



Crveno jezero - the biggest sinkhole in Dinaric Karst (Croatia)

M. Garasic

Faculty of Civil Engineering, University of Zagreb, Geotechnical, Zagreb, Croatia (mgarasic@public.carnet.hr)

Crveno jezero is a karst phenomenon known throughout the world for its size and specific features. In the course of the 1950's, some hydrological measurements were made on the surface of the lake, including depth measurement at 39 points (academician M. Petrik and his associates). The information about the maximum depth of 254 meters actually originates from that research (PETRIK, 1960). This depth has been "attracting" geologists, hydrogeologists and speleologists for many years now. On numerous occasions, people descended to the surface of the lake but, in the period prior to speleohydrogeological research conducted in 1998, no attempt had been made to dive underwater and document the lake depth, nor to investigate by other methods the interior of the lake and give a scientifically documented representation of this karst phenomenon from the speleohydrogeological aspect (GARAŠIĆ, 2000; 2001).

The Red Lake, located one kilometer to the west of Imotski, is the biggest of all lakes situated in the area (featuring 18 big or small dry or water-filled depressions) and this by both its visible (superficial) and invisible (submerged) portions. Its name originates from red rocks perched on cliffs extending to more than 250 meters in height. The lake color is dark blue, and it measures about 150 x 180 meters, depending on water level, i.e. on the time of the year. The easiest way to reach the lake (belay, descend and ascend with ropes) is to approach it from the east side. Here we have a vertical cliff about 60 meters in height, followed by 300 meters of a very steep soil creep zone, after which there is yet another vertical cliff of at least ten meters in height (depending on lake water level).

In other words, a special descending technique must be used to access any point along the lake perimeter in summer months. Vertical and overhanging cliffs rising above the surface of the lake range from 160 to 250 meters in height. However, the depth of the lake is even more fascinating and has been measured on a number of occasions.

Valuable and interesting data about the lake depth, as presented by academician Milivoj Petrik in 1955, show that the lake is about 250 meters deep, which discouraged any attempts to dive to the bottom of the lake.

During the 5th International Congress of Speleology held in Stuttgart in Germany, Croatian cavers and speleologists have tried to add the Red Lake to the list of deepest pits in the world, as its real depth amounted to 518 meters at the time. However, the response of the documentation committee was that the depth had not been duly documented, that no man has been at such depth etc., although in reality it is a real pit one half of which is filled with water.

In late 1970's and early 1980's the speleodiving activities rapidly gathered momentum in all parts of the world and it is in this period that deepest dives were made at the source called Fontaine de Vaucluse. At that time, a special underwater vehicle, the so called "Speleonaut", attained (without crew) the depth of 315 meters. Similar vehicle called Hyball descended down to the depth of 165 meters in Hranicke propasti in Czech Republic. These speleological structures are therefore considered as sufficiently documented and, as such, they have been added to the list of the world's deepest water structures.

In 1980's speleodiving has become an increasingly popular cave exploration method in Croatia. Thus, the decision was made to contact the world's best speleodivers and invite them to investigate the Red Lake. In 1981, during their stay in the USA, Dr. Mladen Garašić contacted Mr. Jochan Hassenmayer who was at that time the best speleodiver of the world. However, because of political climate that prevailed in that period, Mr. Hassenmayer finally decided not to come to our country. In an unfortunate turn of events, this diver was later affected with a permanent disability. In the course of 1989 and 1990, Dr. Garašić established contact with Mr. Sheck Exley (from Florida, USA) who is considered to be the best speleodiver of all times. At the time, it was agreed that he and his team would come to Croatia during the summer of 1991 and that they will, in the course of this visit, investigate the Red Lake. Unfortunately, due to the outbreak of war, this has been postponed and, in 1994, this outstanding diver had a fatal accident while diving at the depth of about 300 meters. This accident has remained unexplained to this date. In the course of 1996, French speleodivers recommended German speleodivers that would be interested in the underwater exploration of deep speleological structures. In this respect, the contact was established in early 1997 with the German Caving Group from Hanover the members of which had by that time been diving at about 200 m below the water surface (ASPACHER, B.& all, 2000). This team visited the Red Lake on several

occasions in 1997 and 1998 and, during these visits, the lake depth was measured (using an echo sounder and highly-accurate depth measuring devices) at the total of 454 points, while previous measurements conducted in 1955 were performed at 39 points only. The maximum depth registered during our measurements was 276.35 meters, which exceeds the depth determined in previous measurements by approximately twenty meters.

The main objective of the "Red Lake 98" expedition was to obtain new data about the speleogenesis of this structure, about its morphology, hydrogeology, tectonics and biospeleology, and to produce an appropriate documentation (video recordings, structural-tectonics and speleological maps). This was a Croatian speleodiving expedition with international participation and was sponsored by the UIS members from Germany, Austria and Switzerland (GARAŠIĆ, 1999). Sedimentologic studies were conducted in cooperation with colleagues from Tübingen-based Max Planck Institute and with those from the Technical Faculty in Munich, while biospeleological studies were performed together with colleagues from Salzburg. Highly accurate topographic instruments were borrowed from the University of Zürich.

