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EXPLORATION OF CHANGES IN RADON CONCENTRATION AND FAULT DISPLACEMENT IN THE BACHO KIRO CAVE (BULGARIA) AS SEISMIC ACTIVITY PRECURSORS

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Since 2009 the Experimental Laboratory of Karstology of the NIGGG-BAS developed a model for Integrated Monitoring of Karst System (MIKS). The research started along the International Research Project „Development of an experimental model of complex monitoring for sustainable development and management of Protected Karst Territories" (ProKARSTerra), supported by the Bulgarian Science Fund. Experimental studies are conducted in representative karst geosystems in Bulgaria. Radiological monitoring (222Rn, 14c and gamma-background) and Fault displacement monitoring (with precise three-dimensional extensometer TM-71) are parts of this model and are conduct together with the Department of Radiation Dosimetry, Nuclear Physics Institute and the Department of Engineering Geology Institute of Rock Structure and Mechanics (incl. and with the financial support provided by a bilateral international research agreement between the Bulgarian and the Czech Academy of Sciences). The most important result is establishment of correlation between abrupt fluctuations of radon concentrations in cave air and fault displacements in the Bacho Kiro cave, due to registered seismic activity (1).

The Bacho Kiro cave is one of the largest caves in the region (total length investigated about 3600 m) and also one of the most popular touristic caves. It is situated in the eastern part of the inverse karst plateau Strazhata in Central Bulgaria. The plateau is made up of Lower Cretaceous limestones. The Bacho Kiro cave entrance (5.8/1.4 m) is at 355 m of altitude, in the base of a rock cliff Buruna. The cave system is a sub-horizontal (slightly ascending, with total displacement of +65 m), four storey labyrinth, oriented along the Strazha syncline axis. In the cave is supported by a relatively good ventilation, which is reflected in the low concentrations of CO2, even in the internal cave parts (seasonal variations between 550-600 and 1200-2200 ppm). These cave parts show stable microclimatic conditions: the cave air temperature stays constant, between 10.8 and 12.6°C, relative humidity of 95-99% (for the entire period of experimental integrated monitoring). The stable temperature and humidity in to the cave are giving perfect laboratory conditions.

During 2012 in the Bacho Kiro the permanent extensometer TM-71 and passive solid state detectors for radon-222 concentration measurement were installed as a part of monitoring networks EU-TecNet and BGSpeleo-RadNet. The extensometer TM-71 is able to measure relative fault displacements in three co-ordinates (x, y, z), with a precision better than ±0.007 mm and horizontal and vertical rotations (gxy and gxz), with a precision better than ±0.00016 rad.

The results between the sharp fluctuations in the radon concentration and the tectonic regime are compared with several local and regional earthquakes with M≥3.5. A correlation between these physical parameters was established. Especially distinct are 3 episodes of significant abnormalities after Aegean Sea earthquake (May 24, 2014, Mw = 6.9 and the long aftershock sequences), Nova Zagora earthquake (April 18, 2016, Mw = 4.3, ML=4.0), and Vranchea, Romania earthquake (23.09.2016, Mw = 5.7, shows a sharp rise of the radon-222 concentration, followed by a drop). These episodes are clearly marked in the TM-71 extensometer records. The focal mechanisms of all earthquakes were determined and compared with the extensometer measurements.

Relation between fast fault sliding and slow tectonic movements were established. The obtained results correspond to the regional stress field of the northern part of Balkan peninsula (2).

The slow movements due to tectonic pulses in the plates and fluctuations in radon concentration can be very valuable precursors for seismic activity and are giving additional information in tectonic regime of Bulgaria. Therefore, their precise monitoring is extremely important for seismic risk assessment. The Bacho Kiro cave has a proven potential of an underground station for this type of research. A strategic goal is to implement a state-of-the-art scientific infrastructure in the cave. Since March 2018 the instrumental monitoring of radon concentration in cave air have begun, parallel with passive detectors measurements.

The maintenance and development of Integrated monitoring in the Bacho Kiro cave continues with two new international projects of the Bulgarian Science Fund:"Exploration of changes in some geophysical fields preceding the occurrence of earthquakes in the Balkans", and "Current impacts of global changes on evolution of karst (based on the integrated monitoring of model karst geosystem in Bulgaria", which results will complement each other. Additional contribution brings the project "Plate-wide tectonic pressure pulses (Correlation of the extensometric monitoring in Mediterranean and Central Europe)", which started in 2017, under the bilateral research agreement between the Bulgarian and the Czech Academy of Sciences.

(1) Stefanov, P., K. Turek, I. Svetlík, M. Briestenský. Radon and fault displacement in Bacho Kiro Cave (Bulgaria) related to closely situated earthquakes, 5th International Scientific Conference, 4-5 November, Shumen, Bulgaria.

(2) Protopopova, V., I. Georgiev, E. Botev, N. Kakar. Seismicity and nowadays movements along northern part of Aegean region – Bulgaria, 35th General Assembly of the European Seismological Commission, 4-10 September 2016, Trieste, Italy.