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FROM TRADITION TOWARDS THE FUTURE - SPELEOLOGY AND KARSTOLOGY IN SLOVENIA

DA TRADIÇÃO PARA O FUTURO – ESPELEOLOGIA E CARSTOLOGIA NA ESLOVÊNIA

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Resumo

A Eslovênia é um país do Carste Clássico, cuja a ideia e o conceito de carste se desenvolveu e seu carste desempenhou um papel essencial no desenvolvimento da Espeleologia, da Carstologia e da Bioespeleologia. Já em meados do século XIX, as atividades espeleológicas estavam bem desenvolvidas. Em 1947 foi fundado o Instituto de Pesquisas do Carste da Academia de Ciências e Artes da Eslovênia. O instituto lida com espeleologia, geomorfologia cárstica, geologia, hidrologia, bioespeleologia, ecologia e microbiologia, bem como a história da Carstologia, cooperando com a Associação Espeleológica Eslovena no gerenciamento do Registro Nacional de Cavernas, além de trabalhar em projetos que estão envolvidos na proteção e gestão de cavernas e águas cársticas.

Palavras-Chave: carste clássico; espeleologia; pesquisa cárstica; Instituto de Pesquisas do Carste da Eslovênia.

Abstract

Slovenia is a country of Classical karst, here the idea and concept of karst developed, and Slovene karst played an essential role in the development of speleology, karstology and speleobiology. Already in the middle of the 19th-century caving and speleological activities were well developed. In 1947 the Karst Research Institute within the Slovene Academy of Sciences and Arts was founded. The institute deals with speleology, karst geomorphology, geology, hydrology, speleobiology, ecology and microbiology, as well as the history of Karstology; cooperate with Slovenian Speleological Association on the management of National Cave Register and work on projects which are engaged in the protection and management of karst waters and caves.

Keywords: classical karst; speleology; karst research; Karst Research Institute Slovenia.

1. INTRODUCTION

Slovenia is a country of Classical karst, here the idea and concept of karst developed, and Slovene karst played an essential role in the development of speleology, karstology and speleobiology. About 44% or 8,700 km² (GAMS, 2003) of Slovenia's surface consists of carbonate rocks. Karst geomorphology and over 13,000 known caves represent a significant proportion of its landscape. According to the general morphological and hydrological conditions and its evolutionary history, it is divided into three major karst areas: Alpine karst, Isolated karst and Dinaric karst. Karst springs provide drinking water to almost half of the inhabitants.

Word karst (kras) entered to international scientific terminology from Slovenia; kras in Slovenian language means rocky and bare landscape, and it is often used as a toponym for such a landscape. It also means the Kras Plateau (Karst

Plateau) in SW Slovenia which extends between the Trieste Gulf (N Adriatic Sea) and Vipava Valley; plateau represents the NW part of Dinaric karst.

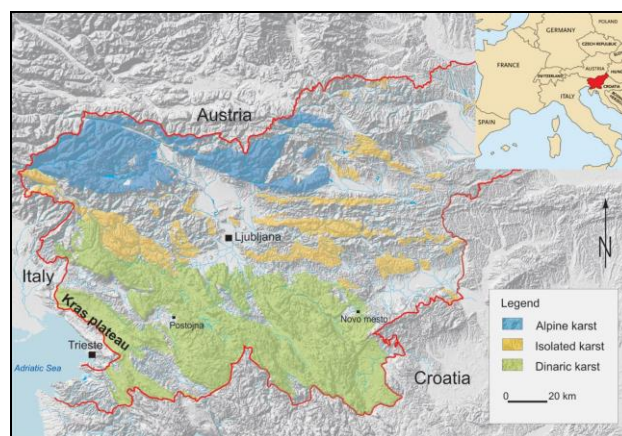


Figure 1: Location of Slovenia with its karst regions.

Karst phenomena located in the actual Slovene territory are already mentioned in antique literature, the first modern printing notes date to the

middle of the 16th century, Slovene Karst and the karst of Notranjska played an essential part in the development of karstology and speleology where the precursors of the modern karstology, such as J.V. Valvasor, J.A. Nagel, F. Steinberg, G. and T. Gruber and J. Cvijić were active (KLANJC, 1997). Already in the middle of the 19th century also caving and speleological activities were well developed in Kranjska (Carniola)(KLANJC, 2002) by Austrians. In 1879 F. Kraus founded in Vienna "Verein für Höhlenkunde" and a year later "Karst Comité". Soon afterwards he wanted to set up a branch of "Verein" at Postojna. In Postojna was in 1889 the speleological club Anthron founded. The Anthron members discovered an important part of the Postojnska Jama system, explored caves nearby and helped the best-known speleologists of that time such as Kraus, Martel, Perko and Putick.

In 1910 the first Slovenian speleological club "Društvo za raziskavanje podzemskih jam/Society for Research of Underground Caves" was founded in Ljubljana (KLANJC, 1997; SHAW, 2010). At the same time was planned the foundation of Speleological Institute at Postojna and they expected that it would be open 1913. The I. W. War prevented all the plans, and after the effects of the war, Postojna becoming an Italian town and the Postojna cave was not opened for the public till September 1922. By that time Perko, as director of Postojna cave, already proposed the creation of an Italian speleological Institute which was established in 1929 as the Instituto Italiano di Speleologia (SHAW, 2010). In 1947, the Karst Research Institute within the Slovene Academy of Sciences and Arts continued the research.

