PALEOSEISMIC EVENTS IN THE KARST TERRAINS. I. BULGARIA

D. ANGELOVA[1], M. A. BELFOUL[2], E. GILLI[3], S. BOUZID[2] and F. FAIK[2]

[1]*Geological Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev St., Bl. 24, 1113 Sofia, Bulgaria,* doraangelova@hotmail.com

[2]*Department of Geology, Faculty of Sciences, Ibnou Zohr University, Agadir 80000, Morocco*

[3]*Department of Geography, University Paris VIII, 06300 Nice, France*

Abstract: The paleoseismic disturbances in karst terrains in Bulgaria have been considered. More than 70 such residual deformations in surface and underground karst have been established till now. The emphasis of the present work is laid on the spatial-time characteristics and stages of display of catastrophic paleoseismic events in regions with different geodynamics. The paper is a part of the development of paleoseismic catalogue of established paleoseismic dislocations in the Mediterranean region.

Key words: paleoseismic events, karst terrains, geodynamics, Bulgaria

The karst surface and underground ecosystems occupy significant areas of the Earth's territory. They are under different geodynamic equilibrium conditions. There is a great worldwide interest in the localization, study and dating of paleoseismic events in surface and underground karst terrains during the recent years. This is understandable since the ecological consequences in them can be catastrophic. Contemporary enhancement of erosion, denudation, loss of groundwater, etc., has been observed in karst terrains with established paleoseismic events (before 8000 B.P.) in different parts of the Mediterranean region. These are usually terrains characterized by low and moderate seismicity. More than 70 local paleoseismic dislocations in karst have been determined in Bulgaria till now (Fig. 1). The predominant established dislocations are in the surface karst since they have exerted direct influence on the ecological comfort of the population during the contemporary and the historical stage. These are one-act events in most of the cases but sometimes there are repeated events or active even at the present moment seismic structures. The relief deformations that had reflected and preserved these events are specific phenomena with various spatial-time range, type, degree of disturbance of the natural geological-geomorphological environment.

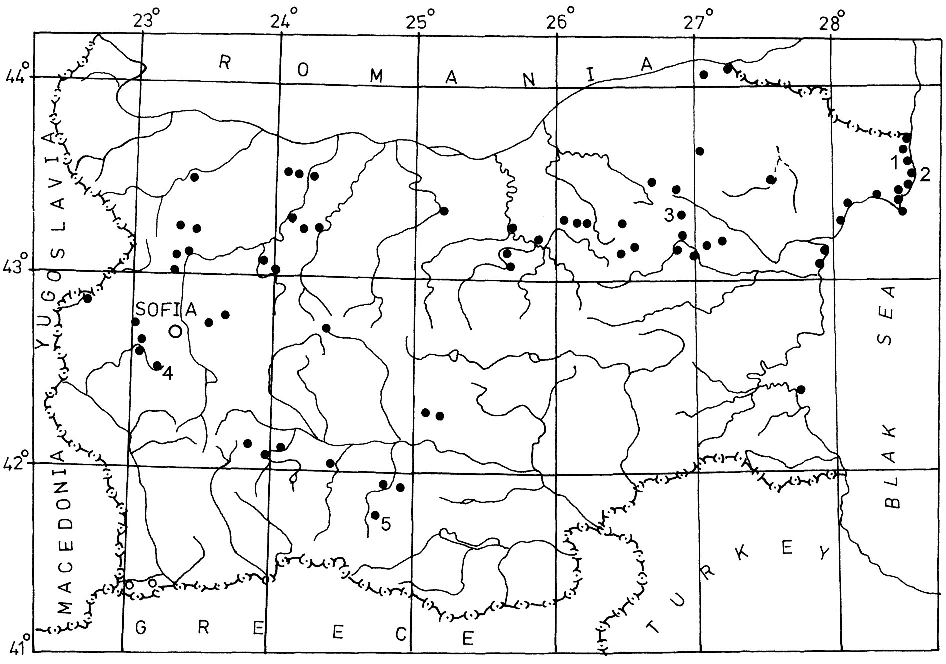

Fig. 1. Map of the paleoseismic dislocations in karst terrains in Bulgaria. (The numbers correspond to the text).

