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KARST AND CAVE SYSTEMS IN BOSNEK REGION (VITOSHA MOUNTAIN, BULGARIA) AND WINTIMDOUINE (HIGH ATLAS MOUNTAIN, MOROCCO)

KRAS IN JAMSKA SISTEMA BOSNEK (VITOŠA, BOLGARIJA) IN WINTIMDOUINE (VISOKI ATLAS, MAROKO)

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Abstract UDC: 551.442(497.2)

Dora Angelova & M'hamed Alaeddine Beloul & Sophia Bouzid & Farid Faik: Karst and cave systems in Bosnek region (Vitosha Mountain, Bulgaria) and Wintimdouine (High Atlas Mountain, Morocco)

The study of both endokarstic systems Bosnek (Vitosha Mountain, Bulgaria) and Wintimdouine (High Atlas Mountain, Morocco) is presented in this work. Both regions are standard for the study of geodynamic processes in Bulgaria and Morocco, and they could be used as geodynamic polygons in the Mediterranean region. The karst is developed in Triassic and Jurassic limestones. The karst processes in both endokarstic systems occur under the conditions of active Quaternary and recent tectonics. A typical structural karst is formed. The present work shows also the results of the comprehensive studies performed in the field of geology, tectonics, geomorphology, hydrology, climatology, etc., of the karst. It is accented on the genesis and the evolution of the greatest cave systems in Bulgaria (Duhlata cave – more than 17 km) and Morocco (Wintimdouine cave – more than 19 km long). Both cave systems are situated in zones with high seismicity, with open surface and sud-surfase paleoseismic disruptions. The karst study and monitoring of its processes has great practical value in Bulgaria and Morocco because they are related to one of the largest urbanized territories (Pernik and Sofia for Bulgaria, and Agadir for Morocco) and they are protected natural objectives as well.
Key words: karst, cave systems, Bosnek, Bulgaria, Wintimdouine, Morocco.

Izvleček UDK: 551.442(497.2)

Dora Angelova & M'hamed Alaeddine Beloul & Sophia Bouzid & Farid Faik: Kras in jamska sistema Bosnek (Vitoša, Bolgarija) in Wintimdouine (Visoki Atlas, Maroko)

V prispevku so predstavljene raziskave jamskih sistemov Bosnek (Vitoša, Bolgarija) in Wintimdouine (Visoki Atlas, Maroko). To sta standardni območji za preučevanje geodinamičnih procesov v Bolgariji in Maroku in bi lahko služili kot geodinamični poligon za celotno Sredozemlje. Tamkajšnji kras je razvit v triasnih in jurskih apnencih. V obeh jamskih sistemih potekajo kraški procesi pod vplivom aktivne kvartarne in recentne tektonike. Izoblikovan je značilni strukturni kras. V članku so predstavljeni tudi izsledki podrobnih preučevanj krasa na področju geologije, tektonike, geomorfologije, hidrologije, klimatologije, itd. Osredotočen je na največja jamska sistema v Bolgariji (preko 17 km dolga jama Duhlata) in Maroku (preko 19 km dolga jama Wintimdouine). Oba sistema sta v območju močne seizmičnosti z odprtimi površinskimi in podpovršinskimi paleoseizmičnimi razpokami. Preučevanje in redno opazovanje krasa in kraških procesov je za Bolgarijo in Maroko velikega praktičnega pomena, saj so vezana tako na največja urabnizirana ozemlja (Pernik in Sofija v Bolgariji, Agadir v Maroku), kot so to tudi zavarovani naravni pojavi.
Ključne besede: kras, jamski sistem, paleoseizmika, Bosnek, Bolgarija, Wintimdouine, Maroko.

INTRODUCTION

The karst in Bulgaria and Morocco takes a sizeable part of the territories of both countries. It includes surface and sub-surface karst systems of various degrees of development and complicated relationship between the systems themselves and the surrounding elementary karst and non-karst landscapes. The terrains, where at the present moment both endokarst domains (Bosnek and Wintimdouine) are located, during the Paleozoic they were parts of the geodynamic space of the African continent. These terrains now bear the marks of Alpine orogens and represent terrains from the geodynamic space of two continents – Eurasia and Africa. The endokarst domains we studied are in terrains between the moving and the constantly deforming convergent edges of Eurasia, Africa and Arabia by their position during Mesozoic and Cenozoic. This article puts the accent on the genesis and the evolution of the karst of structural type, and on the beginning of comparative analysis in the comprehensive study of such karst phenomena in Bulgaria and Morocco. The studies of endokarst domains in Bulgaria and Morocco involve the biggest sub-surface karst systems discovered so far in both countries. These are Duhlata karst system in Bulgaria and Wintimdouine karst system in Morocco. Besides, both systems are not evaluated enough for the purpose of economics and as attractive tourist sites not only of local significance. Moreover, we think that the further extensive studies of these regions will contribute to solve the debatable and even contradictory fundamental problems of the paleo- and recent geodynamics of blocks regmatic movement, as the geodynamic processes, which might rise from such confrontation, will affect not only the karst ecosystems themselves, but the large urban territories of Pernik and Sofia (Bulgaria), and Agadir (Morocco). Furthermore, these two endogenous karst domains could be used as ranges for study and monitoring of karst and its processes, and for geodynamic ranges in the Mediterranean region, as well.

BOSNEK ENDOKARST SYSTEM (BULGARIA)

The Bosnek endokarst system includes the southwestern part of Vitosha Mountain and a small part of eastern slopes of Golo Bardo Mountain, i.e. it involves the karst that is closely related to the development of valley system of Strouma River (Fig. 1). The karst (surface and sub-surface) is formed under the conditions of complicated tectonics. The different neotectonic development of both mountains Vitosha and Golo Bardo leads to the forming of typical asymmetric karst – vertical and horizontal. The karst processes had and have now different spatial and time development. In the Bosnek karst domain are discovered as a whole 30 caves totally, cave systems and potholes so far. They were and still are objectives of many years' exploration and mapping of various speleological teams. The work in the sub-surface karst systems continues to the present. Besides, in the recent years considerable data are accumulated (geological, hydrogeological, geomorphological, mineralogical, biological, etc.). These data allow to make important conclusions referred to the origin, development and the ecology of Bosnek karst system (Bonchev 1961; Velinov 1964; Moev 1968; Tronkov 1975; Zhelev 1982; Gochev 1983; Zagorchev et al. 1994; Benderev & Veselinov 1996; Benderev & Shanov 1997; Shopov et al. 1998; Angelova et al. 1999, 2002, 2003; Benderev & Angelova 1999; Angelova 2001, 2003, etc).

SETTINGS FOR THE KARST FORMING

Physical-geographic settings

The altitude of the relief within the studied region varies from 830 m to 1500 m (Fig. 1). Three altitude belts are outlined here: from 830 m to 1000 m, from 1000 m to 1400 m, and over 1400 m. The slopes surface by its shape and dip is grouped into three groups, too – slopes up to 20°, steep protuberant slopes with dip greater than 20°, and steep to vertical slopes with dip greater than 20°.

From morphohydrographic point of view the Bosnek karst region belongs to the upper catchment part of Strouma River with an area exceeding 60 km^2 and a river-bed dip of 61%.

The forming of the river flow and its regime under the conditions of complicated geological, tectonic and geomorphological environment is important for the karst processes development. Both the vegetation and the soil cover have subordinating importance. The flow of Strouma River from its springs (below the Cherni Vrah peak) to its entering into the limestones is formed completely from the snowfalls under the conditions of alpine climate. The river flow in the contact zone between Vitosha pluton and the "Studena" dam is entirely formed by karst water from the shallow holes. The air temperature influences the annual rainfalls distribution and the river flow, depending on the altitude above sea level and the season character (Table 1).

Great portion of the Strouma River water flowing on the surface disappears in the area of the Duhlata cave entrance and in the shallow holes around Bosnek village. There is permanent surface flow of Strouma River in these areas only in the case of high stand water during the spring.

