest such as: Pobitite kamani (the Upright stones) near Varna, the rock scarps in the Madara and Shoumen plateaus, and Veliko Tarnovo and its beautiful landscapes; there are also mediaeval monuments, such as the Transfiguration Monastery in the valley of Yantra River and the city of Rousse; and the problems with loess collapsibility, different types of lay shapes, river valleys, and geological profiles.
- Most of the monuments are placed in complex geological conditions. They have suffered from collapses and deformations at different levels through geological hazardous processes. Some of them are in critical condition. For example,

Figure 1 - Location map

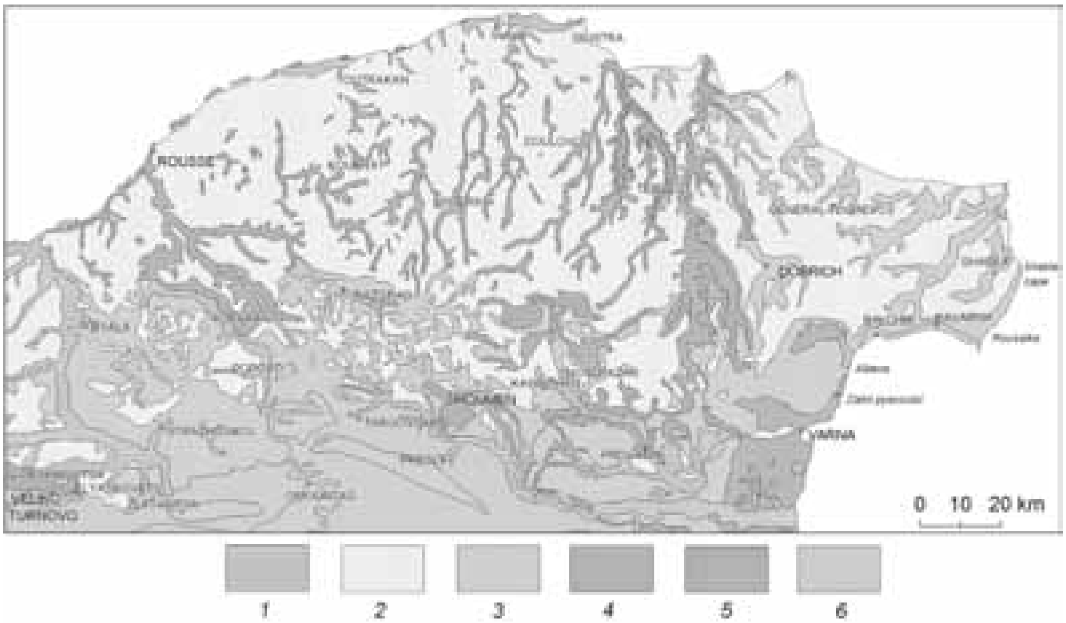

Figure 2 - Geological Map of NE Bulgaria
1 - clays and sands, Qh; 2 - loess, Qp; 3 - limestone with clays and sands, N1s; 4 - clays, sands and sandstones, N1; 5 limestones, K1; 6 - marls and sandstones, K1

the Transfiguration Monastery has been destroyed four times by earthquakes, landslides and rockfalls during the 20th century alone.

- Some precautions have been applied, after much discussion, to reduce the geological risks for the most valuable.
- Bulgaria was established in this region more than 1300 years ago, and three of five of its capitals (Pliska, Preslav, and Veliko Tarnovo), are situated there. There are also many monasteries, sacred places, castles, etc.

During the field trip, discussion on the mitigation of natural and man-made hazard and risk on historical and cultural heritage sites will take place. The main aim of the discussion will be to share information, experience, and ideas on the possibilities for the conservation and stabilization of the affected sites.

Regional geologic settings

The field itinerary passes through the Moesian tectonic platform and partially through the Fore-Balkan folded structures near the Veliko Turnovo area. At this part, two bigger structures of the Moesian platform are the North Bulgarian Swelling in the western part and the Varna Depression to the east. Sediment strata build these structures to deep levels. As a result of the active tectonics, they are divided into blocks by faults, with depths of more than 3 km. In the western section of the area, mainly Lower Cretaceous limestones, marls, and sandstones are revealed. They are covered by loess at the interfluvial massifs, and by alluvial deposits in the river terraces (Figure 2).

Tertiary and Quaternary sediments (sandstones, marls, aragonitites, clays, sands) fill the eastern part of the Varna depression. The Quaternary loess deposits cover the higher parts of the relief, with colluvium on the slopes, alluvium along the river terraces, and mixed alluvial-marine sands, clays, and muds in the plunged terraces of the river that runs into the Black Sea.

The relief forms, which are typical of the platform structure, are hilly in the interfluvial areas, with plateaus with steep scarps, and river valleys with alluvial terraces. The altitudes of the region vary between 0 and 500 m. Karsted limestones build the Dobroudja, Provadia, and Shoumen plateaus, and the area around Veliko Turnovo. The scarps are strongly

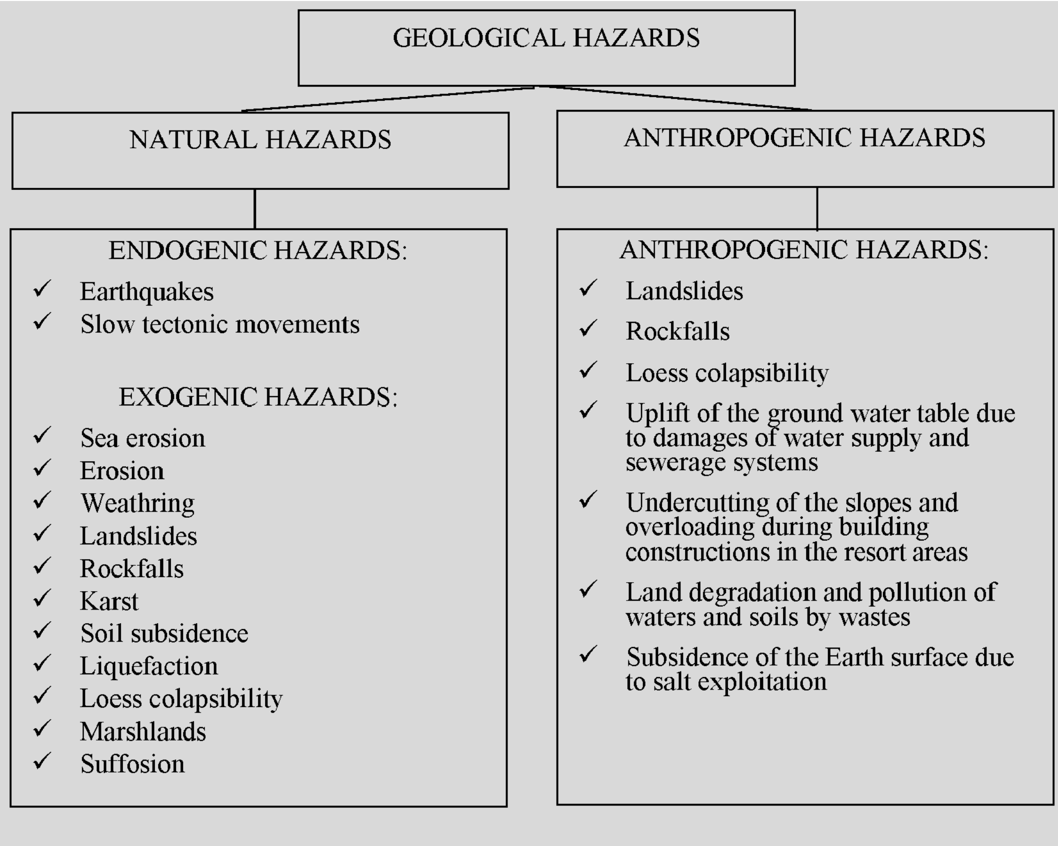

Figure 3 - Structure of the geological hazards in NE Bulgaria

vertical, and usually reach 100 meters high. They form canyon-like valleys that are characteristic for Dobroudja's landscape. Danube River and the Black Sea are important hydrographical units, which border the area in the northern and eastern parts. Few lakes have formed. The most important of them is Srebarna Lake, which is a biological reserve. Varna Lake is a very large seaside lake, and it is also used for commercial purposes. The landslide pond Tuzlata (eastwards from Balchik) is used for rehabilitation therapy due to the healing properties of its mud.

The Engineering Geological conditions are predetermined by the distribution of sedimentary rocks on the surface. The sedimentary rocks are very variable in composition and physical-mechanical properties (Kamenov et al., 1963). Horizontal layers, with a slight inclination to the east, determine the geomechanical model of this area. For the interfluvial massifs and the plateaus, there is the characteristic availability of loess lying over marls and karsted limestones. Along the peripheral parts of the positive relief's units, many steep gullies have developed on the slopes. At the Varna depression, the geomechanical models are more complicated, due to the formation of alternations between hard (limestones, sandstones) and plastic (marls) rocks. They build a complex system of rocks with contrasting physical-mechanical properties.

Geological hazardous processes in NE Bulgaria complicate the sustainable development of this territory. They endanger and affect urban and rural areas, seaside resorts, economic activities, etc. They affect the cultural and historical monuments of various ages.

The structure of the geological hazards involves many and variable destructive geological processes (Figure 3). Seismic intensities of the region are from 7 to 9 degrees MSK-64. The most important earthquake sources are located in the areas of Shabla-

Kaliakra, Veliko Turnovo, and Doulovo. Landslides and rockfalls have greatly affected the Black Sea shoreline, Danube riverbank, and the valley banks of the Yantra River, Kamchia River etc. Sea erosion has changed the Black Sea shoreline to west direction, as well as the unilateral erosion destroys the right Danube riverbank. The karst is widespread on the plateaus and the rock scarps. Such karst forms were used to arrange the sacred places (near Madara Horseman, Aladja Monastery, Ivanovo rock-hewn churches, Transfiguration Monastery, etc). Eolic loess deposits on the plateaus and the terraces are collapsible under water saturation and loading. A large number of human processes have had extensive detrimental consequences on the natural and historical heritage, recent infrastructure, and the environment (Broutchev, ed., 1994).

DAY 1

Trip by bus between Varna and Veliko Tarnovo. The following sites will be visited: the archeological remains of the first old Bulgarian capital Pliska, and the Madara Horseman rock relief monument, which has been affected by earthquakes, weathering and slope processes. Accommodation in Veliko Tarnovo.

Pobitite Kamani

The "Pobitite kamani" site is located about 20 km West of Varna City, and it is a very interesting object of national and international tourism. (Figure 4) In Bulgarian, the name means "Upright stones".