1. The Shabla-Ezerets liman (1, Fig.1, Angelova, 2000) was formed after the subsidence of the littoral land due to a catastrophic paleoearthquake event. Its baseboard was built of Sarmatian limestones. Two strongly disturbed peat layers are found in borehole sections at a depth of 8-9 and 18-19 m under the Holocene deposits. They were probably formed in a paleokarst marshland. In the course of dating investigations in 1999, changes were established in the slopes of the limestone layers and fault disturbances parallel and perpendicular to the coast. The following profile is observed in a borehole in the N periphery of the Ezertets liman: hard-plastic clays lie on the strongly disintegrated base at a depth of 7.2-7.4 m. Their radioactive carbon dating shows the age of 11000±500 B.P. An earthquake event occurred probably during this period and about 0.35 m of gravitation formations were accumulated here, forming a block-type landslide. The period between 6800±110 B.P. and 5000 B.P. was the early stage of the liman development with insignificant and fluctuating connection with the sea basin. The stage includes the sediments between 6.6 and 2.6 m. New interruption in this connection followed accompanied by wetland formation (1.2-2.6 m) and time of the radiocarbon dating from 5000 B.P. to 3700±100 B.P. Pieces of Sarmatian limestone are observed in the liman periphery. It is supposed that they had been formed as a result of block cracking and disintegration due to another catastrophic earthquake. Short-term sea transgression followed then, its duration being determined by radiocarbon dating to be between 3700±105 B.P. and 3070±100 B.P. The development of the Ezerets liman is similar to the Durankulak one after this period (Fig. 2).