Geological-tectonic settings

The Triassic and Jurassic limestones and dolomites, which build up the Golo Bardo thrust unit, are subjects of karstificaton. The limestones are overthrusted on Vitosha pluton (Bonchev 1961; Moev 1968; Tronkov 1975; Zhelev 1982; Gochev 1983; Zagorchev et al. 1994; Benderev & Shanov 1997; Angelova et al. 1999, 2002, 2003; Benderev & Angelova 1999, etc). Generally, the karst in Bosnek karst region is developed amongst the Triassic limestones and dolomites defined as Radomir and Rusinovdel Formations (Tronkov 1975; Zagorchev et al. 1994). Both formations have different $CaCO_3$ content, which is due to the local tectonic setting and the hydrogeological basins development during the limestones sedimentation and crystallization. The limestones where the karst processes are developed are grained, with high $CaCO_3$ content from 72.39% to 89.59%. The dolomites are characteristic with high $CaCO_3$ content, too – up to 95%. Almost always clayey minerals (5-20%) are presented in the carbonate rocks. The thickness of the limestones and dolomites outcropped on the surface is inconstant. The total thickness of karstified surface and sub-surface karst complexes is nearly 200 m. The limestones and dolomites are deposited in shelf environment. The lithological varieties in such environment are turbidites and flysch. The rhythmical sequence is disturbed locally of event sediments (Moev 1968; Stoykova et al. 2000, etc). The primary limestones structures in Vitosha and Golo Bardo are represent with extremely syn-sedimentary and post-sedimentary changed lithified carbonates, because of the specific position of Golo Bardo thrust unit. The sub-surface karst is developed amongst the Triassic carbonate rocks. Packets and lenses of argillites and siltstones up to 50 m thick are identified amongst them. These clastic rocks play the role of local basis (pad) of karst process and they pinch out to the north and to the northeast. The main lithological basis of karst denudation consists of Lower Triassic red-colored sandstones, conglomerates and siltstones, which are altered to quartzites in the contact zone with Vitosha pluton. The same quartzites are outcropped on the surface in separate localities on the left bank of Strouma River (westward of Bosnek village), where they build up the Palevina peak.

From tectonic point of view the Bosnek karst region falls in the north-easternmost part of Golo Bardo thrust unit. It is accepted by Bonchev (1961), Moev (1968), Zhelev (1982), Gochev (1983), Zagorchev et altri (1994), and other authors as sub-Hercynian superstructure consisting of rock masses overthrusted from southwest. At its movement forward the Golo Bardo thrust formed internal folds 75-90° oriented and strongly recumbent toward northeast. These thrusts northward and northeastward of Bosnek village pass into reverse faults. The trace of Golo Bardo thrust was followed during the field work in connection with the micro-seismic districts dividing of Pernik and Sofia regions. It was fixed out that the unit is deformed many times with variable direction of thrusting during the old tectonic phases. It was established also that according to the northern front of erosion the latest thrusting in the Pernik graben system occurred after the deposition of Upper Paleogene-Lower

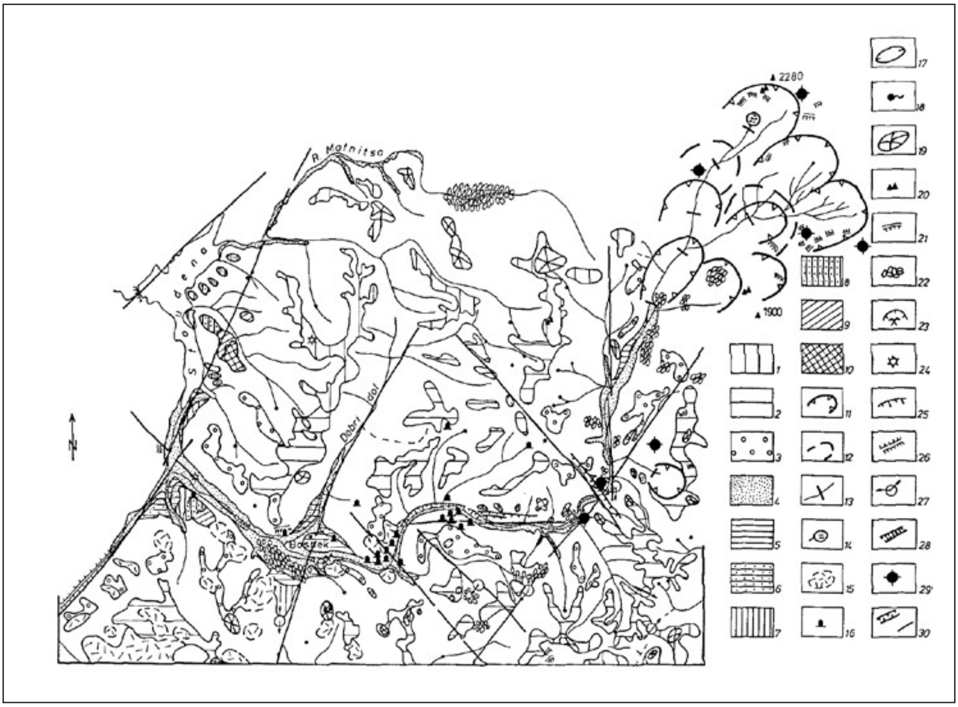


Fig. 1: Geomorphological map of the Bosnek karst region and of the upper part of the Strouma River watershed: (1-3) Plio-Pleistocene levels and terraces:
1 - I level, 2 - II level, 3 - III level; (4-10) River terraces: 4 - flood terraces, 5 -first overflood terrace, 6 - second overflood terrace, 7 - third overflood terrace, 8 - fourth overflood terrace, 9 - fifth overflood terrace, 10 - sixth overflood terrace; (11-13) Glacial forms: 11 - Basic circus, 12 - Inserted circus, 13 - throg step; 14 - peat marshlands; (15-17) Karst forms: 15 - karren fields, 16 - cave, 17 - vallog; 18 - springs; 19 - monadnocks,; 20 - rock dolls; 21 - rock slopes; 22 - ancient gold workings; 23 - quarry; 24 - hillock; 25 - excavation; 26 - canalised riverbed; 27 - river network rearrangement; 28 - erosion slopes; 29 - paleoseismic dislocations; 30 - normal faults and faults.

Miocene sediments (which are definitely dated). The rock complexes of Golo Bardo thrust unit were subjects of fracturing and faulting simultaneously with the thrusting (probably at Middle Miocene time). The active orogenesis of Vitosha and Golo Bardo Mountains, and the forming of Pernik kettle as well were controlled by the Pernik and Vladaya fault zones development and the Mutnitza and Chuypetlovo fault bundles (Velinov 1964; Kostadinov 1965; Matova & Angelova 1994; Angelova et al. 1999; Benderev & Angelova 1999; Angelova 2001, 2003). The Pernik fault zone represents a complicatedly branched group of faults (normal faults and normal strike-slip faults), 130-145° and 85-120° oriented. The zone width exceeds 7 km. The faults of Vladaya fault zone are very important, too, for the forming and development of karst process. This zone represents a complex of arc and normal-fault structures, 0-10° and 45-75° oriented. Thus leads to the block differentiation of the

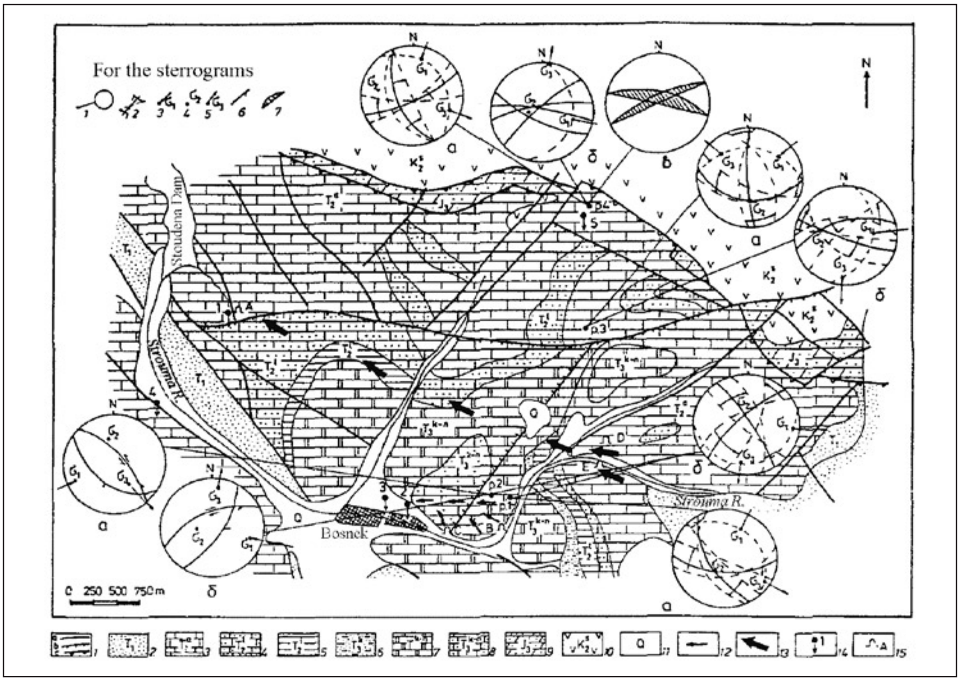


Fig.2: Scheme of the geological, tectonic and hydrogeological characteristics of the Bosnek karst region (Benderev, Shanov, 1997).

