REPORT

on Pre-CEKA excursion to the karst of Montenegro,
29 May – 1 June 2017

Prior the CEKA 2017 course members of the Centre for Karst Hydrogeology of the Faculty of Mining and Geology (CKH) led by Zoran Stevanović were organized and guide the excursion of the participants from USA in period 29 May – 1 June 2017. The excursion took place in southern Montenegro and included visits of Nikšić karstic polje with reservoirs and hydropower plant "Perućica", Regional Waterworks of the Montenegrin Coast with Bolje sestre source, Skadar Lake, Budva and Kotor old cities, the springs along the Boka Kotorska bay, Kameno more ("Stone Sea"), Grahovo karstic polje.

The participants were students Ian Tso, Cameron Rhodes, Robert Hoppe, Michael Bangs, their lecturer Alarick Reiboldt from the School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff and experts Don Manthe (Arizona), Charles Graff (Arizona Department of Environmental Quality), Jeff Bennett (Big Bend National Park).

Members of the CKH and team of experts and students from USA at an introductory session

First stop was above the Slano reservoir, 5km from the Nikšić city. The Nikšićko polje is the largest in Montenegro comprising some 60 km^2. The lake was created in the Mid of 20 Ct. along with two other reservoirs of Nikšićko polje: Krupac and Vrtac, all built to control and use the hydro potential of groundwater and surficial waters of the Upper Zeta catchment.

At the Slano reservoir

Our hosts in Nikšić Ms Olga Radulović, dipl. eng. (Montenegrin Electric Enterprise, AD Nikšić) Dr Mićko Radulović and Dr Milan Radulović (University of Podgorica) provided information on huge engineering works conducted to prevent leakage from these reservoirs and enable maximal possible water utilization for energetic purpose. Some other karstic phenomena and engineering structures have also been visited in this polje.

Slano and Krupac reservoirs and Vrtac retention lake

Gornjepoljski vir estavelle (Nature protected site), Gornje Polje, Nikšić

Visiting of the Hydropower Plant HPP "Perućica"and the Glava Zete spring where most of waters from Nikšić polje drains and is utilized

After HPP "Perućica" the group travelled to Podgorica, the capital of Montenegro, where visit of the Public Water Enterprise (PWE) - Regional Waterworks for the Montenegrin Coast took place. The visit included intake and facilities of the "Bolje sestre" spring in Malo Blato Bay, in the Skadar Lake Basin. The engineers and managers of the PWE Ms Marijana Zenović, Mr Ivan Špadijer, Mr Aleksandar Cerović provided explanations and history of the system.

The group and hosts in front of Bolje sestre spring intake

Z. Stevanović presented geological and hydrogeological setting of the area and difficulties which engineers faced to tap this sublacustrian spring. A. Cerović and M. Zenović have informed guests about “Bolje sestre” current utilization, importance for tourist and economical development and spring water exceptional quality that fulfils all requirements for water bottling.

In the the Regional Waterworks for the Montenegrin Coast

The visit of the Morača River valley, part of the spring catchment

Next day the first stop was at bank of the Skadar Lake in small town Virpazar. Dr Milan Radulović and MSc Veljko Marinović (CKH), presented morphological, geological and hydrological characteristics of the area as well as talked about rich biodiversity of the lake's wider area and its protection (Ramsar Convention site).

Visiting Skadar Lake, Virpazar

The group continued trip through Sozina tunnel which connect inland and Montenegrin coastline and made a short stop in the Old Town of Budva where group enjoyed walks in narrow cobbled streets surrounded by old buildings and walls.