The "Pobitite kamuni" site is apart from the so-called Varna columns. The columns can be divided into 5 groups, which are exposed over an area of 70 km^2. The host rocks are loose sands and silts. In some places, there are 5 levels of columns, which are separated by shallow-marine limestone layers. The whole geological section has a thickness of 40 - 45m.

The stones are a remarkable natural and geological phenomenon, and don't have a complete analogue described in the literature (Figure 5). The famous part of the Varna columns is on the site of "Pobitite

Figure 4 - View of the Upright stones

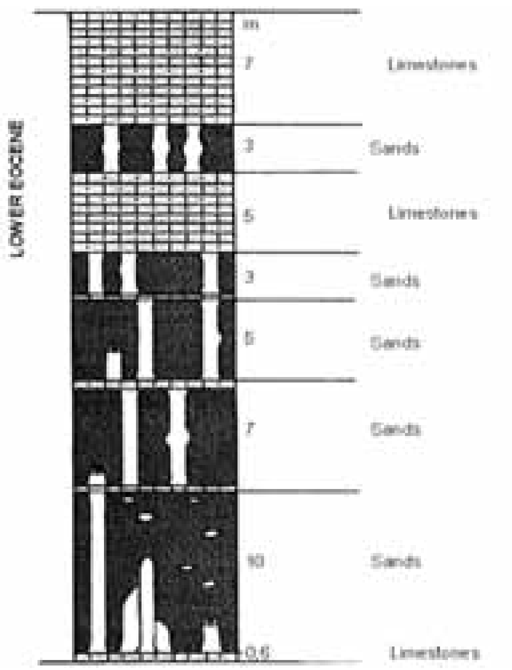

Figure 5 - Geological profile at the Upright Stones (after Nacev & Nacev, 2001).

kamani". It is included in the UNESCO program for the preservation and protection of scientific geological heritage.

The "Pobitite kamani" (the Varna columns) have been studied for a period of 170 years. There are many hypotheses on their origin, and more than 60 publications. Some of these hypotheses are very old and are not supported by facts. They have only historical significance. At present, it is generally accepted that there is no viable hypothesis or explanation.
Some of the most interesting theories about the origin of the columns are as follows: (1) remains of castles or temples; (2) weathered sandstone remains; (3) concretions; (4) infiltration stalactites; (5) coral reefs; (6) stone forest or trees; (7) stone cavities of trees; (8) algal build-ups; (9) algal annelida bioherms etc.

Stop 1.1:

Pliska

The ruins of the ancient city of Pliska are situated 3 km northward from today's Pliska village.
Pliska was the first capital (from 681 till 893) of the first Bulgarian Kingdom, founded by Khan Asparuh (Figure 6). The city comprised of an inner and an outer part, and the area was about 23 km^2. A defense embankment surrounded the city. It was 21 km long, with a fortress wall 2.9 km long and 8-10 m high. Inside the city, a great number of houses, stone palaces, and churches were built. The Big Basilica was one of the most impressive religious structures built on the Balkan Peninsula at that time (Figure 7).

The inner town had an area of 0.5 km^2, and was rectangular in shape, and had about 12 m high fortress walls. In the inner town, there was situated the Big Palace (or Khan Krum's palace), which had its own defensive walls and towers.

In 811, the town was reduced to ashes by the Byzantine army of the emperor Nicephorus I. After that, Preslav was declared capital of Bulgaria (893), and Pliska fell into decay.

The terrain where Pliska was built is rather dry, and has the relief of loess plain. The relief is flat, with a slight inclination to the south. The geology is represented by a topsoil layer (1 m thick); a carbonate soil layer (0.5 m thick), and loess (thick between 2 and 9 m) (Evstatiev et al. 1983).

According to the older descriptions, a part of the ancient capital of Pliska was founded on marshland area. The main hazards are the high seismicity (8th degree MSK) and loess collapsibility (Figure 8).
Various approaches to strengthen the soil were applied during the construction of the city. The builders were aware that they had to cope with weak soil, and therefore they took measures to prepare it in advance before starting to build the foundations. They applied the following methods for that purpose:

1. The building of a cushion of compacted soil 0.2-0.4 m deep, on top of which a layer of mortar was poured;
2. The building of a substrate that consisted of a wooden raft with mortar poured on top of it;
3. The compaction of the bottom of a ditch made for the foundation of wooden piles, stuck in the soil: 0.6-0.8 m long, with a diameter of 0.08-0.10 m;
4. The construction of a substrate, consisting of a wooden raft on piles, with mortar poured onto them.

Consequently, all methods of foundation work on

Figure 6 - The ruins of Pliska

weak soils known at that time were used. and yet the foundations are still not by far completely safe.

The large Basilica was also founded in collapsible loess, 2-3 m thick (Figure 9). When the soil base was being prepared, a substrate of compacted soil 0.3 m thick, and piles, was used. Due to the great weight of the structure, there occurred settlements and subsidences, reaching to 0.3 m below the overloaded pilasters of the central nave. Due to the bending accompanying the settlements, the masonry of the uppermost row of the wall of the foundation has cracked. As a result of the settlement, the loess under the foundation has become compacted to $\rho_d = 1.65$ g/cm^3, whereas outside the foundation $\rho_d = 1.35$ g/cm^3. Irregular subsidence of the wall can be seen, too. The deformations reach 0.15-0.20 m.

Stop 1.2:

Madara Horseman

The historical complex Madara is situated in the eastern periphery of the village Madara, and is 17 km to the east of the town of Shoumen, 70 km to the west of the town of Varna and 10 km to the SSW of the first Bulgarian capital - the town of Pliska. The historical bas-relief is situated in a place with many other historical monuments that are involved in the Madara archeological and historical reserve (Figure 10).

The Madara area has a very long history. The Caves of Madara were inhabited starting from the Neolithic time. The Big Cave was considered sacred and used mainly for spiritual rituals. The Big Cave had a 70 m high entrance. It was also known as the Cave of Nymphs, the Nymphs of nature, water, and the forest. In different periods of time, the Little Cave was inhabited by Thracian, Roman, Slav, and Bulgarian peoples. Some traces of a Thracian settlement were studied at the foot of the Plateau. The Thracian hills discovered at the top of the Madara Plateau are still to be researched.
The relicts of a large Roman villa (2nd Century A.D.-4th century A.D.), including 45 rooms and covering an area of 5,000 sq.m, are placed on the territory

Figure 7 - The ruins of the Big Basilica

565), up to the Bulgarian Middle Age (1386). The relicts of the Proto-Bulgarian Pagan sanctuary (9th century A.D.) and of the Orthodox monastery (9th century A.D.- 10th century A.D.), were situated at the foot of the Plateau. Another rock monastery (12th century A.D.- 14th century A.D.), was placed on the western Madara Plateau slope. Certain small karst niches, fractures, and man-made constructions had permitted the creation of the rock monasteries. The monastery relicts now are marked now by the holes in the high part of the western slope of the Madara Plateau. The historical relicts supply very useful information for state development during the First (9th century A.D.- 11th century A.D.) and the Second (12th century A.D.- 14th century A.D.) Bulgarian States.

The Madara Horseman is a magnificent bas-relief cut into a vertical rock surface at a height of 23 m. The bas-relief represents a scene of a horseman, who is said to be Khan Tervel, piercing a lion with a spear and followed by a dog, all to life size. The details speak in favor of the Bulgarian origin of the bas-relief.

between the village of Madara, and the slope of the Madara Plateau. The villa testifies to the good economic development of the locality at the beginning of the first millennium. The Madara castle (6^{th} Century A.D.- 14^{th} Century A.D.) ,indicates the important strategic position of the Madara Plateau, from the Roman period of Justinianus I (527-

Figure 8 - Loess subsidence affected the Pliska walls

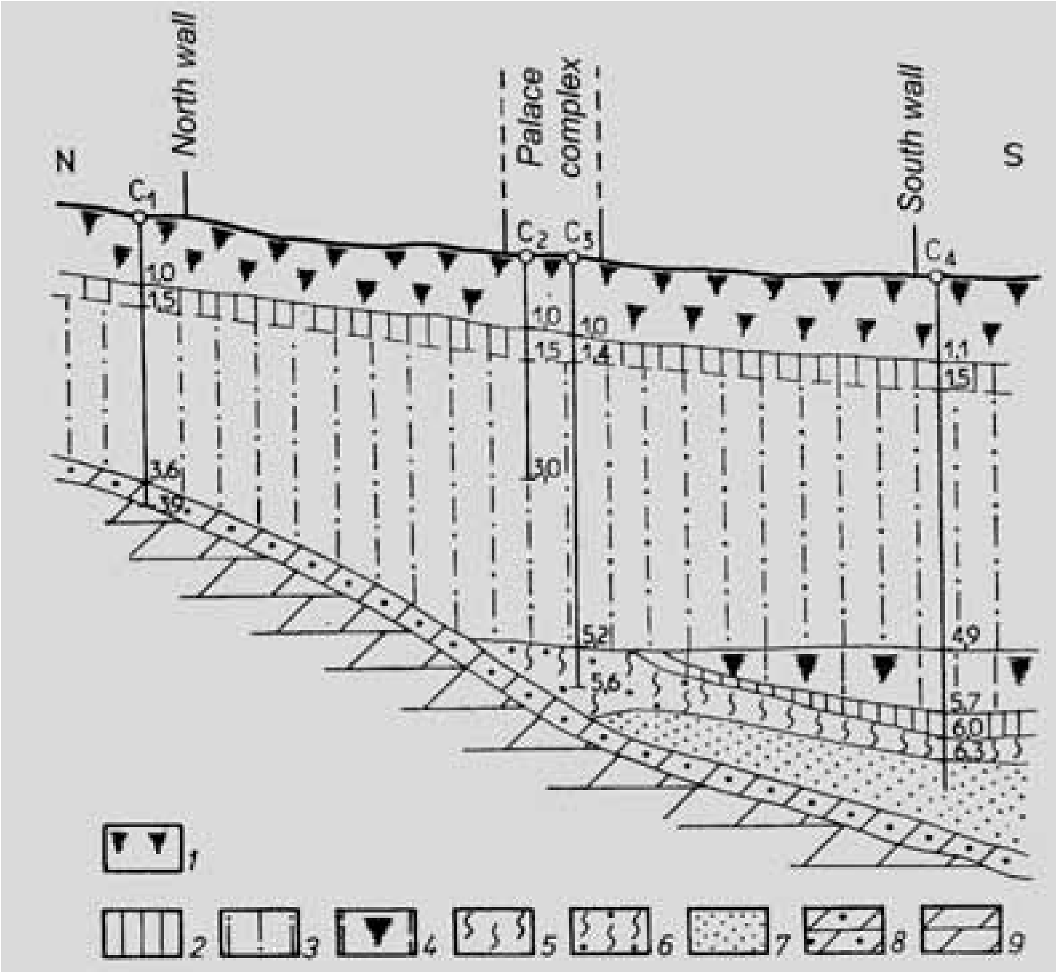

Figure 9 - Geological profile of Pliska (Evstatiev et al., 1983): 1-topsoil; 2-calcareous layer; 3-loess; 4-palaeosoil; 5-sandy-silty clay; 6-sandy-gravelly clay; 7-sand; 8-weathered marl; 9-marl

There is an assumption that the relief depicts Khan Tervel as a winner. The Greek inscriptions are placed on the left, the right, and the bottom sides of the bas-relief. They represent the first short chronology for the creation and development of the Bulgarian state. The text is only partially saved. It is interpreted as being related to three historical periods. They are the following: the period of Khan Tervel, and his significant military help to the Byzantine Emperor Justinianus II in 705, the following periods of successful State development during Khan Kormisosh's reign and that of Khan Omurtag (8th century A.D.- 9th century A.D.).