1 - Faults (a - with unknown displacement, b) normal fault, c - thrust); Sandstone (Lower Triassic); 3 - Limestones (Anisian); 4 - Dolomites (Landinian); 5 - Shales (Landinian);

6 - Limestones (Carnian); 7 - Dolomites (Carnian-Norian); 8 - Limestones (Carnian-Norian); 9 - Siltstones and marls (Tithonian); 10 - Volcanic rocks (Senonian);

11 - Quaternary sediments; 12 - Water flow direction in the Douhlata karst system;

13 - Water flow direction in the Vreloto karst system; 14 - Springs (1 - Vreloto,

2 - Douhlata, 3 - Bosnek village, 4 - Popov Izvor, 5 - Zhivara Voda); 15 - Caves

(A - Vreloto, B - Douhlata, C - Akademik, D - P.P.D., E - Chuchulyan). In the stereograms (upper hemisphere): 1 - measurement site; 2 - group of shear joints with standard deviation bars; 3 - maximum stress axis; 4 - intermediate stress axis; 5 - minimum stress axis; 6 - tectonic mirror surface with striations; 7 - main open system with development of karst processes.

territory and to outcropping on the surface of non-karstifying rocks from the pad of Pernik graben. These rocks are water impermeable and divide the sub-surface water basins of Duhlata, Vreloto and Zhivata Voda caves (Benderev & Veselinov 1996; Benderev & Shanov 1997; Angelova et al. 1999). Various by rate and character movements in Quaternary predominantly occurred along the complicatedly branched faults, which lead to macro- and micro-blocky differentiation and forming of the multi-leveled cave systems in Vitosha Mountain (Bosnek karst region), and supporting the higher vertical rise of the mountain, compared to Golo Bardo (Angelova 2001). The process of tectonic activity continues through the whole Quaternary and it is still uncompleted. This is confirmed with the earthquakes – established on the surface and sub-surface, paleo, historic and contemporary earthquakes (Angelova et al. 1999, 2002). The reconstruction of tectonic stress fields made after bulk measurements on fractures within Triassic carbonate rocks outcropped on the surface and sub-cropped in the passages of Duhlata and Zhivata Voda caves also confirms this tectonic activity (Benderev & Shanov, 1997) (Fig. 2).

During the field studies of surface and sub-surface karst numerous disturbances of the geological environment and the relief, as a result of paleo, historic and recent catastrophic earthquakes are fixed. The Bosnek karst region belongs to the Sredogorie seismic region with the Sofia high energy seismic zone in it, too. The Bosnek karst region is close to the rest high energy seismic zones in Bulgaria – the Kresna and the Velingrad ones. In the immediate vicinity to Bosnek recent earthquakes are recorded – on 16 March 1911 with focus in Radomir (I_{max}=V), and on 7 June 1934, focused in Breznik (I_{max}=V). Earthquakes of I_0=IV degree are noted within the studied territory. The earthquake from 28 January 1965 (Batandjiev et al. 1966) with focus in Pernik, M=4.6 and I_{max}=VI-VII (Grigorova & Glavcheva 1979) destroyed a part of the buildings within the town and disturbed the surrounding relief as well. As a whole, for the period 1818-1991 there are data about 100 earthquakes nearly, with intensity greater than III degree. These earthquakes have shallow depth of realization (seismogenic layer) – h=2-15 km. The region at the present stage is re-activated with the earthquakes in Krupnik, Velingrad, Sofia, Plovdiv, etc., focuses. The most impressive earthquake during the historic stage was in 1063, when the entire Krakra fortress together with the habitation buildings was ruined and the greater part of the local population died. The comprehensive analysis of the paleo, historic and recent earthquakes resulted in the fact that the most probable intensity that might affects the karst in the region is of VIII-IX rate. Having in mind that the local focuses are predominantly shallow, the surface and sub-surface karst systems might be catastrophically damaged during high energy earthquakes

Station	Altitude, m	Month' Temperature, °C												Av. annual
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Studena dam	832	-1.2	-0.2	0.9	8.0	13.2	16.9	19.0	19.8	14.5	9.2	4.0	-0.7	8.6
Cherni Vrah peak	2286	-7.0	-6.4	-6.9	-3.0	3.1	7.1	8.4	9.8	5.5	2.5	-2.2	-5.9	0.4

Table 1. Air temperature (degrees Centigrade).

Hydrogeological settings

The karst water within Bosnek karst region is dependent on all factors, which are broadly discussed by: Metodiev (1983), Benderev & Veselinov (1996), Benderev & Shanov (1997), Shopov et al. (1998), and Benderev & Angelova (1999). Two sub-surface karst basins – of Duhlata and Vreloto caves, and one completely drained karst massif (Table 2) are differentiated here as a result of geological-tectonic factors activity and geomorphological stages of karst development. Both sub-surface karst systems in general are formed and developed by the river flow of Strouma River, which disappears completely under the ground and by the rainfall as well. The water within the region of Bosnek karst is of hydrocarbonate-calcium-magnesium and hydrocarbonate-magnesium-calcium type. Its salinity varies in wide range from 145 mg/dm^3 to 575 mg/dm^3, as the highest values are measured for springs of joint water, and the lowest ones – for river flow (Benderev & Veselinov 1996; Metodiev 1983). The total average salinity for both sub-surface karst systems is shown in Table 3.

The karst denudation is dependent on the different $CaCO_3$ content in the limestones and the dolomites, the tectonic environment, the hydrological and hydrogeological development of aquifers and basins, and the climate. The karst surface and sub-surface denudation went off with various rates in the interformation and intraformation spaces and in the contact to the non-karstified rock complexes. The contemporary surface and sub-surface karst denudation goes off with a different rate, too (Table 3).

Karst and evolution of the karst relief

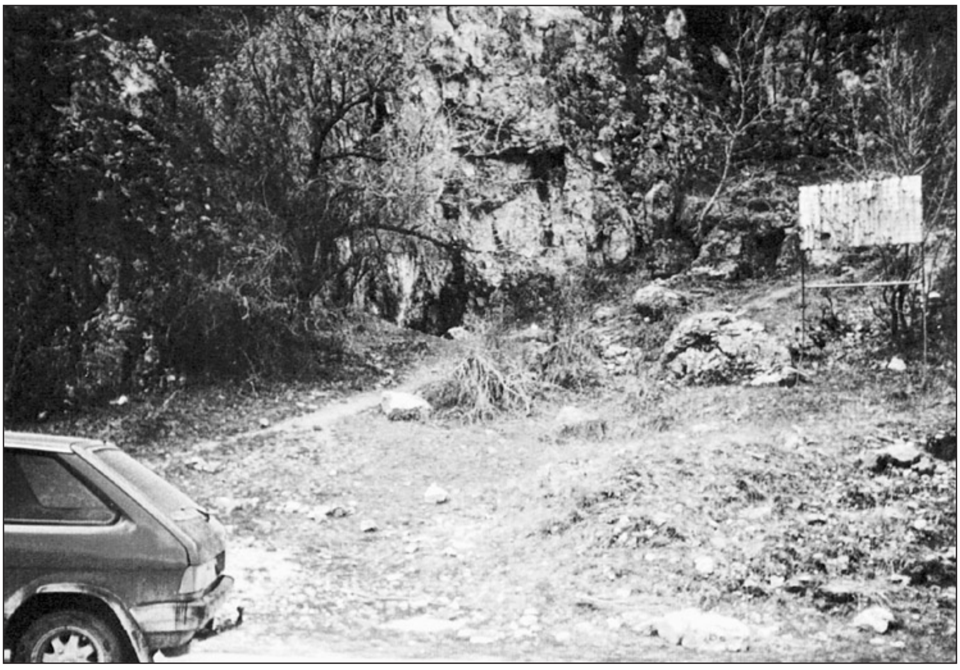
Three main stages are differentiated in the development of Bosnek karst region (Fig. 1). The studied terrains of Vitosha and Golo Bardo are a part of the Pernik basin during Paleogene. At the time of thrusting in Middle Miocene conditions for typical allogeneous karst forming in compli-

#	Name	Age of rocks	Area, km^2	Sub-surface distance, km	Resurgence	Q_{av}, dm^3/s	Q_{max}, dm^3/s	Q_{min}, dm^3/s	Measure-ment
1	Vreloto	M. Tri-assic	23.0	4.5	Vreloto	310	1140	83	Daily
2	Duhlata	U. Tri-assic	3.8	1.2	Duhlata	Approxi-mately 140	720	5	Episodic

Table 2. Main karst systems in the region of Bosnek (Benderev & Shanov, 1997).

#	Karst system	Area, km^2	Q_{av}, dm^3/s	Number of samples	ΔSalinity, mg/dm^3	$\Delta(CaCO_3+MgCO_3)$, mg/dm^3	Karst denudation, $t/year.km^2$	Total denudation, $t/year.km^2$
1	Vreloto	23.0	310	10	170	96	40.8	72.3
2	Duhlata	3.8	140	4	190	94	109.2	220.7

Table 3. Denudation in the region of Bosnek (Benderev & Shanov, 1997).