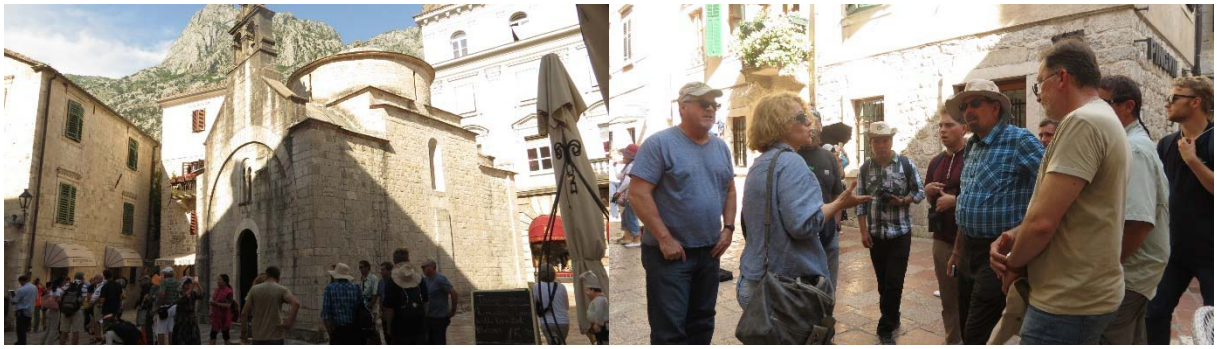
The Old Town of Budva

The next stop was in the Boka Kotorska (Bay of Kotor) and Old Kotor city one of the UNESCO heritage sites. Z. Stevanović shown the two main karstic springs supplying the city: Škudra and Gudrić, which water quality strongly depend on actual pressures in aquifer system due to altitude equal to sea level. Afterwards the group took a hike to the ancient walls which stretch for 4.5 km directly above the city reaching the top of the fort St. John. At the end, the tourist guide leads the group through the city and gave explanation about history and heritage of the city.







The next day started with visits of Kotor Bay karst springs. Saša Milanović presented hydrogeological setting of three rather large, but ephemeral karstic springs: Orahovačka Ljuta, Spila Risanska and Sopot.

Orahovačka Ljuta spring and deep pothole (minimum 70m below the sea)

Spila Risanska

Sopot spring and dry cave (discharging >150 m^3/s during floods)

On the way back to Trebinje (Bosnia & Herzegovina) visits of the highly karstified terrains of Kameno more ("Stone Sea") above Risan city and Kotor Bay, as well as Grahovo karstic polje have also been undertaken.

Above the Kotor Bay (left) and in the Kameno more (right)

At the edge of Grahovsko polje. A small pond with endemic species called Mali mrmoljak (Lissotriton vulgaris)

REPORT
on post-CEKA excursion 9-11 June 2017
Cultural and scientific tour of Bosnia & Herzegovina and Croatia

After successfully completed the International Course and Field Seminar "Characterization and Engineering of Karst Aquifers", which was held in Trebinje, Bosnia & Herzegovina between 01-8 June 2017, members of the Centre for Karst Hydrogeology and participants from Arizona and Texas, USA have jointly visited number of sites in the western Herzegovina and along Dalmatian (Adriatic) Coast of Croatia: Tučevac estavella (Popovo polje, Trebinje), Buna spring (Blagaj), Mostar city, Kravica waterfalls (Trebižat River), Imotski city (Modro and Crveno karstic lakes), Split city, Jadro spring, the Neretva River deltaic confluence, the Mali Zaton – Robinzon spring, Ombla spring and Dubrovnik city. The group of students and experts from the USA which joined pre-CEKA excursion was this time accompanied by Professor Dr Abraham Springer, from School of Earth Sciences and Environmental Sustainability, Northern Arizona University, Flagstaff.

The first stop wasTučevac estavella, around 5 km west of Trebinje, near the Trebinje-Stolac road. Led by Saša Milanović the group entered a small cave and climbed down to the groundwater level. In this period of the year the level is much below the entrance while discharge is usually activates only for a short period after heavy Fall rains.

Tučevac estavella

Next stop on this trip was in Radimlja stećak necropolis near Stolac. It is in Vidovo polje, 3 km west of Stolac, on the Mostar - Stolac road. The Radimlja necropolis is one of the most precious and protected monuments in Bosnia and Herzegovina of the medieval period.

Radimlja stećak necropolis

Buna and Bunica are the two springs listed among the first thirty world's largest springs. The tour included visit of Buna spring site at the left perimeter of the Neretva River valley in Blagaj, downstream of the Mostar city.

Z. Stevanović presented geological and hydrogeological setting of Buna spring (Qmax = 380 m^3/s), results of several campaigns of this cave diving, connection with upper horizons of karst of Herzegovina and ecological implications of on-going engineering projects.

Buna spring

Mostar is a large city and municipality in southern Bosnia & Herzegovina and its old town is under UNESCO protection. Mostar is situated on the Neretva River and was named after the bridge keepers (*mostari*) who in the medieval times guarded the Stari Most (Old Bridge) over the river. The Old Bridge, built by the Ottomans in the 16th century, is one of Bosnia and

Herzegovina’s most recognizable landmarks, and is considered one of the most exemplary pieces of Islamic architecture in the Balkans. The tourist guidance through the city was organized.