The bas-relief and the text are of great importance for Bulgarian culture and history. The Horseman of Madara is the first document where the name Bulgarian is used, and where significant historical events with Bulgarian participation are noted. The monument testifies to the triumphant recognition of the Bulgarian Kingdom by the Byzantine Emperor. The rock monument is the only one of its kind in Europe. It is among the sites included in the List of the World Cultural Heritage Sites of UNESCO in 1979.

The Bulgarian geologist and archaeologist Raphail Popov was the initiator for the establishment of the Madara Museum and the Madara reserve area in the first half of the 20th century. His work was of great importance for the region and for the state. Now the national archaeological and historical Madara reserve area, with the famous The Horseman of Madara, is among the major tourist attractions in Bulgaria.

10 a

characteristic of a plateau and its surface is about 400 m a.s.l.. Madara Plateau is in the range of the northern flank of the Provadia Syncline, with layers inclined by 5 to 7 to SE (Figure 11).

The rock massif consists of two complexes (Figure 12): the upper one comprises limy-sandy sediments of Upper Cretaceous - Cenomanian age; the lower one is marly of the Lower Cretaceous - Hauterivian age (Tzankov, 1943). A borehole carried out in the year 1990, and located in the bas-relief profile in the plateau, found 137.50 m of the Cenomanian rock complex, showing several lithologic grades. Originally, it had been described as characteristic of the lower one - conglomeratic, and the upper one - fine-grained, which is generally in accordance with the drilling investigations (Frangov et al. 1992). The bas-relief was carved out of yellowish

10 b

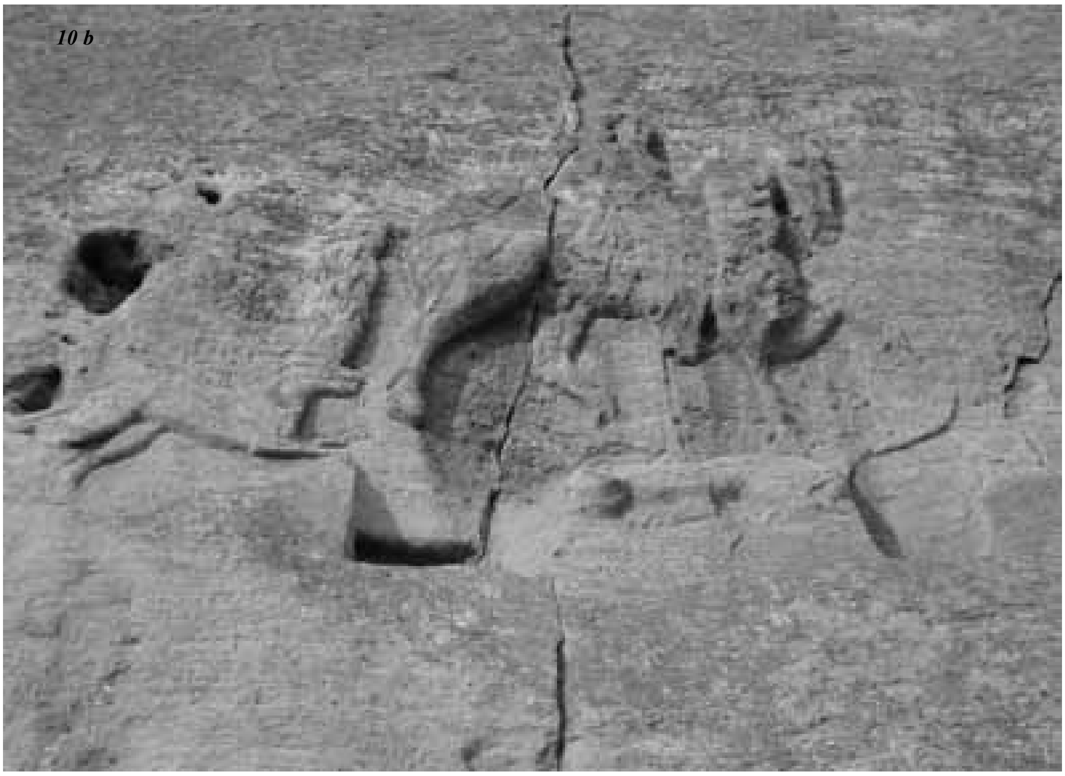

Figure 10 - a) General view of the Madara Plateau periphery; b) rock relief of the Madara Horseman on it.

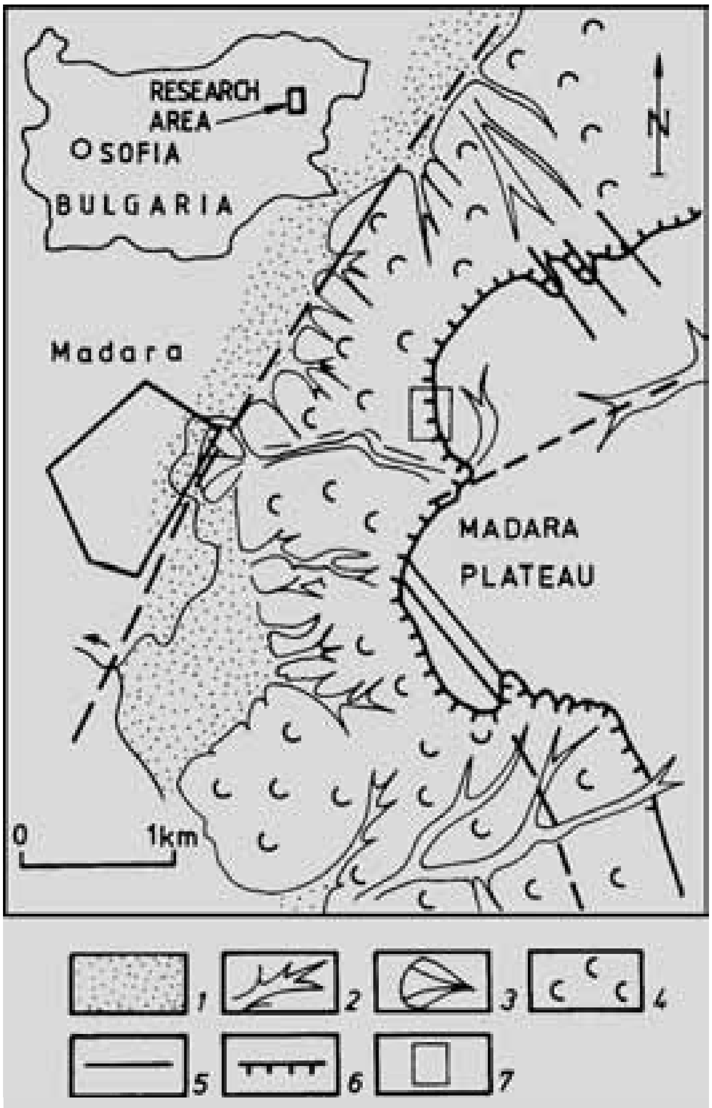

Figure 11 - Geomorphological map of the western part of the Madara Plateau (after Angelova 1995): 1 alluvial terrace deposits; 2 gully; 3 alluvial fan; 4 creeping and sliding colluvial deposits; 5 fault; 6 plateau scarp; 7 Madara Horseman locality

limy sandstones found between 17 and 100 m. A second lower complex is marly, and consists of grey-bluish layered marlstones, creeping if heavily loaded. Between the Hauterivian and Cenomanian complexes, a layer of yellow plastic silty clay have been discovered. It contains montmorillonite, carbonate content - up to 7.5%, grains of quartz and limonite flakes. The Thickness of this particular layer varies from 0.4 to 6.5 m, about 1.5 m nominally. The underground water table was found in the depth of 110 m from the plateau surface. The Caves of Madara were formed under a complex influence of the natural phenomena (karst, tectonic - partially moderate and strong earthquakes, gravity phenomena), and of human activity. The later was manifested in certain corrections in the natural forms. The Caves lay in the basement of the western slope of the Madara Plateau.

The morphology of the slope in the NW periphery of the Madara Plateau is determined by a two-layer model. The rock wall is almost vertical, built of a limy-sandy complex. Down the slope, marlstones are covered by colluvial deposits, sloping from 10 to 20.

The peripheral zone of the Madara Plateau developed a specific structure of rock slices released from the edge (Figure 13). The slices or blocks show a thickness of from 1 to 3 m on average. The Madara Horseman cross section developed six slices like that, separated from the plateau. The first three of them can be found now as very low steps in the lowest section of the wall and are relics of old frontal blocks which disintegrated in their towering heads. The bas-relief is carried by the fourth rock slice, which is followed by other ones. Formation of two or three new slices about 3 m wide can be detected behind the furthermost edge of the plateau by traces of cracks.