Photos 1 and 2: Location of Duhlata Caves Systems (autor Benderev).

cated geological-tectonic environment under the permanent impact of the Strouma River flowing on the surface are created (Angelova et al. 1999; Benderev & Angelova 1999; Angelova 2001; Angelova et al. 2002; Angelova 2003). The karstification processes are not intensive due to the poorly outcropped karstifying rocks and the low inclination of topographic surface. The initial tectonic impulse at the beginning of Plio-Pleistocene is not strong and the Strouma River keeps its flow direction through the Radomir kettle. The relics of this old river valley are well preserved on the present relief between Kosmatitza and Petrus peaks. The open karst is still undeveloped. The boundary Plio-Pleistocene/Pleistocene is accompanied by intensive vertical tectonic deformations. As a result of an impulsive tectonic movement and the consecutive movements along the faults of Vladaya fault zone, and along the Bosnek fault in particular, a global shifting of the Strouma River flow direction is realized. The denudation everywhere outcrops on the surface the karstifying rock complexes, and structurally oriented surface and sub-surface karst starts its forming by the strongly fractured rocks. Its beginning is dated as 0.73 Ma according to the fauna found.

Two main sub-regions are differentiated in Bosnek karst region – southern and northern, separated with the Strouma River, which is the basic drainage system for the development of dolines type of karst. The main directions of southern region development (a part of Golo Bardo Mountain now) are 55-60° NE and 40-45° SE, and in the southwestern part of Vitosha Mountain (the northern sub-region

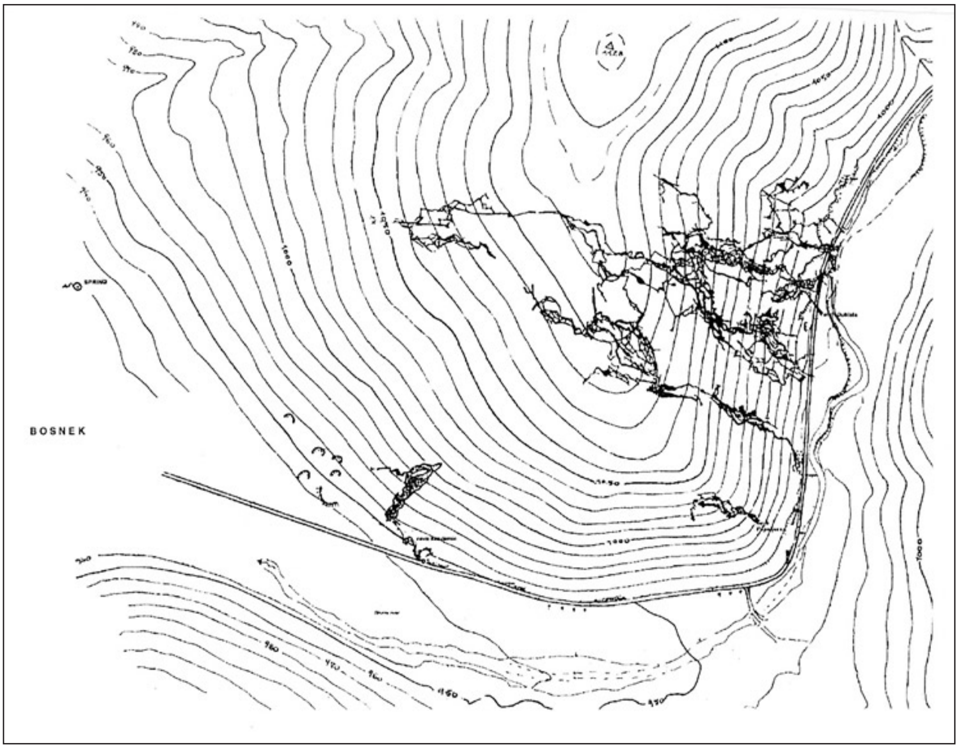


Fig. 3: Situation of the Duhlata Karst Systems (Rusev, 1966 a), according to materials of the Bulgarian Federation of Speleology

of Bosnek karst region) these are from E-W to NE-SW. The river-terrace complex and the multi-leveled karst complex are formed in Pleistocene with the change of the character and the intensity of tectonic movements under the conditions of all over rising of Vitosha and Golo Bardo mountains (the Vitosha Mountain rising is greater than Golo Bardo Mountain one), the phases of global climate changes (glacial and interglacial epochs), and the lithostructural specific of the rocks. The Dobridol fault represents an active tectonic structure in Middle Pleistocene time. It plays the role of an erosion base for the northern and the southern karst massifs (northward and southward of Strouma River, correspondingly). At that time the river is fed by the Paleo-Klisura, as the base of erosion there is with 40 m higher than the contemporary one. During the Upper Pleistocene the faults of Pernik fault zone are activated. A new reorientation of the river basins is performed – Paleo-Klisura changes its flow to the south-southwest toward the Radomir kettle. The karst processes during the Pleistocene, Holocene and the recent stage are preconditioned by the development of surface and sub-surface drainage system of Strouma River in peri-glacial environment at Pleistocene and in post-glacial environment at the time after the global climate warm (Shopov et al., 1998; Angelova et al., 2002; Angelova, 2003). The biggest cave system "Duhlata" with more than 17 km length mapped so far is a multi-level cave of 7 levels, with constant water flow at 40 m higher than the Strouma River present level (Photos 1 and 2) . The cave entrance is located on the level of the first flood terrace of Strouma. Above this terrace 5 levels of the cave are situated Fig. 3). Their development is correlated to the river terraces, although the entrances (exits) of the cave levels are not discovered yet (Fig. 4). The second by length cave is "Vreloto" – 6500 m long, and multi-level, too. The pothole cave "PPD" is quite characteristic and tied to the main stages of Vitosha Mountain relief development. It is about

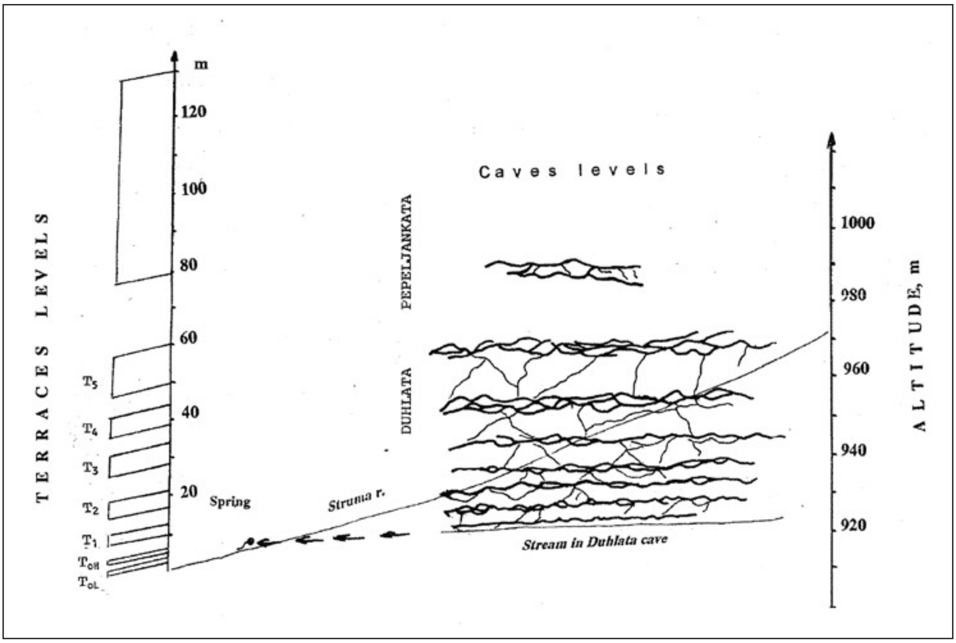


Fig. 4: Situation of the Struma River, its terraces and cave levels (Benderev & Angelova, 1999)