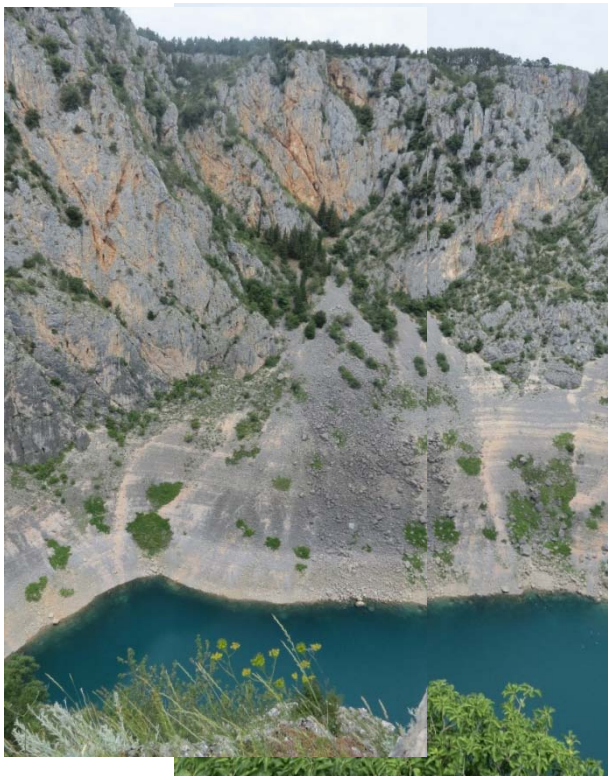
Mostar city

The Kravice Waterfall on Trebižat (Tihaljina) River is formed on tufa barriers. The main open stream, with a length of about 106 km from spring to mouth in the Neretva River, undergoes eight name changes. In fact, the eight-name river represents a system of losing, sinking and underground stream sections.

The Kravica waterfalls

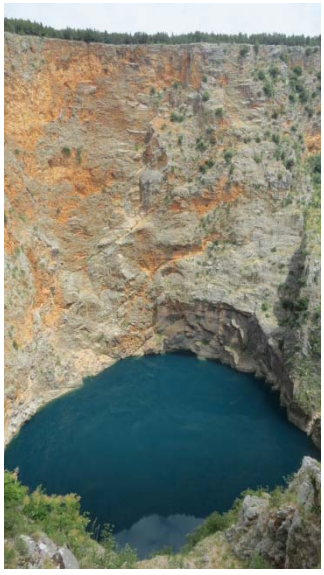
Imotski is a small town situated on the northern side of Biokovo massif, Dalmatian Hinterland, Croatia. Blue Lake (in Croatian: *Modro jezero*) is a karst lake in a deep sinkhole possibly formed by the collapse of an enormous underground cave. The total depth from the upper rim is around 220 meters, while water depth varies with season.

Modro jezero (Blue Lake)



Modro jezero (Blue Lake)

Nearby located the Red Lake (in Croatian: *Crveno jezero*) is also a sinkhole containing a karst lake. The total explored depth of this sinkhole is approximately 530 metres with a volume of water of roughly 25–30 million cubic meters, thus it is the third largest sinkhole in the world. The sinkhole is named after the reddish-brown color of the surrounding cliffs, colored by iron oxides.



Red Lake (Crveno jezero)

Split is the second-largest city of Croatia and the largest city of the Adriatic region of Dalmatia. It lies on the eastern shore of the Adriatic Sea, centered on the Roman Palace of the Emperor Diocletian. The group had an opportunity to be the guest of the Faculty of Civil Engineering, Architecture and Geodesy, Split University. The Vice-Dean for the International Cooperation of the Faculty Prof. Mirela Galić, Prof. Emeritus Ognjen Bonacci and Dr Ivo Andrić have welcomed the guests and presented history of the institution, system of education and promoted the Summer School which is regularly organized by the Faculty. Some possible cooperation issues have also been discussed. Z. Stevanović gave the lecture about sustainable development of karst aquifers in the Mediterranean Region.

Visiting the Faculty of Civil Engineering, Architecture and Geodesy, Split University