Fissures that develop during the gravitational extension in this slope and the splitting of it, were given sign “X” by different investigators (Venkov & Kossev 1974; Frangov et al. 1992). Two uppermost and most extended fissures at present, are described as X1 and X2, and separate Slices 5 and 6 in the

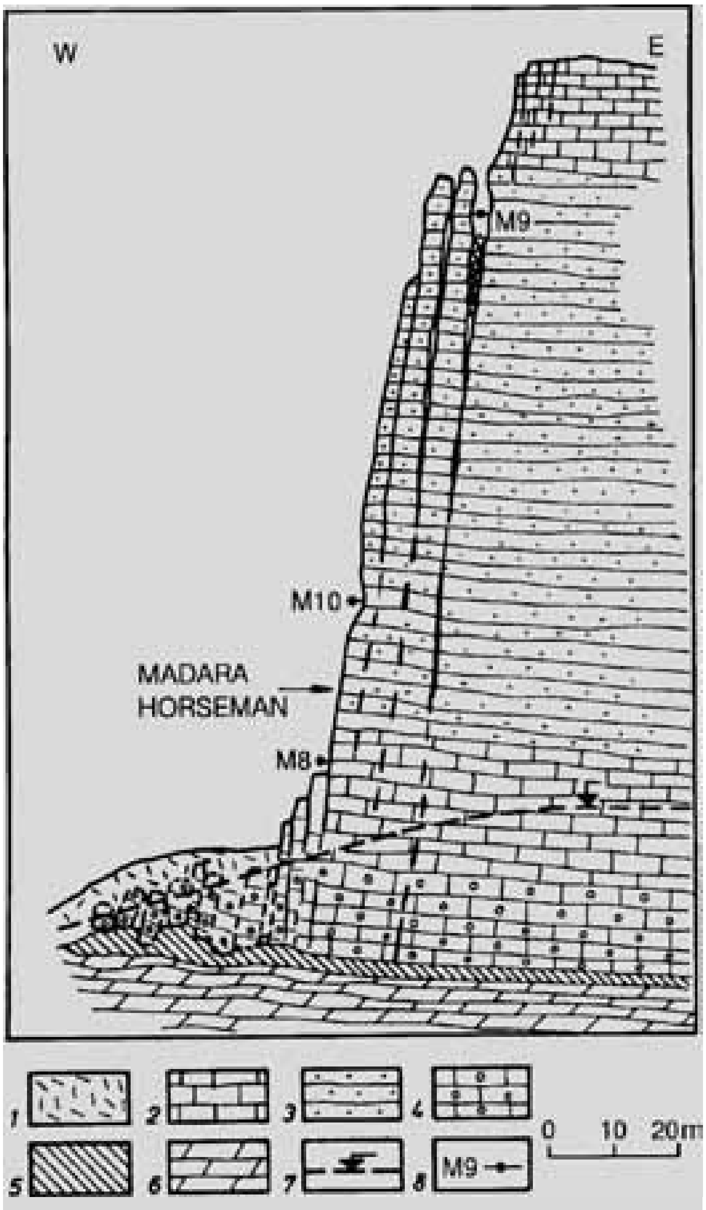

Figure 12 - Engineering-geological profile of the Madara rock wall (after Frangov et al. 1992): 1 - colluvial slope materials; 2 - whitish sandy limestone; 3 - yellowish calcareous sandstone; 4 - conglomeratic limestone; 5 - yellow clay; 6 - grey marl; 7 - ground water table; 8 - gauge TM-71.

plateau, respectively. Fissure X2 is oriented 150 to 170° (SSE), dipping 80° to W from horizontal. It is extended by 1.2 m in its uppermost part, and 5 to 6 m lower, the extension reads 3 m. It has been inspected to the depth of 12 m, then filled up with broken material. The fissure X1 is extended to 1 m, and expected to reach a depth of 6 m.

Slice 4 carries the Madara Horseman. It is cut by three basic cracks which threaten the compactness of the bas-relief, and these are numbered as No. 1, No. 2, and No. 3 (Venkov & Kossev 1974).
Crack No. 1 forms the northern boundary of Slice 4. It is almost all its length vertical from the top down to the level of the bas-relief where it turns into an "S", and disappears behind the tail of the dog. An erosional furrow identifies with most of the length of Crack No.1, and traces the wall to the bottom.

Crack No.2 cuts the horse into two parts, and reaches the depth of the fifth slice from the surface. Four to five other different cracks are detected between Slice 3 and the base of the massif. The cracks join together to form a single one near the head of Slice 3, and they are opened 20-30 mm under the bas-relief.

Crack No.3 is the most dangerous one for the monument. Extending to 20 mm out of the rock wall, near the bas-relief and above, it becomes wavy, and about 6 to 7 m above the monument, it disappears. Thus, the crack is most likely going to separate a prismatic piece of rock between No.3 and No.2 cracks. It is described as a "rock flake", and threatens the frontal part of the monument.

The stability of the rock mass is a function of rock properties and jointing, and is also affected by seismic events, erosional processes, climatic conditions, and human activities.

Figure 13 - Rock slices divided from the plateau

Crack gauges of the type TM-71, as applied to many rock stability projects, were successfully installed here in 1990 (Figure 14). According to the seismotectonic prognostication of NE Bulgaria, the Madara Plateau and its wider region is characteristic of high potential seismicity, whereby earthquakes with magnitudes more than 5 could be generated.
The most significant influences were noticed during the Vrancea earthquake on 30 May 1990, when stone blocks fell down from the scarp, endangering human lives at the foot of the plateau. During the strong Turkish earthquake on 17 July 1999, large displacements between rock lamellae were established by the high precise monitoring system. The last rock fall happened in the middle of May 2003, when a large block of a few cubic meters fell down near the rock bas-relief.

It is evident that the monitored cracks (selected for monitoring) are easily accessible from the surface, and, at the same time, represent deep discontinuities which give an insight into some deeper processes in the massif, including its instability.

The data about displacements are given in three components X, Y, and Z, where X and Y are horizontal, and Z - vertical. Regarding the powerful gravitational forces, Z is to be seen in connection with subsidence, having mostly a shear character in the respective crack. The component Y represents mostly horizontal shear, whereas component X represents the opening or closing in all of the three investigated cracks. Angular deviations indexed XZ and XY represent turns round axes Y and Z, respectively.

To characterize the displacement diagrams, one can see at first certain delayed responses to seasonal temperatures. They reflect volumetric changes in the rock, mainly summer opening, and winter closing, of cracks, resulting in a seasonal character in X, sometimes produced in Y or Z, also. Temperature variations in the rock appear in a span of 45°C, from -7°C to +38°C, as recorded, resulting in up to 1.6 mm seasonal amplitude, as seen at M8 and M9.

DAY 2

Stop 2.1:

Transfiguration Monastery

The Transfiguration Monastery (Figure 15), is located 7 km N from Veliko Turnovo – the capital city of the second Bulgarian State (1189-1393).

The monastery dates back to the reign of Tsar Ivan Alexander (1331-1371). The Turks took the capital of the Second Bulgarian State in 1393; it was burned to the ground. The rebuilding of the monastery started in 1825. In it were built the second church (1832), the residential wings (1849-1851), and the guesthouse. The construction work was lead by the famous Bulgarian architect, Kolyu Ficheto. Zachary Zograph painted the Transfiguration Church.

Actually the Monastery complex includes the national heritage monument, “The Assu” Church, famous for its frescoes, “The Circle of Life”, and for

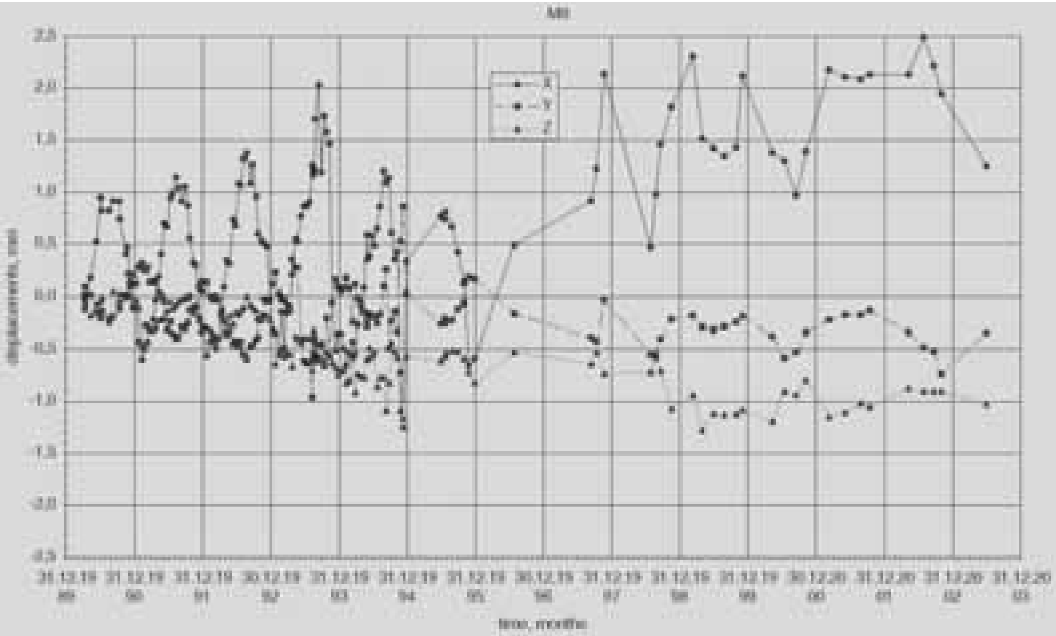

Figure 14 - Measured displacements along crack no.2

Figure 15 - View of the Monastery after the rock-fall

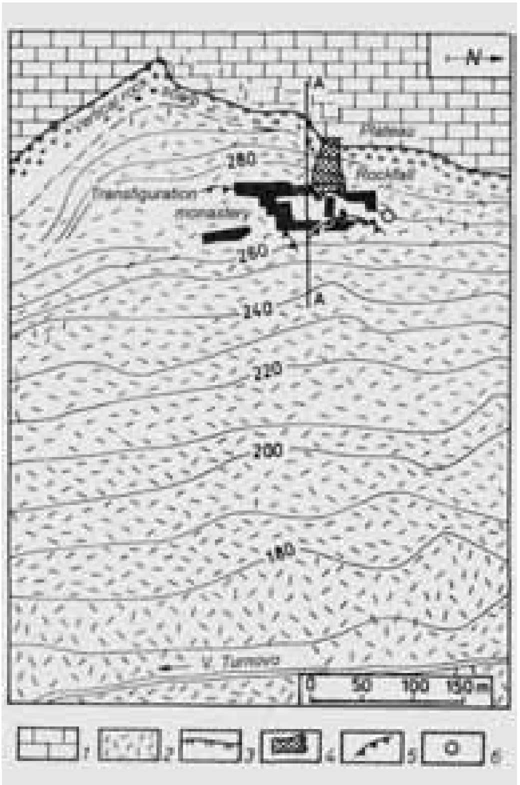

Figure 16 - Geological and relief map of the Transfiguration monastery (after Iliev et al. 1993).
1- Lower Cretaceous limestones, 2 - Quaternary colluvial deposits, 3 - rocky crown, 4 - rockfall, 5 - landslide movement, which damaged the Monastery, 6 - well.

its bell-tower, built by the famous Bulgarian architect, Kolyu Ficheto.