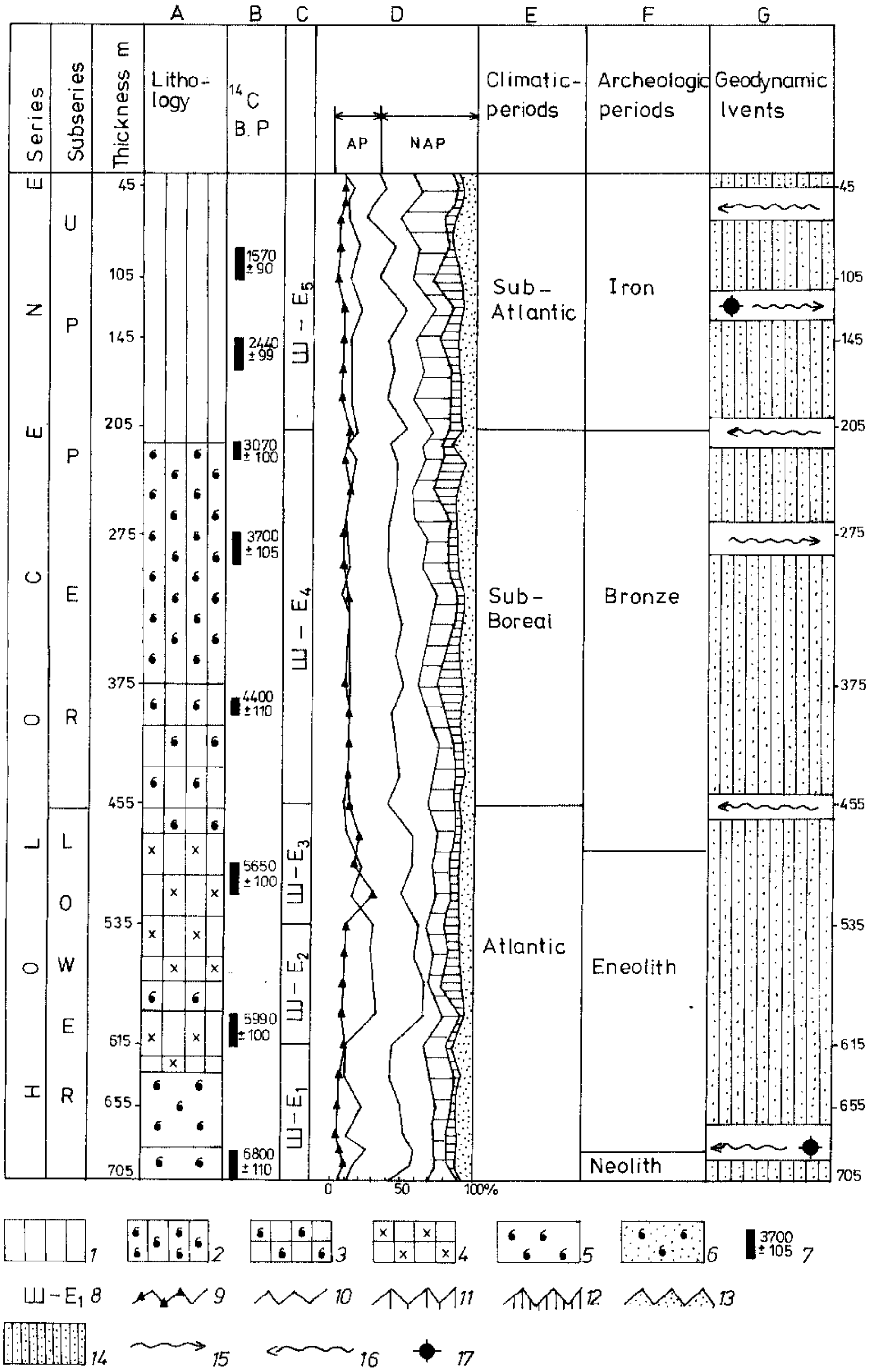

Fig. 2. Correlation scheme of the sediments and the events in the Shabla-Ezerets wetland: A. Lithological column of the lithological varieties (authors: Filipova-Marinova, Bozhilova, 1990): 1 – peat; 2 – peat with mollusca; 3 – gyttja with mollusca; 4 – gyttja; 5 – mollusca; 6 – mollusca with sand; B. Radiocarbon datings of Prof. Delibrias, France: 7 – 14 c. B.P. (in Filipova-Marinova, Bozhilova, 1990); C – 8 – Spore-pollen zones (authors: Filipova-Marinova, Bozhilova, 1990); D – Spore-pollen diaframs (authors: Filipova-Marinova, Bozhilova, 1990): 9 – *Quercus*; 10 *Carpinus betulus*; 11 – *Poaceae*; 12 – *Chenopodiaeceae*; 13 – *Artemisia*; E – Climatic periods (according to Blit-Sercander); F – Archaeological periods (according to Todorova, 1979); G – Geodynamic events: 14 – sediment deposition; 15 – regression; 16 – transgression; 17 – paleoseismic events.

2. The North Bulgarian Black Sea coast is one of the sections that had been subjected to the greatest extent to paleo, historic and contemporary earthquakes. The region is among the high-energy areas in Bulgaria (intensity of 9-10 degrees).

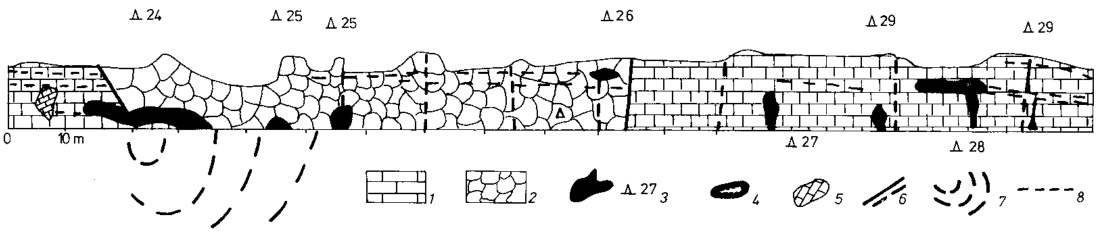

Fig. 3. Geological-geomorphological profiles in the region of the “Tyulenovo” dislocation: 1 - Sarmatian limestones; 2 - blocking; 3 - a cave with its number; 4 - a cave dwelling; 5 - olistolith; 6 - faults; 7 - event localisation; 8 - horizontal cracks and sea levels during the time of the transgression.