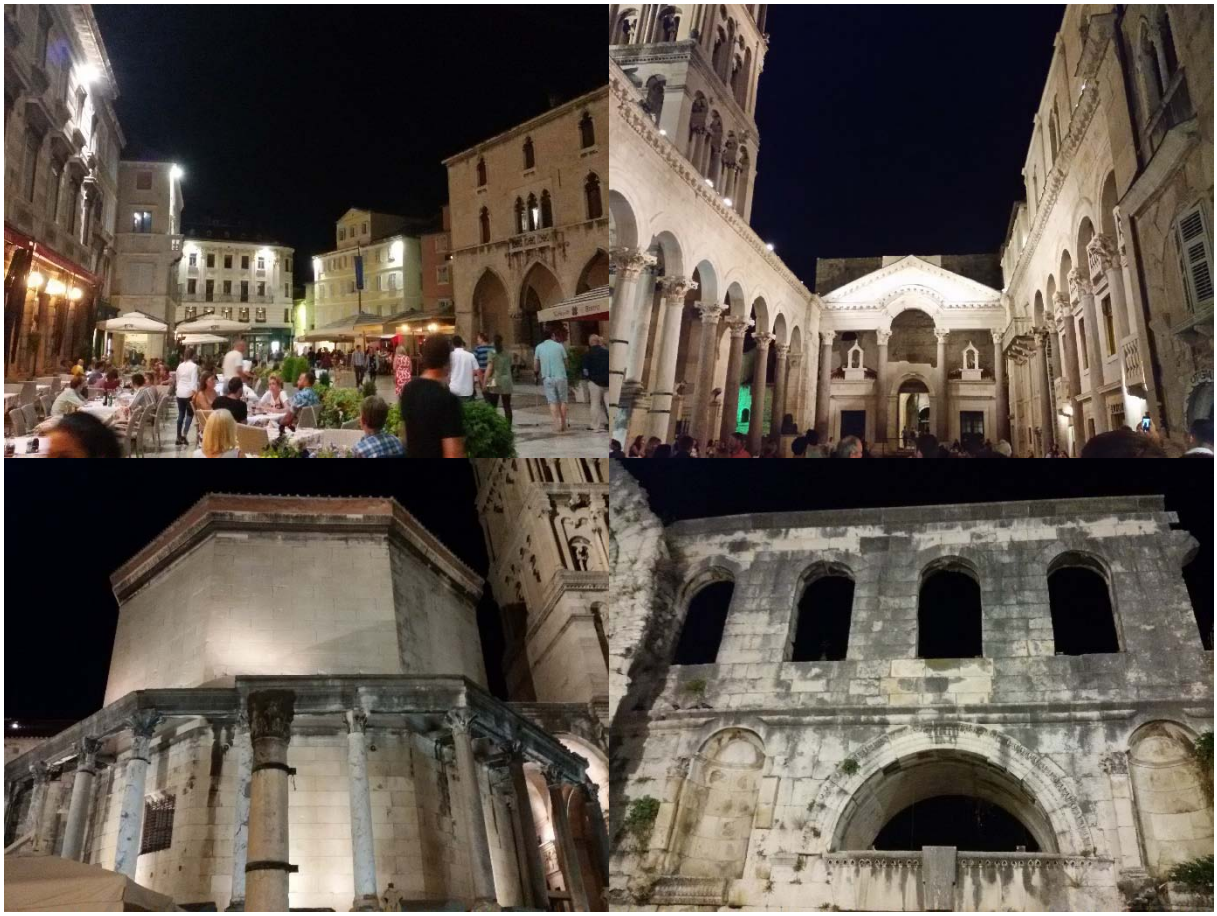
In front of the Faculty of Civil Engineering, Architecture and Geodesy

After nice lunch in the students' canteen, the group led by O. Bonacci and I. Andrić, went to visit Jadro spring, one of the strongest perennial springs at the Adriatic coastline and an ancient engineering masterpiece. This was an opportunity to learn more about geology and hydrology of this spring, history of waterworks system created by the Romans to supply Diocletian Palace, but also on installed modern monitoring system and applied spring protection measures.

Jadro spring

Hydrological gauging station downstream of water intake structure

Split is one of the oldest cities in the Adriatic basin and its historical center was included into the UNESCO list of World Heritage Sites. The tourist guide shown the old city, Diocletian's Palace (dated back in 305 AC) and gave explanation about history and the cultural heritage of the city.



The following day the trip continued to the south, towards city of Dubrovnik. Beautiful panoramic view of the Adriatic Sea coast was almost all the way. One of the stops was above the Neretva River confluence and next was in Neum city (B&H).

The Neretva River deltaic valley near the confluence with the Adriatic Sea

The spring Palata – Robinzon at Mali Zaton Bay is situated on the seacoast, and is one of many springs at a tectonic contact between karst aquifer and impervious flysch barrier. Presentation about engineering project of Dr Petar Milanović for regulating discharge of this spring was given.

Spring Palata – Robinzon at Mali Zaton bay

The next stop was at the Ombla Spring on the Adriatic coast near the town of Dubrovnik. This spring which drains most of the water from Trebinje and Popovo polje (the Hydrosystem Trebišnjica, B&H) is located just a few meters above sea level, which is dictated by the impermeable flysch barrier. Z. Stevanović presented hydrogeological setting of Ombla spring catchment, its transboundary character as well as design and possible implications of proposed building of an underground dam for hydropower utilization.

Ombla spring

The last stop of the excursion was famous historical city of Dubrovnik. It is one of the most prominent tourist destinations in the Mediterranean Basin. In 1979, the city of Dubrovnik joined the UNESCO list of World Heritage Sites.The tourist guide leads the group through the old city and provided explanation about history, monuments and the cultural heritage of the city.








The Old city of Dubrovnik

Branislav Petrović, PhD student