The monastery complex is located on a colluvial plane level, at the toe of a picturesque 120 m high limestone cliff of the Yantra River canyon. The rock slope is formed by river side erosion of the tectonically-processed limestone plateau (Figure16).

The cliff is 42-45 m high, and is composed of cream-colored to dark-grey colored lower Cretaceous flint limestones (Baremian - Aptian age). At about 10 m depth, they are under bedded by marls of the same age. The bottom of the slope is covered by colluvium deposits of rock blocks with sandy and clayey filling (Figure 17).

Three major faults and four joints systems were registered on the cliff. The site is located in a highly seismic zone of VIII degree MSK. In 1913, the Monastery was partially destroyed after the falling of rock blocks during the Gorna Oryahovitza earthquake. In 1974, a landslide developed on the colluvial slope, completely destroying the eastern wing of the complex, and directly endangering the Church. As a consequence, the landslide was reinforced by back ties and a drainage gallery. In 1991, after intensive rainfalls, a 300 m^3 rock-fall occurred from the extended cliff section and completely destroyed the western wings of the Monastery. Luckily, no casualties occurred and by chance, the Church was preserved when the rock flow was divided into two by a tree and ran on either side of it.
The studies of the rock properties have revealed as major factors for the "development" of the rock massif, the inverse strength structure of the cliff, the unequal support of the hard limestones from the weathered upper section of the marls affected by creep processes, and the weathering and the destruction processes along the joints.

An alert system has been designed and installed on the most dangerous blocks above the Monastery buildings.

Stop 2.2:
Ivanovo Rock-hewn Churches
The Ivanovo rock churches are located 5 km outside Ivanovo Village, 25 km south of Rousse City, in the picturesque canyon of the Roussenski Lom River Reservation (Figure 18). In this place, the river forms a big meander with a wide valley. The high rock scarps are almost vertical, and their height often reaches 100 m. The altitude of the site is about 120 m a.s.l..
Some openings of picturesque caves that were inhabited in earlier times by medieval hermits and issichasts (monks), can be seen on the vertical river scarps, 50 m above the ground. The church complex is composed of groups of cells, hewn at different levels above the river, and developed in the karst forms of the river canyon. Some of the cells are connected by corridors. At some places, 2 or 3 floors are present.

Historic sources refer to a monastery complex that existed here from 12th - 14th century as a part of a big religious complex in the area of the ancient town of Cherven. The first information about this site is from Patriarch Joachim I in 13th Century. After his return from Athon Monastery (now in Chalkidiki Peninsula, Greece), he hewed a cell and a small church in the

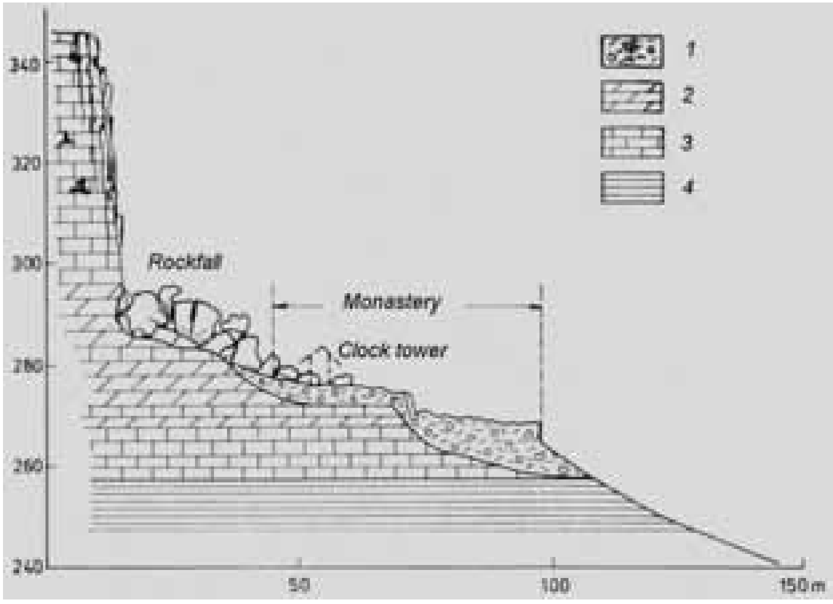

Figure 17 - Geological cross section of the slope (after Iliev et al. 1993)., 1 - Colluvial slope deposits; 2 - Lower Cretaceous marls, sandy, calcareous, fractured; 3 - Lower Cretaceous limestones, karsted; 4 - Lower Cretaceous marls

river scarp with the assistance of three disciples. Later on, Joachim became patriarch of the Bulgarian Church (1235) when he created a big rock monastery complex near his first church. A great number of cells and churches were hewn in karstic voids and sites and were additionally enlarged by the monks. The patron of the rock monastery was St. Archangel Michael. Monks inhabited the monastery until the 17th century.

Most of the monks were grammarians and manuscript illustrators. They used the walls to make mural paintings,

Figure 18 - The side of the canyon of the Rusenski Lom River

Figure 19 - Frescoes from the church of the Holy Virgin

which range among the most essential monuments of medieval painting in Eastern Europe. Of all the murals that have survived over the centuries, those in the Holy Virgin Church are the best preserved. Full-length portraits of the church donors - Tsar Ivan Alexander (1331 - 1370) and Tsarina Theodora - are painted on the northwest wall (Figure 19). The presence of their images in the church is an illustration of the close links between the monks in the Monastery, Veliko Tarnovo - the capital city of the Second Bulgarian State and Cherven - the neighboring bishopric, administrative and military center. Over time, blocks have fallen from the ceilings and the walls. In most of the churches, these processes are irreversible. The church “Our Lady” is the most preserved one, with original conserved frescoes. It is shaped in a 55m high rock cliff, and consists of an altar space and two other premises situated on 2 levels.

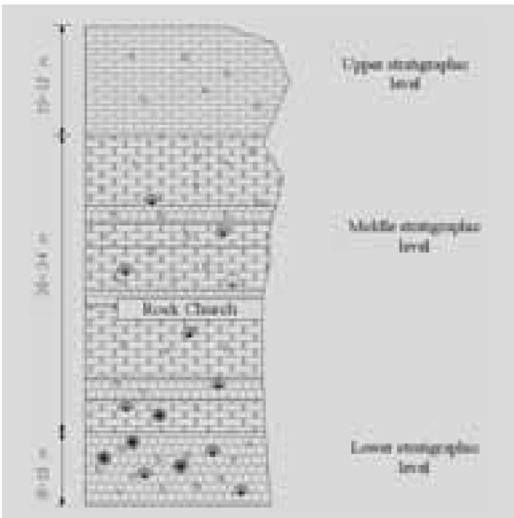

Figure 20 - Geological profile

Of the whole wealth of murals in the Church, only the frescoes on the ceiling have endured, while the images on the walls are quite indistinct. Decoration frames on the ceiling outline 25 quadrangle fields. The images in them represent popular scenes from the New Testament, showing the last days of the life of Jesus. The illustrations of the anonymous

Figure 21 - Internal view of the Church, with the fractures and blocks outcrop.

medieval icon painter are colorful and realistic; the scenes are close to reality and to ordinary people, and that makes the frescoes different from the asceticism and austerity that predominated in the paintings of that period of the Middle Ages. The nude human bodies and the architectural details are clear signs of the revival of the Hellenic tradition, hence the murals in The Church are considered a supreme achievement of medieval Bulgarian art. The church complex was included in the UNESCO's List of World Cultural and Wildlife Heritage in 1979.

The rock massif is built by organogenic reef-limestones of a Lower Cretaceous age. The churches are created in the karst forms of the Lower Cretaceous (Hauterive-Barremian age) porous and water permeable limestone. Three levels have been defined – an upper level with a more micritic texture, a middle detrital level, and a lower level with larger fragments from shells and corals (Figure20).

The main geological hazards which are dangerous for the church's constructions and mural paintings are as following: cracking, karst, seismicity, weathering, and ground water impact. The slope and a part of the churches are partially affected by local demolition and the influence of superficial water.

Totally four sets of joints, and about 20 individual fractures, were established for the site and the church. Some joint groups are parallel to the bedding planes (Figs. 21, 22). Probably they were initially formed with the rock lithification. Other joint groups are younger and with tectonic origin. The relationship between joint systems and the local tectonic lineaments and positive structures is not clear.

Within the Church, the joints systems are presented by individual fractures that occur on the floor, the walls and the sealing surfaces, and create more than 10 separate blocks.

Stop 3.1:

The Thracian Tombs at Sveshtari

Some joints from the church rooms have apertures from 3-4 to 10-15 cm, with a rapid convergence of their walls up towards the cliff top. Only a frontal blocks system, engaging the outer part of the Church premises, outcrops today's surface and was estimated to be free to fall (slide) at the front (northern) wall of the cliff. It is the only one with a visible displacement of a gypsum mark by 1-2 cm up until 1983. All other blocks occurring inside the church seem to be interlocked and not vulnerable to falling. A similar pattern of destruction of the cliff is observed along

Figure 22 - Internal view of the Church with the fractures.

both sides of the canyon in the area.

In general, the small water-collecting areas and the vertical walls of the rock cliff, suppose a quick water draw and insignificant infiltration to restricted depths in the cliff, and no impact on the church. The site is located at a highly seismic zone of VIII degree MSK, and the seismic impact in the past is estimated to be the trigger factor for the destruction of the massif in the area.

The Thracian tombs near Sveshtari village were discovered in 1982 (Figure 23, 24, 25). They are dated around the 3rd century BC, from the early Hellenistic era. The Necropolis consists of many tumuli with different sizes and specifications. The central chamber has many ornaments. It was decorated as the facade of a temple, which depicts a horseman who takes a golden garland from the hands of a goddess with a religious procession following her.