Results and Final Considerations

The development of speleological, speleo-hydrogeological and speleodiving methods encouraged new investigations and, in that respect, new exploration was carried out in the Red Lake during the summer of 1998. The depth of the lake was measured at 454 points, topographic measurements of underwater parts of the lake were made, and several hundred meters of cave canals (dry and submerged), within the area delineated by the lake's vertical cliffs, were investigated. The maximum depth of the lake (-281 meters) was measured and recorded by means of a special autonomous underwater vehicle, the quantity of water flowing into the lake through a cave canal was established, and the quantity of water contained in the lake was determined (approx. 16 million of cubic meters). Recent studies provided information that is highly useful for better understanding of this karst phenomenon. The inverse karstification was dominant in the genesis, while gravity karstification had an accessory role only (GARAŠIĆ & KOVAČEVIĆ, 2000). The bottom of the lake is inclined towards the west, and the lowest point lies 6 meters below sea level. At the time of these investigations, strong water currents in the direction of southwest were observed at the depths ranging from -206 to -281 meters. The total difference in height is 528 meters (from the highest point at lake periphery to the lowest point registered at the bottom of the lake). The bottom of the lake is deeper down but, due to technical difficulties, the camera was unable to penetrate any further. This extension is in fact a large cave canal spreading obliquely in the southwest direction.

The International speleodiving expedition "Crveno jezero 98" resulted in numerous new findings some of which are listed below:

- a fully documented material (photographs, topographic maps, video recordings) about the previously unknown parts of the lake was established,
- an inflow cave-shaped canal (measuring 30 x 30 meters) was discovered in the eastern part of the lake, at the depth of approximately 175 meters,
- new assumptions were made about ground water circulation in this area,
- it was concluded that principal karstification processes develop in the interior and spread towards the surface, i.e. that this is the zone dominated by an inverse karstification; a room measuring 400 x 300 x 500 meters has been created in the interior, which is quite amazing,
- some new species of cave fish, crabs, frogs and insects were discovered and determined within the lake and in speleological structures,
- all speleo-hydrogeological features, as well as most significant tectonic elements, were determined down to 90 m in depth,
- sedimentological and petrological testing of the lake bottom was conducted (at four locations),
- more than 800 meters of cave canals were discovered within the lake "crater",
- more than 22 hours of video material was recorded,
- the deepest point registered by ROV (Remotely Operated Vehicle) is 236 meters,
- the deepest point measured in the lake is 281 meters, i.e. 6 meters below sea level,
- the constant water temperature is +7.9 [U+F0B0] C (50 m below the surface),
- (westward) movement of ground water was registered at the bottom of the lake,
- the total of 454 points were measured,
- heliox was used to dive to the depth of 181 m, which is one of the deepest cave dives ever performed in the world (ASPACHER & BEHREND, 1999),
- vertical difference between the highest and lowest points in the lake is - 528 meters,
- the size of the lake bottom was established (about 300 x 300 m) while on its surface the lake measures approximately 180 x 200 meters,
- as many as 43 members have participated in the expedition (22 from Croatia, 18 from Germany, 2 from Austria and 1 from Switzerland)
- more than 20 tons of equipment and material were transported to the site., etc.

The Red Lake is ONE OF THE DEEPEST KARST (CAVE) LAKES IN THE WORLD and its deepest measured level of -281 METERS is still not the deepest point of the lake! It is a water storage containing more than 16,000,000 cubic meters of water.

More accurate figures will be obtained in the course of future explorations to be undertaken by a special kind of bathyscaph. The Red Lake is the world's largest documented and surveyed ground water storage in karst, and deserves to be appreciated as such.

References

- ASPACHER, B. & BEHREND, T. (1999): Umbekannte Tiefe. Tauchen, vol.45, 5, 81-85, Hamburg.
- ASPACHER, B, HASLINGER, R, MEYER, U. & OERTEL A. (2000): Beyond the Blue. NSS News, vol.58, no.5, 141-149, Huntsville.
- BAHUN, S. (1991): O postanku Crvenog i Modrog jezera. Geol. vjesnik, vol.44, 275-280, Zagreb.
- BOJANIĆ, L., IVIČIĆ, D. & BATIĆ, V. (1981): Hidrogeologija Imotskog polja s osvrtom na značaj u regionalnom smislu. Geol.vjesnik, vol.34, 127-135, Zagreb.
- BONACCI, O. (2006): Crveno i Modro jezero kod Imotskog. Hrvatske vode, vol.14,54;45-54, Zagreb.
- BOZIČEVIĆ, S. (1971): Da li je Crveno jezero kod Imotskoga naša najdublja jama ? Priroda, vol.58, 6, 188, Zagreb.
- GARAŠIĆ, M. (1999): Međunarodna speleološka ekspedicija u Crveno jezero kraj Imotskoga. Hrvatska vodoprivreda, vol.7, 78, 40-42, Zagreb.
- GARAŠIĆ, M. (2000): Speleohydrogeological research of crveno jezero (Red Lake) near Imotski in Dinaric Karst Area (Croatia). Second Croatian Geological Congress, Cavtat-Dubrovnik, Proceedings,587-590, Zagreb.
- GARAŠIĆ, M. (2001): New Speleohydrogeological Researc of Crveno jezero (Red Lake) near Imotski in Dinaric Karst Area (Croatia, Europe) – International speleodiving expedition „Crveno jezero 98“. 13th International Congress of Speleology, pp. 555-559, Brasilia.
- KOVAČEVIĆ, T. (1999): Crveno jezero - Imotski. Hrvatska vodoprivreda, vol.7, 78, 43-46, Zagreb.
- PETRIK, M. (1960): Hidrografska mjerenja u okolini Imotskog. Ljetopis JAZU, vol.64, 266-286, Zagreb.
- ROGLIĆ, J. (1938): Imotsko polje (Fizičko geografske osobine). Posebna izdanja Geogr. društva, vol.21, 1-125, Beograd.