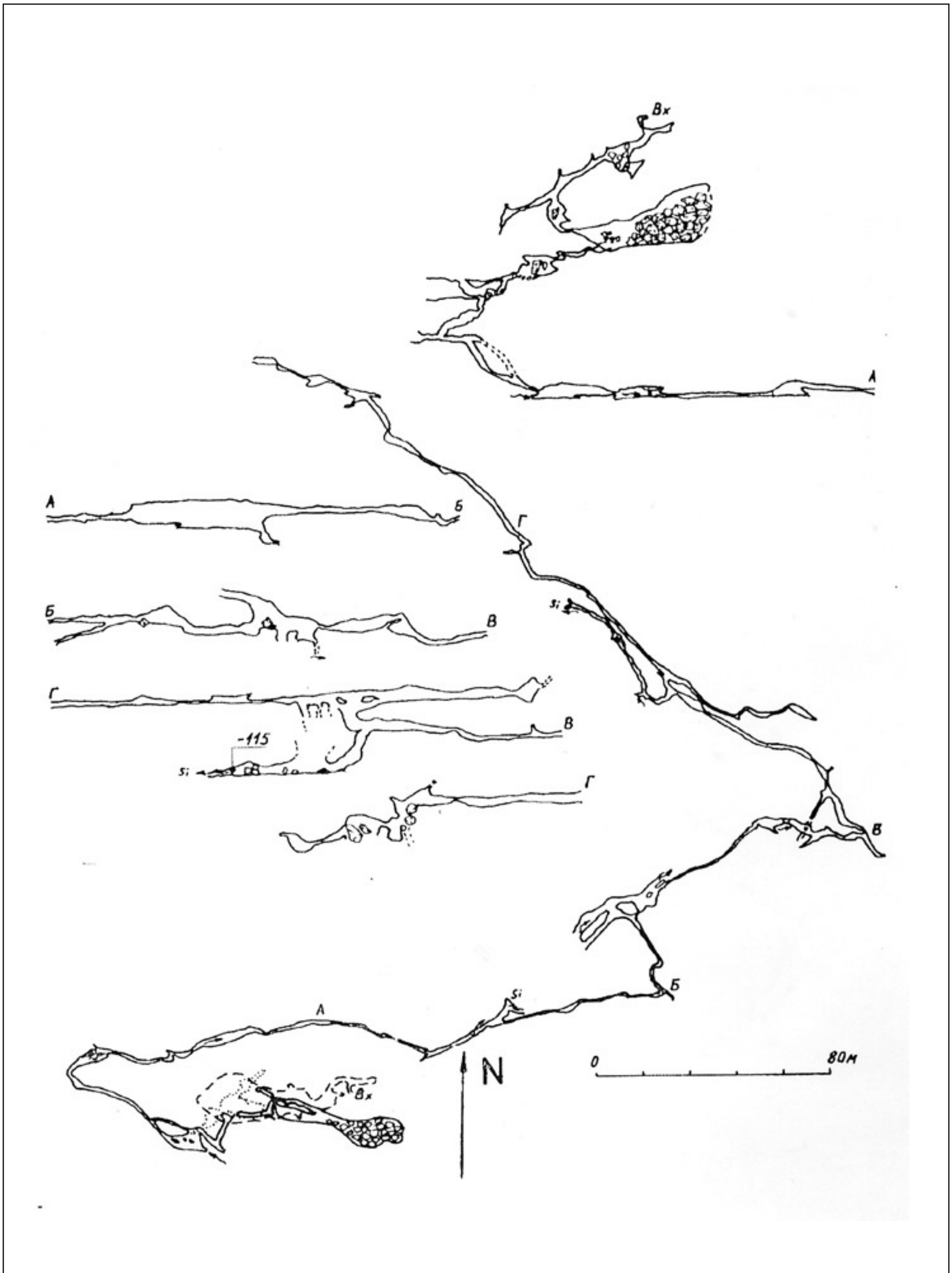
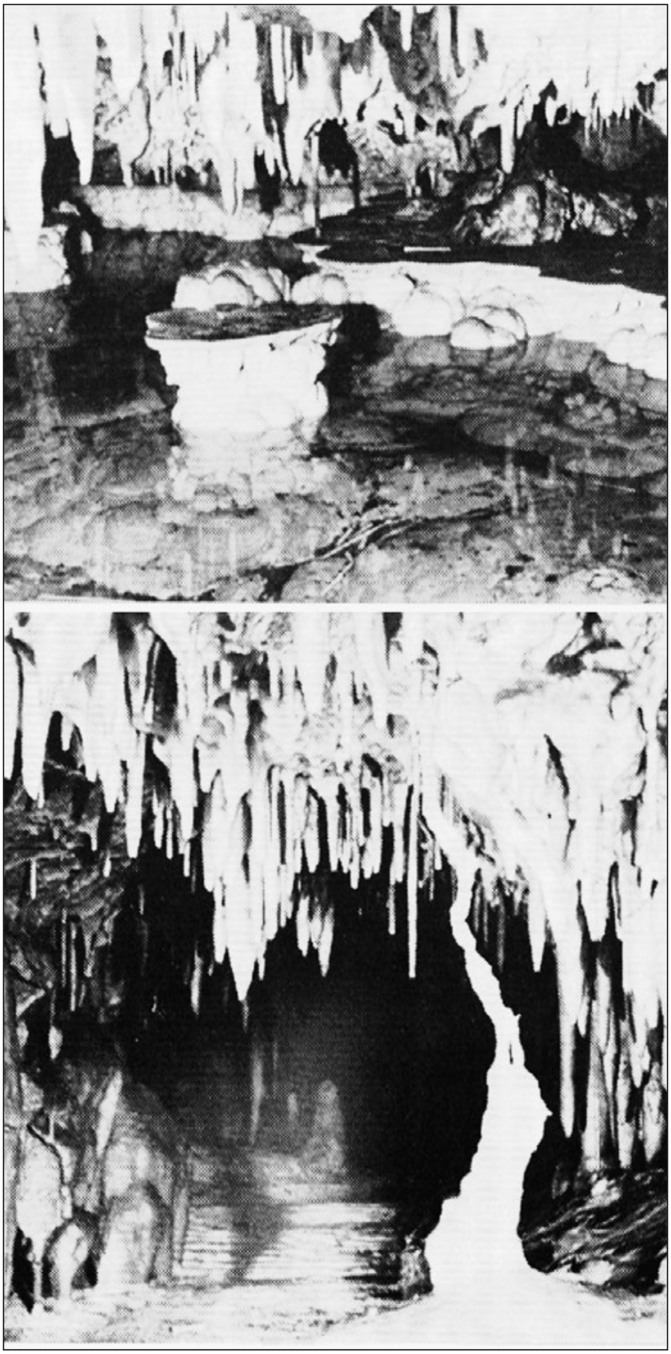


Fig. 5: PPD Cave (Rusev, 1996 b), according to materials of the Bulgarian Federation of Speleology

1000 m long and -125 m displacement (Rusev 1996 b, Fig. 5). Having in mind the structural commitment with the fracture-fault net, the opinion is that the other caves and cave systems discovered (more than 30 after the data of Bulgarian Speleological Federation and Rusev 1996 a) in this sub-region are a part of the common cave system of “Duhlata”. Taking into consideration the correlative connection between the cave levels and the river terraces, it is defined that the time of cave levels forming is from 0.73 Ma to 0.18-0.15 Ma. The forming of the recent passages, which present level reaches up to -40 m below the contemporary level of Strouma River, starts after this time. The Krapetz fault, located in the Strouma artificial lake plays the role of erosion base. The hydroclimatic changes in Holocene and at the present stage a capping at high stand water, which is an indication for incomplete karst process is fixed (Benderev & Angelova 1999).

The intensive orogenesis of Vitosha Mountain, high inclination of topographic surface, denudation

Photos 3 and 4: Structural Features of Karst Landscapes, Bosnek Karst Region (autor Benderev).



Photos 5 and 6 (autor Nedkov):Duhlata Caves Systems - speleothems

of carbonate rocks, and the greater quantity of rainfall – all this supports the shaping of alpine surface karst landscapes at: 830-1000 m, 1000-1400 m, and over 1400 m (Photos 3 and 4), and well developed multi-leveled karst forms. The surface karst is presented with different types of karren, karrenfields, dolines and single uvalas (Fig. 1). The sub-surface karst is not so well developed along the left bank of Strouma River. Small caves of fracture type are discovered here so far. Because of the more specific neotectonic rising (of slower rate) the surface karst here is better developed and unique autonomous recent and relict karst landscapes are developed on it. The paleo-earthquakes, the historic and the contemporary earthquakes put a specific stamp on the surface and the sub-surface karst relief – breakdowns, anomalous shears and breaks of speleothems (Angelova et al. 2001, 2003). The reasons for the cyclic recurrence and anomaly in the sedimentation fixed by Shopov et altri (1998) in “Duhlata” are the climatic and paleo-seismic changes during Quaternary (Photos 5 and 6).