The tumuli are situated on a flat area. The region of Sveshtari is constituted by sedimentary complexes, almost horizontal in layering. In the area of the Sveshtari Necropolis, the uppermost part of the geological profile consists in the Lower Cretaceous limestones from the Rousse Formation, covered by Quaternary loess deposits. From a geomechanical point of view, there is a two-layer system, with large differences in mechanical

Figure 23 - Thracian tumulus at Sveshtari area

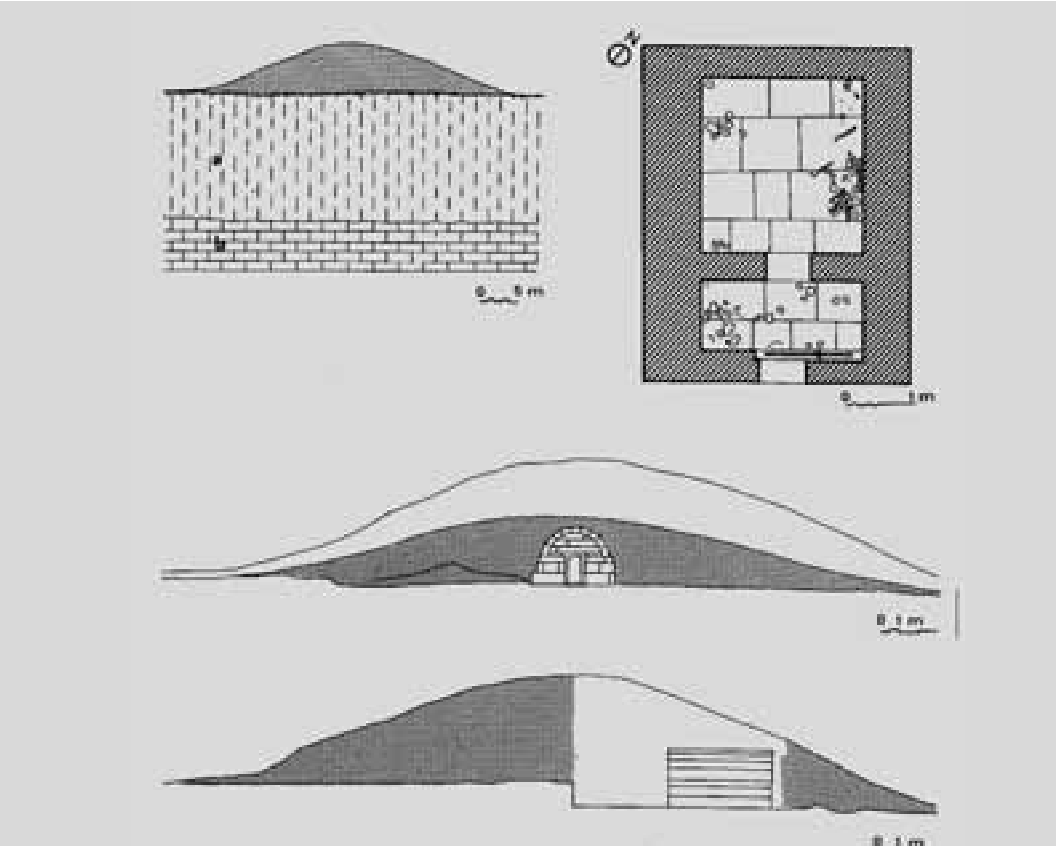

Figure 24 - Cross-section of a Thracian tumulus (Christoskov et al., 1995)

properties, rigid at the base, and plastic in the layer where the monument was built. This system is not favorable to stability because the contrasting parameters between the limestone and loess layers amplify the seismic effect.

New experimental data on the physical properties of the loess deposits, using seismic prospecting, gave us V_p = 330-390 m/s, V_s = 130-180 m/s, and a Poisson's ratio of 0.36-0.47, with a rigidity modulus of 30-40 kg/m.s and a density - obtained by laboratory tests - of 1,8 g/cm^3.

The necropolis of Sveshtari is located in the eastern part of the Moesian Platform, in a region bordered by a seismogenic area. In accordance with the seismological data of the region, over the past 100 years the examined area has been affected by several seismic shocks (eight of them were up to VII MSK in the tumuli site), with epicenters both in the region of Shabla in Bulgaria and in the Vrancea region in Romania.
On the map of the prognostic seismic zonation of Bulgaria (for a period of 1000 years) the region under investigation shows the same parameters with an iso-seismic line of intensity VIII passing very close to it. There are data on the most important earthquakes in the region in the last thousand years, but not on the previous historical period of the existence of the monument under study (from 2400 years ago). After the discovery of the main tombs, many displacements were found, whose origin is presumed to be seismic considering that strong earthquakes happened in the past (Figure 26).

Stop 3.2:
Chirakman Cape
Among the few Thracian centers investigated, special interest has been aroused by the ancient city of Bizone, located on the easternmost part of Chirakman

Figure 25 - The entrance of the Thracian Tomb

Cape, close to the present-day harbor of Kavarna town on the Northern Black Sea coast, about 40 km northward from Varna City (Figure 27). Its catastrophic destruction by an earthquake has been mentioned by many ancient authors. In the "Catalogo dei Terremoti" (Guidoboni, 1989), the end of Bizone was attributed - following the written indications given by Posidonio - to sinking caused by an earthquake; the sinking happened in an uncertain age, between the Bura earthquake (373 B.C.) and the lst century

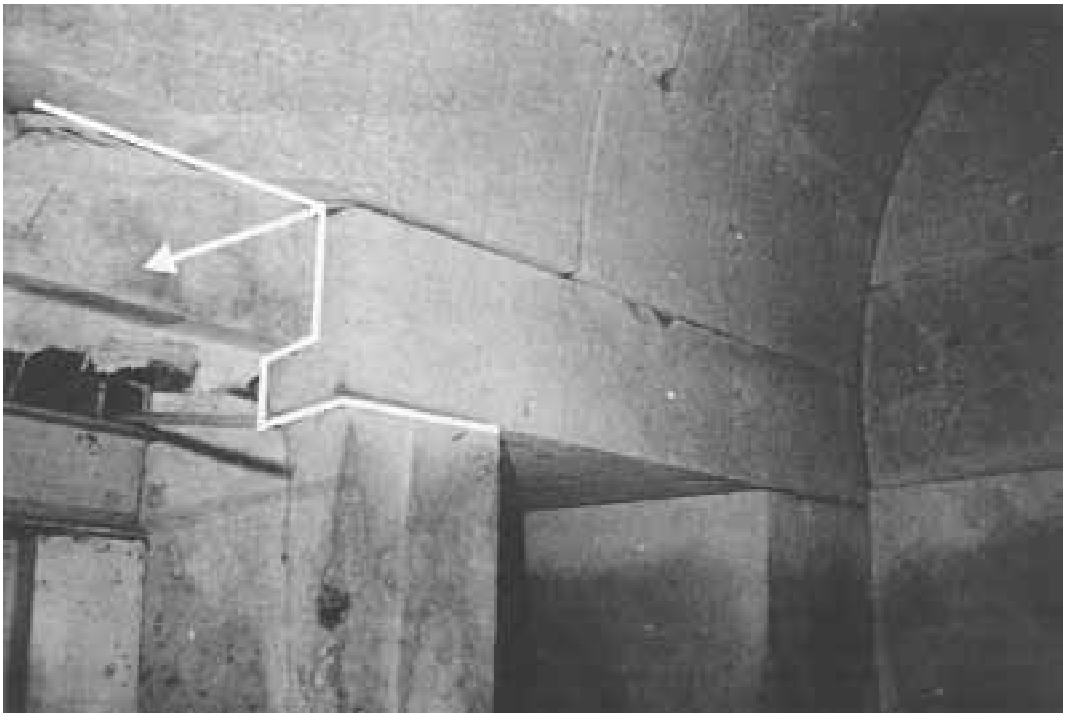

Figure 26 - Displacements of building blocks by seismic impact (Christoskov et al., 1995)

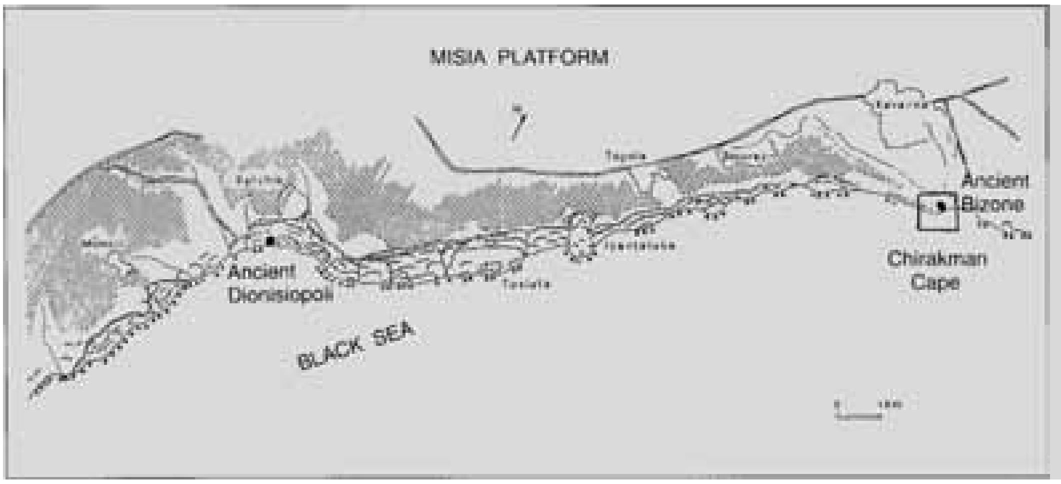

Figure 27 - Map of the region (Evstatiev & Rizzo, 1984)

B.C. (the time of Demetrio da Callatio who gave the information of such an event to Strabo). in the "Catologo dei Terremoti" the date of the banking has been orientatively assigned to the 3rd century B.C.. In the same book the words of Strabo were reported as follows: "…there was Bizone that was almost entirely swallowed up by earthquakes".

The actual observation on the morphology of the site clearly denotes that the end of the city was caused by a fall-type landslide, that slid into the sea. On the basis of archaeological data collected in Bulgaria the abandonment of the ancient city dates back to the lst century B.C.