The Tyulenovo paleoseismic dislocation (2, Fig. 1 and Fig. 3, Angelova, 2000) is situated in the eastern most point of the coast on a 23 m high abrasion cliff in immediate proximity to the S of the village. The formed paleoseismic dislocation marked the epicentral part of the catastrophic earthquake. It was located in the cross-point of longitudinal and transverse structures with directions 20-25º and 110-130º. The time of its origin was probably during the great Chaudian transgression since all the changes in the sea level occurring before it had been preserved in the cliff. Except for the Shabla-Kavarna gravitation steps, the Durankulak negative and the Bulgarene positive local morphostructural units were formed during the Upper Chaudian as a result of the enhanced tectonic activity (Angelova, 1999). The seismotectonic structures were reactivated during the Karangathian and New Black Sea transgressions. It could be assumed that the huge rock-fall represents the collapsed roof of a big cave. Except the vertical cracks, horizontal cracks in the Middle Sarmatian limestone were formed too in the terrain due to the repeated reactivation of the fault. The marine caves and surf niches were formed in these cracks during the transgression (Popov, Mishev, 1974, Angelova, 2000). This paleoseismic structure was active during the contemporary stage too and was marked by magnetic and gravimetric anomaly.

It is supposed that this was the epicentre of the catastrophic earthquake on March 3rd 1901 with intensity of 9 degree, magnitude 7 and depth of the focus – 10-20 km. The active geodynamic processes in the parallel to the coast fault zone had been morphologically expressed in the shelf too, where contemporary active graben structure was formed. It exerted a considerable effect on the landslide process dynamics. Paleoseismic events that had left significant relief disturbances had been established in the region of Tyulenovo, Kamen Bryag, Balchik, Batova, Varna, Galata. The disturbances are of the seismic-gravitation type, but seismic-vibration ones are encountered too. They are found along almost the whole coast from the Romanian border to the Galata Cape. The landslides are of linear or circus type. They were repeatedly activated (3 to 8 times) during the Quaternary and the historic period. They were reactivated by the earthquakes in 1444, 1858, 1891, 1901, 1902, 1903.

3. The region around the historic monument "Madara Horseman" and the regions situated to the north and to the north-east of it, were subjected to bilateral impulse movements during the Middle Pleistocene. The "Madara" (1.5-2.0 km long, N-S direction) and "Kyulevcha" (1.0-1.5 km long, NW-SE direction) dislocations were formed. Both are of the seismogravitation type. Open fissures were formed in the basic massif and the movements of the two paleoseismic faults were in the range of 0.5 to 0.8 m. The width of the external open fissure reaches up to 0.8 m in the upper part of the gravitation block and more than 1.5 m in the lower part, where the Malka Cave is found (inhabited by primitive men). Its width increases under the influence of gravitation. This phenomenon could be created for similar characteristics of the rock complexes and relief deformation in the case of 10-11 degree earthquake with a magnitude of 8-9 and a depth of the epicentre within the range of 2-10 km. Contemporary seismic dislocations with destructive effects were recorded in the region – the collapse under the Nimfite Cave in 1928, the widening of the cracks of the base-relief and the rock-fall near the Kyulevcha village caused by the Vrancea earthquake in 1977. Besides its own seismic energy, the region possesses an induced seismic hazard caused by other earthquakes and the anthropogenic activities on the salt body in the Provadia district. Paleoseismic relief and geological deformations of older age were also established during a revision on the Provadia Plateau in 1997.

4. One of the most interesting caves and the longest one (more than 17 km) in Bulgaria is the Douhlata Cave. It was formed in the over-thrusted from SW Triassic and Jurassic rocks on the Upper Paleogene – Lower Miocene sediments and on the rock complexes of the Vitosha Mt. pluton. The active mountain formation had led to block differentiation and strong cracking of the rocks (Angelova et al., 1999, Benderev, Angelova, 2000). The Plio-Pleistocene boundary was accompanied by active vertical tectonic movement and the subsequent movements along the faults in the Vladaya zone and along the Bosnek fault in particular (Fig. 4). The karstified complexes were revealed at the surface and the formation of underground karst was started. Its beginning is dated as 0.73 Ma. Two karst sections were distinguished – to the south and to the north of the Strouma River. The main directions of karst development were 55-60º NE and 40-45º SE in the Golo Bardo unit to the S of the Strouma River and E-W to NE-SW in the southern part of the Vitosha Mt.

Fig. 4. 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 - mormal faults and faults.