NATURAL HERITAGE, GEOECOLOGICAL PROBLEMS AND SOCIAL ASPECTS

The karst of Bosnek karst region, as it is unique, represents a natural phenomenon (Angelova 2003). Till 1999 it is a part of "Vitosha" Natural Park. Parts of the Bosnek karst region were re-categorized as a result of changes of nature legislation. The cave "Duhlata" together with a small part of the surface remained in the category of protected objectives. As a whole, the changes influenced the entire mutually related surface and sub-surface karst ecosystems, expressed as follows:

- Polymetallic ore-shows are fixed within the Bosnek karst region. Since Thracian time (between 2000 B.C. and 460-340 B.C.) the polymetallic ores are objectives of development and production. The ore production is extremely big at the time of Romans and Ottomans rule. Just for the production of placers gold more than 10,000 m^3 rock mass of river terraces was reworked here. This together with the moving and accumulation of rock masses on other places (Fig. 1) shows distinctly the rate of change of the autonomous surface karst landscapes. The natural (background) ore mineralization is presented by galenite, sphalerite, pyrite, chalcopyrite, gold, electrum, scheelite, molibdenite, magnetite, hematite, white pyrite, pyrrhotine, etc., as products of their hypergenetic alteration, too. These minerals are related genetically to the Upper Cretaceous volcanism and the Late Alpine tectonic activity. These minerals are presented with skarns developed on Triassic dolomites and limestones (Velinov 1964; Marinova & Vitov 1996). The interest in the sources of placer gold and gold in situ increased in last years (Velinov & Velinova 1999). It is proved that this territory is rich and prospective for gold production in particular, and it is tendered for concession permits. At the same time, the rich mineralization within the region predominates also in the crystallization and the aggregates character of the sub-surface flowstones. Unique crystals and needle-shaped aragonite forms, sinter (moon-milk and pearls), corallites, variegated stalactites, stalagmites, stalactones, etc. are formed, which make the "Duhlata" cave one of the most beautiful in Bulgaria. The changes of nature legislation and the lack of financial resources deprived the cave of security guards and managing. Now, in the cave are frequently found out disturbances of sub-surface river sediments as a result of criminal gold production. Some of the unique crystal forms are destructed, too.
- The water flowing into the cave system is polluted. This water together with the karst one and the water of "Studena" dam are used for supply of Pernik and the surrounding villages. The water samples analysis showed pollution exceeding the sanitary requirements.
- Moreover, the analyses from the first geochemical studies of soil after the reform showed a disturbance of the background landscape-geochemical structure, exceeding 2 times for the separate parts. This caused elements migration and disturbed the equilibrium in the elementary and in the complex (cascade) landscape-geochemical systems in horizontal and in vertical plane. As the relation between the surface and the sub-surface karst ecosystems is very intensive, it should be accepted that the rate of anthropogeneous geochemical differentiation of the karst sub-surface ecosystems varies from very poor (1.2-1.5) to medium (2-5) for the chromium, manganese, nickel and cobalt, and high (5-10) – for the lead.
- The proximity of Bosnek karst region to the Pernik and Radomir industrial zones lead to accumulations of chromium 1.8 mg/kg and lead 5-10 mg/kg in the leafs of fruticose and ligneous specimens. These data exceed significantly the average admissible standards, while the other heavy metals content is within the frames of average standards (Penin, 1992, 1993).

For the elimination of the consequences we propose:

- Assessment and monitoring on the surface and the sub-surface karst ecosystems.
- Evaluation of recreation resources and Bosnek karst region return to the territory of "Vitosha" Natural Park.
- To make the local municipality and the entire country population more sensitive to this unique karst in Bulgaria, and to forbid the tender permissions for placers development within the region.

ENDOKARST SYSTEMS WINTIMDOUINE (HIGH ATLAS MOUNTAIN, MOROCCO)

Morocco takes the northwestern corner of the African continent and the country represents a mosaic of various geodynamic events from the geological annals of Africa from the Pre-Cambrian time till the present moment. The favorable conditions here help the preservation of unique paleo and neo karst. For example, the karst domain in the Anti Atlas, Lakhssass plateau southward of Agadir in the southern part of the country, is developed in Cambrian limestones, while the main karst systems are developed both in Middle and High Atlas Mountains – the highest mountains in the whole Northern Africa (Photo 7).

The Atlas system is a segment of the Alpine orogenesis, which includes also the Rif chain. The High Atlas is subdivided usually into three parts – eastern, central and western one, on the base of paleogeographic features. The western part is predominated by Meso-Cenozoic marine platform deposits, as the direction of their better development is towards the west and the southwest.

The endokarst system Wintimdouine (Fig. 6) is one of the biggest in Morocco. It is very interesting for research, because it is a wonderful range within the Mediterranean region for the study of paleo and recent geodynamic processes. We should note the fact that this objective is located in one of the highest energy zones worldwide, unfortunately, sorry known with the earthquake from 29 February 1960, when 13100 people died here in the region of Agadir. Besides, at the present moment this town takes one of the most urbanized territories in Morocco. Within the region of the karst domain Wintimdouine a lot of surface and sub-surface relief disturbances are found, caused by catastrophic paleo-earthquakes (Bouzid et al. 2001; Angelova et al. 2002, 2003, etc). In addition, Agadir is the biggest balneological center in Morocco, and at a good assessment of recreation resources it could be used for the tourists' interest quickening.

In the local Berberian language the word 'wintimdouine" means "the source of the lakes". The sub-surface Wintimdouine cave is located in the Western High Atlas range, at 70 km north-north-eastward of Agadir town. Its Lambert coordinates are as follows: X=122.00, Y=415.30, and Z=1200 (according to the Topographic map of Imouzzer des Ida-OuTananes).

SETTINGS FOR THE KARST FORMING

Physical-geographic settings

The altitude of the relief within the studied region is 1200 -1400 m. It is characterized with high inclination of the slopes towards the river-ravine system, and with plain relief on the leveled away surface of Tasroukht Plateau (Photo 8). The climate is semi-arid. The average rainfall value exceeds 400 mm per year. The surface and the sub-surface feed of river basins is predominantly rainfall one. Both the soil and the vegetation have subordinate relation to the karst process. The physical-geo-

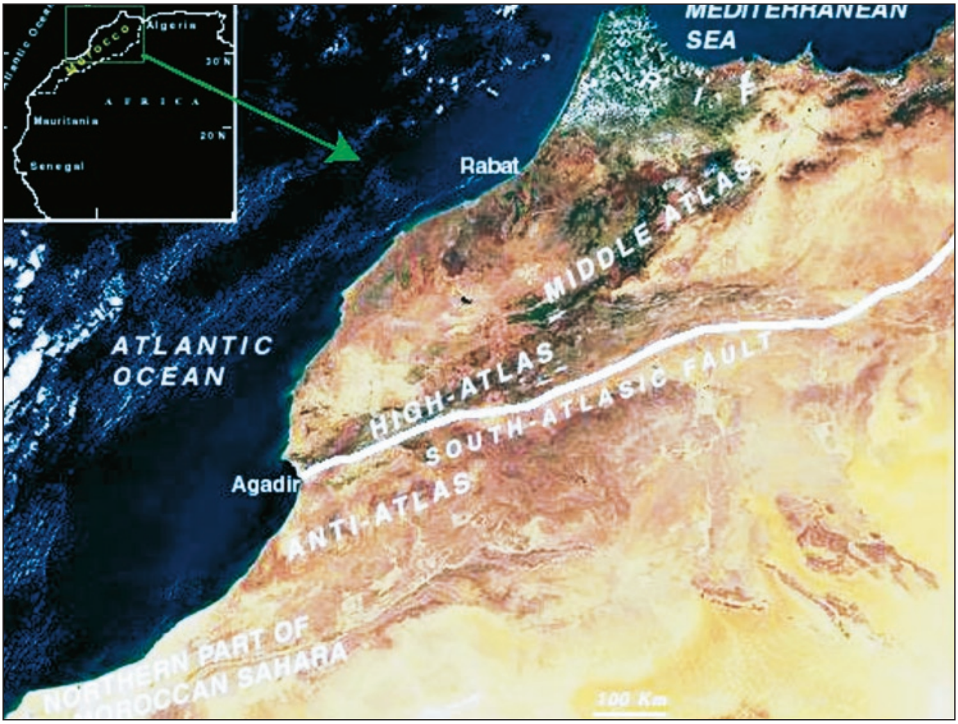


Photo 7: Satellite view of Morocco.