The relief is characterized by a large plateau which reaches the sea shore and large landslide strips below the peripheries of the plateau. The Dobroudja Plateau

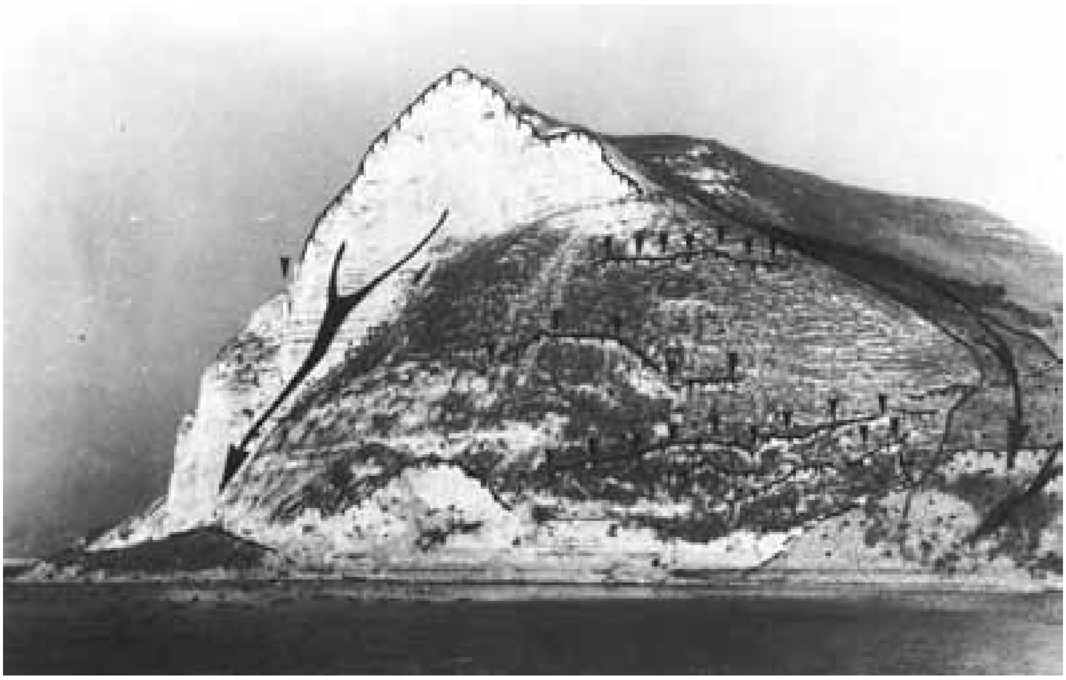

Figure 28 - General view of Chirakman Cape (Evstatiev & Rizzo, 1984

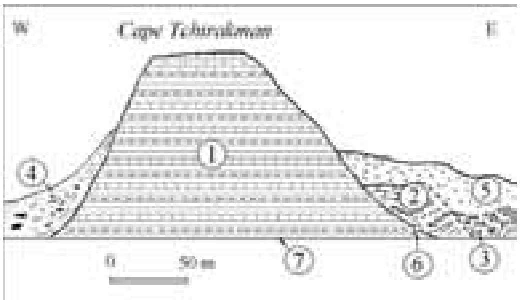

Figure 29 - Schematic profile of the Chirakman Cape (modified after Iliev 1973). 1 - Aragonitites with micrite limestone and clay interlayers, covered by shell limestones; 2 - Landslide block; 3 - Oriented limestone patches; 4 - Ancient earthflow with archaeological relics; 5 - Disintegrated material and redeposited aragonitites; 6 - Spring at the slip surface; 7 - Sea-level.

is elevated about 200 m above sea level at the sea-side resort of Albena, 140 m from the town of Kavarna, and 70 m from the Kaliakra Cape. The scarp of the plateau is nominally 20-30 m high. The dip of slope below the plateau scarp is 7-15º.

It is built entirely of Middle Sarmatian horizontal layers. Three formations build the area: namely, Euxinograd, Topola, and Karvouna. The Euxinograd formation is built up of grey, grey-blue, or buff sandy and clayey aleurolites.

The sediments of the Euxinograd Formation are revealing along the Black Sea shore from Albena to the village of Topola. Their thickness ranges between 100 and 110 m. The dip of strata is 1-3° NE (Kamenov et al., 1972).

The sediments of the Topola Formation lie over the materials of the Euxinograd Formation. In the investigated area, the Topola Formation is revealed from Albena up to the west of the Kaliakra Cape. The sediments are slightly inclined to the NE. The width of this Formation is about 140 m, fixed by boreholes in the plateau. The materials of the Topola Formation build large landslide blocks.

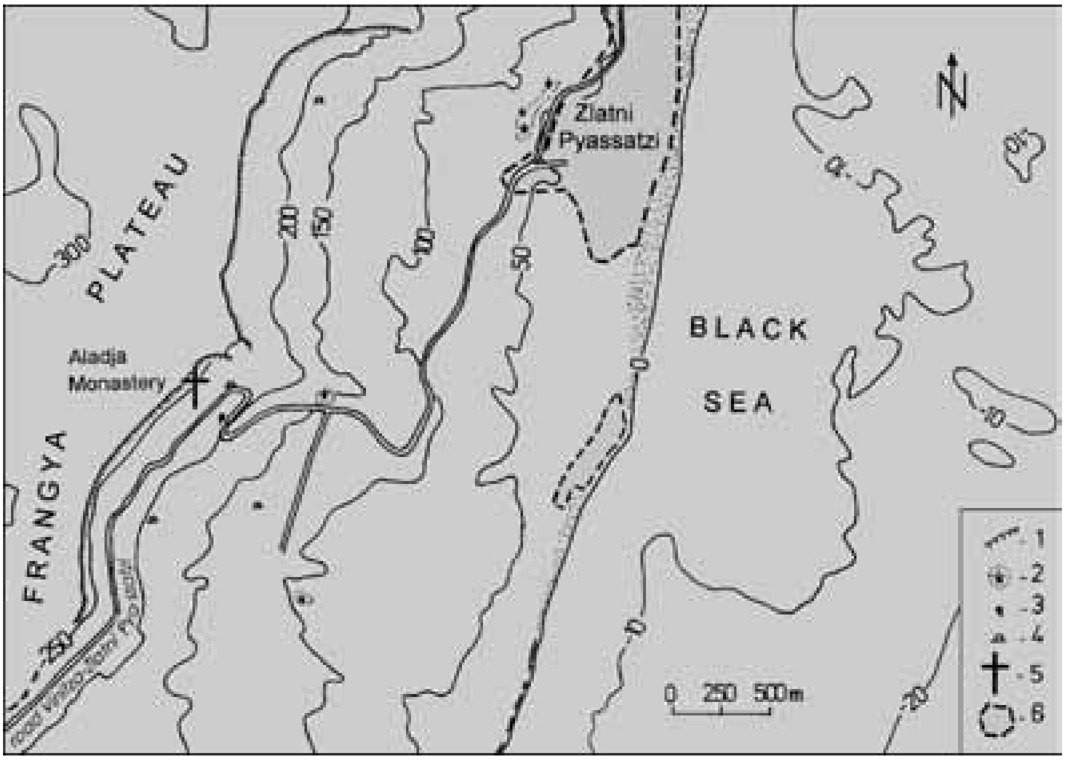

Figure 30 - Scene of Frangya plateau above the Zlatni Pyassatzi sea-side resort (Frangov & Dobrev 2000): 1 - plateau scarp of cliff; 2 - marshland; 3 - spring; 4 - catchment drainage; 5 - Aladja Monastery site; 6 - resort area

Figure 31 - General view of Aladja Monastery

The Topola Formation is built up mainly of white unconsolidated aragonite sediments (aragonitites) of Sarmatian age. The thickness of different strata varies from 0.30 up to 1.00 m, nominally. White and light grey micrite limestones alternate with them with the thickness of the different strata being 0.07-0.30 m.

Karsted shell limestones build the Karvouna Formation. The karstic voids are filled by terra rossa. These limestones build the upper part of the geological profile, and their thickness is small. They do not take part in landslide processes in the investigated area.

Geological and archaeological research has shown that Bizone was located at the end of Chirakman Cape. The southern part of the cape collapsed, together with a part of the city, and tank into the sea, where ceramic fragments, remnants of walls, etc. have been found, chaotically mixed with rock massef below sea level.

The morphology of Chirakman Cape on the sea front side denotes an evolution by falls, whose cause is in relation to the combined action of seismsc activity and sea erosion. Previous studies have pointed out the rule of seismic shock on the landslide mobilisation in this area, where - from a geotechnical point of view - the outcrops are made up of brittle materials. As a recent example we recall the landslide of Momchil, about 15 km south-west from the site), caused by a fall following the earthquake at the beginning of 20th century, that moved down, on a similar slope, about 20 million cubic meter soft material.

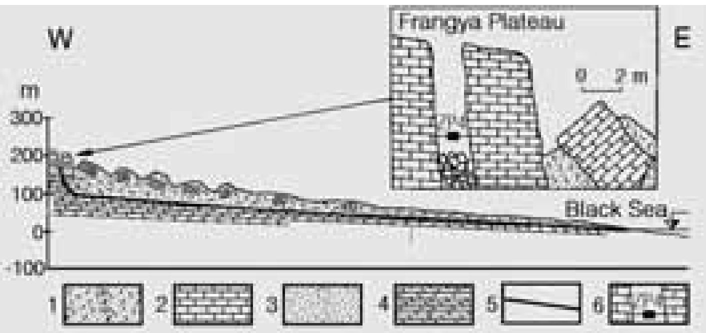

Figure 32 - Geological profile between Frangya Plateau and the Black Sea (Avramova-Tacheva et al., 1998)

The result of seismic activity can still be seen in the frontal part of the cape, towards the sea, by the open fissures running parallel to the angle of the front of the cape (Figure 29), where we can observe recurrent slidings below them. The landslide bodies at the base of Chirakman Cape have been destroyed by sea erosion; they have been preserved in the lateral side, where one can observe the rounded relief typical of this material. The landslide that tore off the frontal part of the cape so that it falls in the direction of the valley and into the present-day harbor, is of great interest. By sea

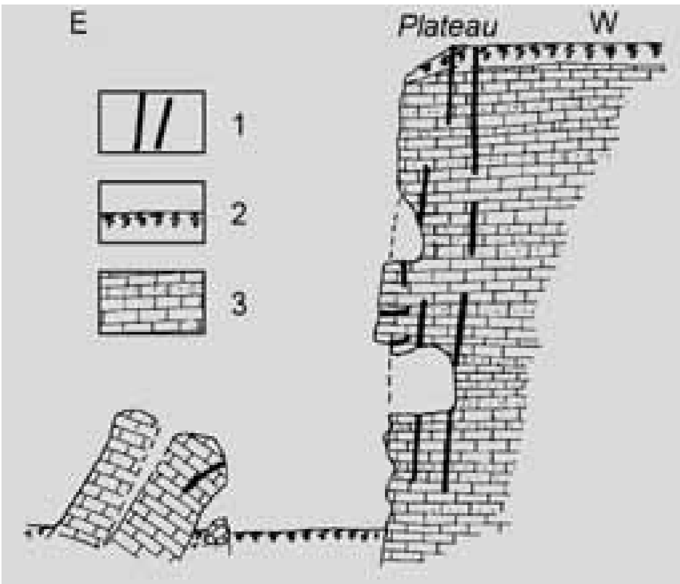

Figure 33 - Cross-section at the Aladja Monastery locality (Frangov & Dobrev, 2000): 1 - fissures; 2 - soil surface; 3 - Sarmatian limestones

erosion along the shoreline, the sea has exposed the transverse profile of the landslide and it is possible to see the typical landslide elements, destroyed rock blocks, sloping layers, disturbed zones, a steep sliding surface which distinguishes the immobile massif with horizontal layers from the strongly disturbed landslide body.