The river terrace and the storied cave complexes were formed during the Pleistocene with the changes in the tectonic movement character under the conditions of ubiquitous rising of the Vitosha and Golo Bardo Mts., the phases of the glacial and stadial epochs and the lithostructural peculiarities. The Dobri Dol fault was an active tectonic structure during the Middle Pleistocene. It served as an erosion basis for the water of the karst massifs to the N and S of the Strouma River. In that time it received here the water of the Paleo-Klisura River and the erosion basis was situated 40 m higher than the contemporary one. The faults of the Pernik fault zone were activated during the Upper Pleistocene. New rearrangement of the river basins took place – the Paleo-Klisura River redirected its run-off towards the Radomir kettle. The karst processes during the Pleistocene, the Holocene and the contemporary stage were determined by a common drainage system (of the Strouma River) under periglacial conditions during the Pleistocene and post-glacial conditions after the global climatic warming (Shopov et al., 1998). The same authors have established paleoseismic disturbances in the speleothems.

5. Paleoseismic disturbances in underground karst have been established in the Rhodopes Mt. in the regions of the Chepelare (Angelova, 2002) and the Velingrad towns (in the Lepenitsa Cave - Shanov et al., 2001). The region of the Chepelare town falls within a zone of high seismicity (5-8 degree). It is a part of one of the most active seismic foci in the Rhodopes. The paleokarst investigation has proved the existence of shifted galleries with a vertical amplitude of 20-140 m and huge collapses, as well as of completely destroyed cave galleries in some sections due to catastrophic earthquakes (8 to 12 degree). Some of the gravitation blocks in the caves are cemented by calcite crusts. Considerable terrain subsidence has been established as a result of the investigations in the Yanchova River region (5, Fig. 1, Fig. 5).

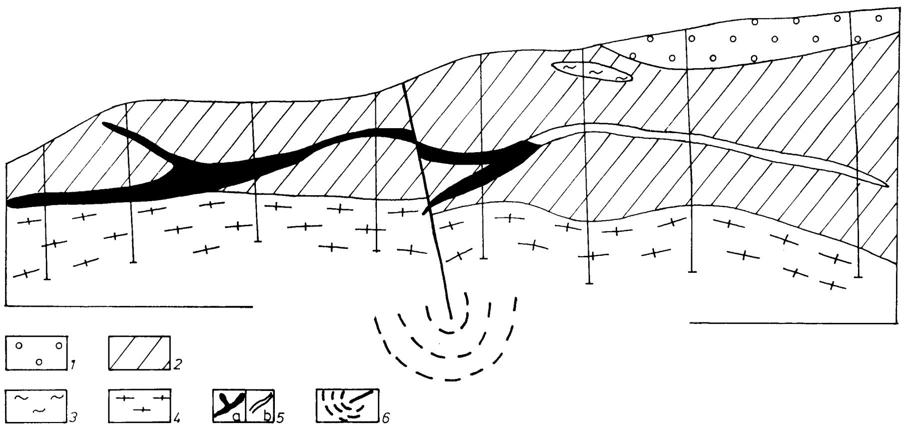

Fig. 5. Geological section across the “Yanchova River” paleoseismic dislocation: 1 – Paleogene marble breccia; 2 – marbles; 3 – biotite gneisses; 4 – granitised biotite gneisses; 5 – paleokarst (caves): a) filled, b) hollow; 6 – paleoseismic fault.

This subsidence has provoked breaks in the watersheds of the river-valley network, heaping in the caves, seismic-gravitation deformations of the valley slopes, etc. The relief deformations prove that the paleoseismic phenomena occurred at the Pliocene-Quaternary boundary and that they were repeatedly reactivated. The relief deformations in the studied area confirm that it possesses very high induced energy and the foci are relatively deep. The specific features of the relief and the geological structure predetermine the peculiarities in the development of the paleo- and contemporary earthquakes. The Chepelare-Hvoyna earthquake centre did not react to the earthquakes in the Maritsa zone but reacted to those in the Kresna zone. This proves that the Shiroka Laka fault zone is a long-lived one, being active during the Paleogene. The paleoseismic effects in the karst fall within its range but they are new structures (from the Plio-Pleistocene till now) and are localised in single sites to the east and west of this zone.