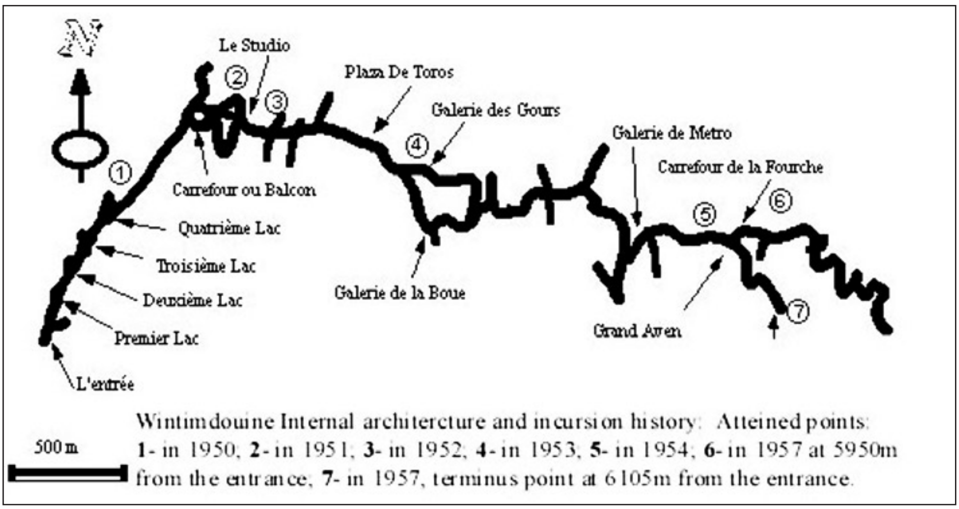


Fig. 6: Wintimdouine Cave.

graphic compounds combined together with the lithological-structural features of Tasroukht plateau precondition the karst process development.

Geological-tectonic settings

Several studies treat with the geological setting of Wintimdouine karst system (Ambroggi 1954; Qurtobi 1996; Belfoul et al. 2000; Angelova et al. 2003).

The karstified formations in Wintimdouine are aged as Jurassic (Upper Lias – Kimmeridgian). The river flows on a semi-permeable bed consisting of about 20-m thick blue-gray marls (Oxfordian). The main karst levels (at 42 m and approximately at 50 m) are referred to Callovian chalks and Upper Toarcian blue dolomitized reefal limestones. The Tasroukht plateau is built up by clayey-marl formation, surrounded by chalky bars underlying the Kimmeridgian micro-conglomerate sandstones (Fig. 7).

This zone belongs to the domain of Atlas orogen, which marks out the Africa-European submeridional geodynamic closeness.

As a whole the main tectonic structures are presented with sub-equatorial anticlines with steeply dipping right limbs, and usually sustained with wide synclines in back slope shape. A lot of diffuse schistosity exists very frequently in the bended axial part. Besides, the fractures are indicated and grouped into three general directions: E-W as fracture cleavage (parallel to the folding geometry), NNE-SSW sinistral, and NW-SE dextral faults, as a transverse conjugated system and a result of tectonic stresses (Fig. 8).

The interesting fact for this site is that it is situated not far from Agadir town, which is built on the famous current seismo-tectonic Tizi n'test fault network. Therefore, both are solicited to the same dynamics.

The synthesis of the different expeditions which objective for 50 years was the cave is to rise up its topography. All investigations emphasize that Wintimdouine cave has just one entrance in the southwestern end of the network, which coincides with the cartographic N30 sinistral strike-slip fault. This disposition undergoes a virgation towards the east, at about 2 km further, on the same way to Tasroukht syncline axial part.

In 1996 Qurtobi raised a trend rose of the sub-surface cave passages. The result obtained showed that the main body of Wintimdouine network could be subdivided into two parts: NNE axis (N20-30) and ESE axis (N100-120), from which started numerous guts.

We proceed with the comparison of Tasroukht plateau main fractures directions to those by which the passages of the sub-surface river are cut. The perfect superposition shows that the sub-surface cave topography and the Tasroukht plateau fractures are closely bound and interactive. The précising of cave roof interior – with convex ogive shape, is still remaining. It is due to the fact that the apex of the ogive coincides with the fracture on the roof, where the infiltration and dissolution are performed. Calcite speleothems are deposited laterally.

Obviously, the sub-surface cave network Wintimdouine is controlled by the regional geological tectonic structures themselves, depending on the seismo-tectonic behaviour of the site. Besides, the karst forms are developed in general by the faults, the fractures and the discontinuities.

It is clear from the field observations that the Wintimdouine karst occurred at least from the Mesozoic till the Quaternary and in recent times under the conditions of active tectonic and geomorphology.

The presence of tuff and chalk sediments agrees with the high energy dissolution/precipitation process, which testifies for a well developed karst network. This phenomenon raises several spectacular speleothems (stalactites, stalagmites, draperies, calcite veils, etc). Some of the speleothems' shapes prove that karst development and increase are influenced by the seismo-tectonic activity (Angelova et al. 2003 , Photos 9 and 10). As significant markers are cited such forms, as: unstuck parts of the vault, broken stalactites, and horizontally sheared columns. They show that the cave was and still is modeled during the time of vertical and horizontal shifts that correspond to the contemporary rising up of High Atlas and its thrusting to the south. This dynamic is sprinkled by brief seismo-tectonic events, such as the recorded in the speleothems.

Obviously, the Wintimdouine system is a real natural laboratory where we teach ourselves in the best manner to monitor such substantial parameters, as lithological and structural peculiarities of the karst developing under the conditions of regional geodynamic activity.

1.3. Hydrogeological settings

The biggest sub-surface river in Northern Africa flows through the Wintimdouine cave. About 19.128 km of its length are explored so far.

The sub-surface Wintimdouine River flows under the Tasroukht plateau, which is a real catchment's basin as its structure represents a wide syncline slope. As we saw above, it is intensively fractured. The rainfall is infiltrated immediately by gravity through the dense fracture sets and through the different forms of dissolution. The water so captured flows deep inside and feeds the sub-surface rivers, and, most probably, constitutes the internal reservoir of Wintimdouine. The high rate of infiltration underlines the good circulation through the fractures, dolines, lapiaz and shallow holes, and low water impermeability as well. This aspect is well illustrated with the accident happened in the summer of 1988, when a brief and unexpected thunderstorm for few hours plugged the cave exit and entrapped a group of speleologists through fast water level rise. The water flow rate measured in 1997 was 10 l/s.

As a whole, the hydrogeological regime is quite irregular. Nevertheless, during some exclusively heavy winter rainfalls (1994, 1997, 2002) the sub-surface river revived a spectacular waterfall, which appeared down the flow to Oued Issafene at the level of Tizgui n'Chorfa village. These activities that must be more frequent in the past, created magnificent travertine and calcareous tuff forms.

The surrounding landscape shows a morphology that is characterized with numerous valleys and springs, scattered over the topographic levels. It is important to note that the springs reviving predominantly close to cave entrance is just a part of the real sub-surface water volume, which should flow inside with high rate, and flow outside through lateral ducts in sizable quantities. The real size of the losses is unknown, as specific studies on the hydrogeological dynamics of Wintimdouine are not carried out.

Karst and karst evolution

The surface and the sub-surface karst systems in the Tasroukht plateau are a result of the orogeneous processes in High Atlas Mountain. The forming of Wintimdouine cave started probably in the Mesozoic, when the wide syncline was formed and started the water accumulation in it. Its forming began without any exit of karst water flow. During the Quaternary as a result of the vertical raising of the High Atlas and Atlantic Ocean level changes, the relief was completely altered, a typical erosion-tectonic relief was formed and the plateau was shaped. The conditions for karst water flow outside the cave were favorable then. The surface karst forms are presented with karren, dolines, shallow holes and springs, situated on different levels, which marks out the stages of karst relief development. Because of the longer development of sub-surface Wintimdouine karst system, impressive speleothems are formed there. The process of forming of surface and sub-surface karst is still incomplete. The intensive seismic activity leads to anomalous changes of the surface and the sub-surface karst.