The coincidence between historical evidence on the fate of Bizone and current geomorphological observation of that place suggests that the destruction of a large part of the cape in a southern and eastern direction caused by massive landslides was induced by strong earthquakes, in a period between the 1st and the 4th century B.C. During the same series of events, the town of Dionisiopolis (modern Balchik) was probably damaged.

Stop 3.3:
Aladja Monastery

The rocky Aladja Monastery is carved into the limestone rock scarp of the eastern periphery of the Frangya Plateau, about 14 kilometers from Varna City (Figure 30, 31). This is one of the many medieval rock monasteries found in the Northeast part of Bulgaria. The first Bulgarian archeologists - the brothers Karel and Hermengild Škorpil at the close of the last century, put the beginning of systematic explorations of this old monument of Christianity.

Hermits inhabited the monastery from the 4th Century until the 18th Century. The monastery complex is arranged in two floors hewn into the rock wall. In the first floor, there are "the monastery church", "monastic cells", "dining room and kitchen", "church for requiescats" and the "crypt". The second floor has a long niche and a chapel. The rock wall is high about 25-30 m at this place. The first floor is situated about 3-5 m above the foot of the scarp; the second one - 6-8 m below the plateau edge.

The premises of the monastery are situated on two levels, and have been cut in high sheer limestone rock almost 40 meters high. Due to the extensive corrosion of the rock, it is supposed that what is seen nowadays is only a part of the one-time cloister. At the most eastern side of the first level, is the entrance to the monastery. At the far end of the entrance hall, behind a stone wall, (part of which still exists), was the crypt (tomb). Left of the entrance, there is a cut in the rock staircase, leading to an inside corridor and to the refectory, the kitchen and six monks' cells. Immediately above the entrance and the crypt, there was a chapel where mass for the dead used to be served, of which only the northern and eastern walls can still be seen. Westwards, the corridor reaches a narrow passage leading through a stone staircase to the Minster (church). Similar to other Orthodox churches, this one has also been decorated with frescoes, but unfortunately the easy access made their destruction possible. Only Fragments are still discernible and there is a color copy preserved, which was made in the 30s. It depicts Virgin Mary sitting on a throne with the Infant on her lap.

The second level of the monastery actually is a natural recess in the rock, with a chapel at its eastern end. The only access to the chapel was by a wooden corkscrew staircase from the first level, fixed in a chimney - like outlet in the cliff. Thanks to its difficult access, some of the original frescoes have survived up until today. Best preserved is the ceiling composition, depicting the Ascension Day. Probably, life in the Aladja Monastery declined when Bulgaria fell under the domination of the Turks at the end of the 14th century, but the local people continued to honor it and to come to this place long afterwards – evidence of which is an 18th century silver ring-seal, found in one of the tombs at the entrance.

The Christian name of the monastery is unknown. The name Aladja has a Turkish origin, meaning "parti-colored", "patterned", and perhaps the reason the monastery to be called so were the frescoes in the Minster (church) and in the Chapel, that were preserved till the beginning of 20th century.

No written documents about the Aladja Monastery and the Catacombs have been found. There are only the legends of forest deities and untold riches, maybe true, hidden in bottomless underground labyrinths connected with the past days of this beautiful and mysterious place.

Miocene sediments build the region of Aladja Monastery (Figure 32). Three lithological formations build the geological profile – from limy clays (in the lower parts), and fine sands and limestone in the upper parts of the plateau. The strata are slightly declined 3-4° to ENE. The edge of the Frangya plateau is 270 m a.s.l. at the Aladja Monastery site.

The slope below the plateau begins with a vertical rock scarp that is built up of limestone. The dip of slope is 7-15° nominally. Its relief has a characteristic landslide geomorphology. The foot of the slope finishes with the cliff or beach strip. The cultural site of the Aladja Monastery is situated in the northern part of the Aladja Monastery landslide cirque. This landslide is 1.5 km wide and 2.5 km long.

The weathering of the limestone is the most serious problem of the Aladja Monastery. It is not uniform in the variable layers. The rapid weathering of the weak (clayey) layers forms niches along the rock scarp. The karsting is a process connected partially with the weathering and cracking of the limestone. Erosional couloirs and hollows are formed, and the weathered materials ("the rock meal") are transported down slope by the ephemeral streams.

Cracking and toppling affect the peripheral zone of the Frangya plateau (Figure 33). The cracks are of a different origin. Their formation is connected with the change of the stress-strain state in the peripheral zone of the rock massif after the exogenic geodynamic processes - sea erosion, landslides, weathering, and karst – mentioned above. Additionally, subsurface erosional processes in the fine sands of the Frangya Formation create voids in them, which can provoke a cracking in the upper limestones and additional stresses in the last ones. The cracking of the peripheral zone usually precedes the falling and toppling of rock blocks Relics of a toppled rock slice reveal just below the recent rock scarp Vertical rates of positive tectonic movements between Kaliakra Cape and the town of Varna (in the Aladja Monastery locality) are within the limits from 2 to 4 mm annually. For the same reason, many large landslides have occurred along the shoreline north of Varna, and landslides are less distributed in the western part of the region.
According to the seismotectonic prognostication of NE Bulgaria, the research region is characterized by a high potential seismicity, where earthquakes with magnitudes more than 5 can be generated. Just 50-60 km ENE from Aladja Monastery, the Shabla focal zone is to be found, and many strong and catastrophic earthquakes have happened here. There is an account of a catastrophic earthquake that happened in 1444, when the towns near Varna were completely destroyed. The last catastrophic earthquake happened on March 31, 1901 (M = 7.2). The local earthquakes in the last few years are connected mainly with the Provadia focal zone. At the same time, the region is influenced by seismic events coming from outside. This may be exemplified by the Vrancea earthquakes (Romania), and the North-Anatolian earthquakes (Turkey). During the last strong events, many cases of rock fallings and topplings took place in NE Bulgaria.

Acknowledgments

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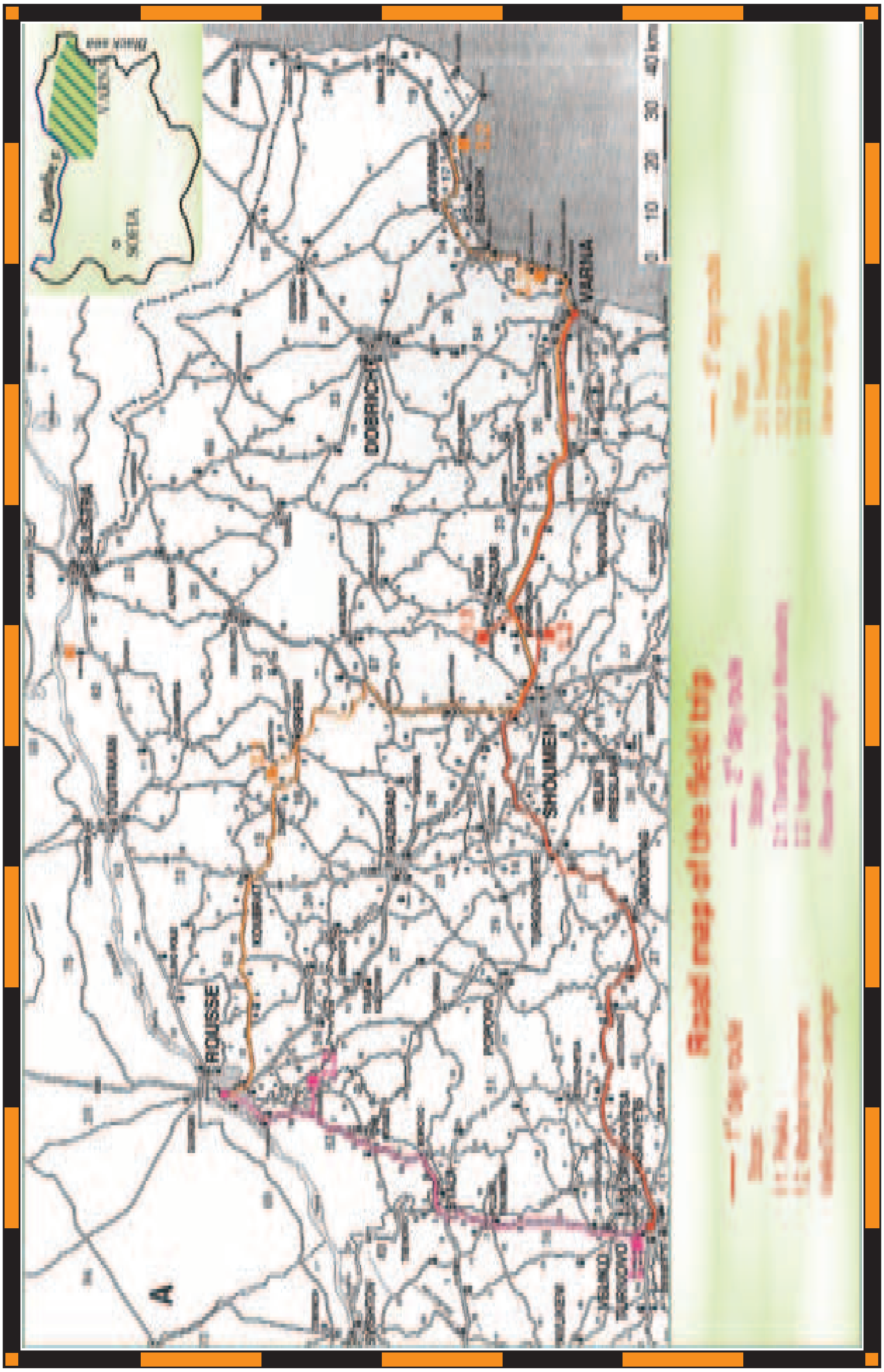
Back Cover:
field trip itinerary

32nd INTERNATIONAL GEOLOGICAL CONGRESS

FIELD TRIP MAP



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