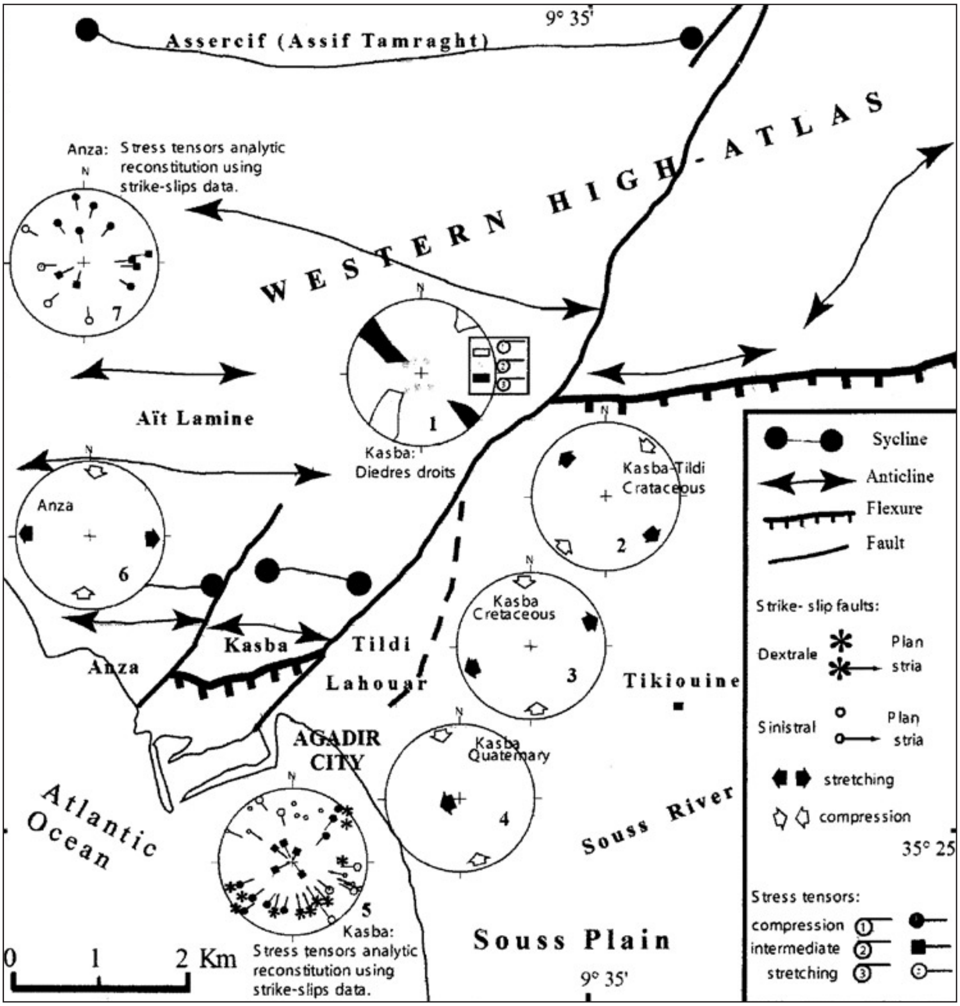


Figure 8: Structural map of Agadir region with data analytic treatment (Lower hemisphere, Wullf net).

NATURAL HERITAGE, GEOECOLOGICAL PROBLEMS AND SOCIAL ASPECTS

The karst and the Wintimdouine cave in particular are called to play a fundamental role in the region of Agadir. One of ours study purposes is to convert this site to natural heritage objective and a protected national patrimony.

The Wintimdouine site is still not so famous karst objective, but we propose to plan its enduring regional development and public opening, as follows:

- To make the population sensitive for the wealth of this natural heritage objective and to make it an active partner for the site management also. This is necessary knowing that the preservation and protection of the patrimony are both combined with the physical and the cultural-anthropological behaviors.
- To develop the local agriculture. The Wintimdouine water reserve is an asset for the local supply of population and for irrigation. It is estimated to 2 millions m^3 per year at least (Qurtobi 1996).
- To preserve the karst groundwater, as it is unavoidable to delimit a large protected area from the contamination.
- To equip the site with all reception infrastructures, taking in account the preservation of the natural environment (outside the cave – small constructions for attraction, restoration and rest, able to be melted into the landscape; inside the cave – suitable equipment, corresponding to the endokarst environment).
- To integrate completely the site into the tourists circuit. This might ensure a wide diffusion and force the setting of an information stand. The karst all over the world is an increasing tourists'

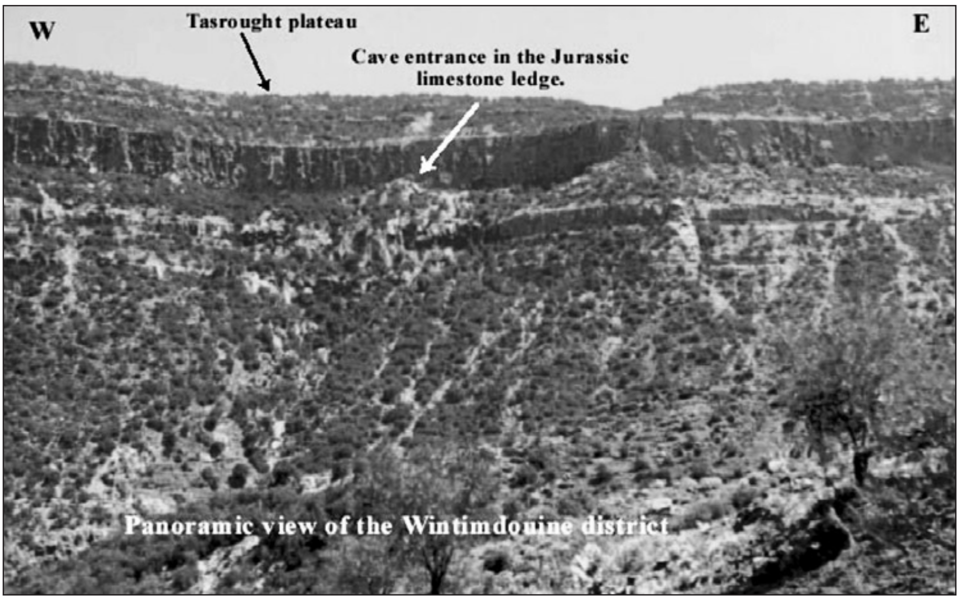


Photo 8: Panoramic view of the Wintimdouine district.

attraction. The subterranean tourism is gaining popularity and contributes to the local economics, particularly the use of karst protected areas.

- In the ideal case if the chemical analysis results are favorable, the Wintimdouine water could be bottled as a high quality mineral water, totally free of contamination, and it might have curative properties as to use it as balneological source, too.

CONCLUSION

The karst within the studied terrains of Bulgaria and Morocco is of fundamental (scientific and practical) importance in national scale and worldwide. More attention is paid worldwide to the organization and the monitoring of karst surface and sub-surface ecosystems. They have very complicated relationship to the surrounding karst and non-karst ecosystems. Specific elementary landscapes are formed also. The fast anthropogenization destructs them completely or partially, and changes them as well. With this article we put the beginning of a precise evaluation of the natural and anthropogenic impacts on the karst environment in order to facilitate its management and protection, and its rational usage as well. It was fixed that the tectonic movements as a result of the geodynamic events precondition the forming of typical structural karst, which is intensified by the incomplete process of recent tectonic activity and by the exogenic relief energy related to the tectonics. This leads to the forming of unique relict and recent autonomous karst systems both bound and non-bound. With this article the accent is put on the degree of study of the different factors, which influenced the karst development in both karst phenomena of Bulgaria and Morocco.

Photo 9: The Wintimdouine paleoseismic dislocation.

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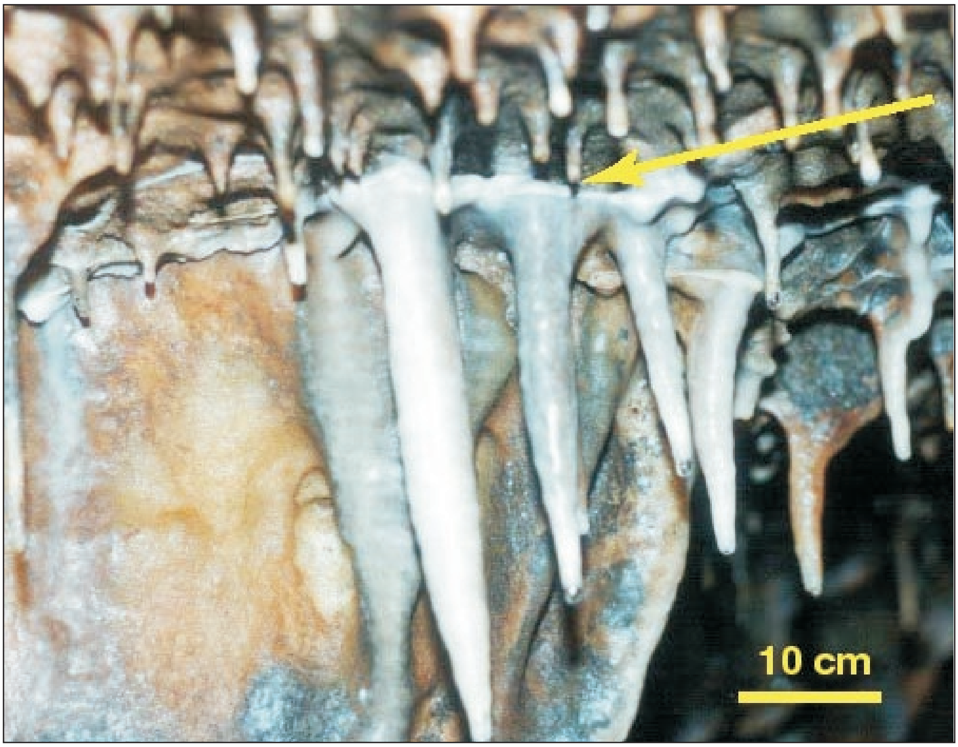

Photo 10: Paleoseismic affecting a stalactite, Wintimdouine Cave.

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