Institute also collects documentation of all known caves in Slovenia; materials are stored in the archives of Cave registry, which is jointly operated by the Speleological Association of Slovenia. According to the Slovene Cave Protection Act, Institute has authority for the collection, technical verification and reporting of data on caves to Ministry of the Environment and Spatial Planning, which is responsible for nature conservation. Basic information on caves required for reporting to the Ministry has open access through its geoportal Environmental Atlas of Slovenia.

At the Institute building also International Union of Speleology _UIS is seated. UIS was established during the 4th International Congress of Speleology, which was held in Ljubljana and Postojna in 1965 and since 2002 is officially registered in Slovenia. UIS works and communicates through its departments,

commissions, working groups, open access publications (International Journal of Speleology_IJS, UIS Bulletin, Speleological Bibliography & Abstracts_BBS/AS) and portals (UIS website; Karst Information Portal - digital library; Speleogenesis & Evolution of karst aquifers).

2. KARST RESEARCH INSTITUTE

Scientific research of karst phenomena as are surface, caves, waters, biology and ecology has been the aim of the Karst Research Institute ZRC SAZU in Postojna since 1947. Primary research includes field studies, laboratory investigations and numerical modelling.

In addition to the primary research, Institute conducts also applied studies; e.g. monitoring of tourist caves, planning of the roads and railway, water quality problems. To spread the knowledge of the scientific research and of protecting and raising awareness of the importance of landscapes, caves, water and biodiversity in the karst areas, the Institute carries out numerous activities. For example monitoring of tourist caves (e.g. GABROVŠEK et al., 2014; RAVBAR; ŠEBELA, 2015), monitoring of cave fauna (e.g. CULVER; PIPAN, 2014), water tracing tests (e.g. PETRIČ, 2010), publications (e.g. PRELOVŠEK; ZUPAN HAJNA, 2011; ZUPAN HAJNA et al., 2015), exhibitions and educational trails for diverse clients (e.g. museums, caves, municipalities) and implements various projects funded by the EU, Slovene Government, Agencies, etc. (<http://izrk.zrc-sazu.si/>).

Education of various target groups, from the youngest children in schools to the adult population, life planners, legislators, and potential visitors, is especially crucial due to the exceptional geological, geomorphological and archaeological content of the caves, their vulnerability, specific environment and habitats. Since 1993 Institute has been organising a regular annual conference with the name International Karstological School "Classical Karst" (<http://iks.zrc-sazu.si/en/index.html>); at which from 50 to 200 participants gather each year. Different aspects of karst studies are presented during the conference. The primary objectives are to present the state-of-the-art in the selected topic and to encourage discussions related to the school's topic through lectures, poster presentations and field trips in the Classical Karst of Slovenia. Several of the institute's researchers are also lecturers in the postgraduate Karstology program offered by the

University of Nova Gorica, which in 2014 became the UNESCO Chair on Karst Education.

Acta Carsologica

The Institute is editing the *Acta Carsologica* journal for 64 years (<https://ojs.zrc-sazu.si/Carsologica>). *Acta Carsologica* (GABROVŠEK; RAVBAR, 2015) publishes original research papers and reviews in all the fields related to karst (karst geology, hydrology and geomorphology, speleology, hydrogeology, biospeleology and history of karst science). In the 1990s the electronic version of *Acta Carsologica* was released; the shift to electronic editing was fundamental. The oldest version of the website, with full open access to all papers, was launched in the mid-1990s and has been upgraded several times. A significant upgrade, including a full redesign of the website, was carried out in 2006. The oldest issues from 1955 to 1997 are available as pdf images. Since then *Acta Carsologica* has been included in the Web of Science and Scopus databases. After some consideration the Open Journal System (OJS) was selected as a platform for electronic publishing; now *Acta* is edited and published within this platform.

Library of the Karst Research Institute

The Library at the Karst Research Institute ZRC SAZU in Postojna holds around 38,000 catalogued items of national and international literature on karst history, exploration and research (<http://izrk.zrc-sazu.si/en/>). The Library obtains material mostly through donation and exchange for *Acta Carsologica* journal while the purchased literature represents a negligible part of the collection. The Library holds some rare and unique material with limited access. Since its foundation, the primary role of the Library is support for the research carried out by the institute. Information about library holdings is possible through COBISS-virtual library of Slovenia or via the web application e-Library IZRK.

The Library provides cataloguing service for the newly acquired material at the Slovenian Academy of Sciences and Arts in Ljubljana. Except for the old collection, a list of recently acquired items is regularly updated and can be browsed via COBISS (Co-operative Online Bibliographic System & Services; OPAC) online application. COBISS represents an organisational model of joining libraries into a national library information system with shared cataloguing, the COBIB union bibliographic/catalogue database and local bibliographic databases of participating libraries.

Cave Register

All caves in Slovenia are state property and assets and are protected by law (Cave Protection Act, OG RS, No. 2/2004). The Cave Protection Act regulates protection and use of underground caves, protection regimes, protection measures and other rules of conduct. Caves have the status of subterranean geomorphological natural assets of national importance. The results of exploration (surveys, cave maps, reports) have been collected by the national Cave registry, which is jointly operated by Karst Research Institute ZRC SAZU (<http://izrk.zrc-sazu.si/en/>) and the JZS-Speleological Association of Slovenia (<https://www.jamarska-zveza.si/>).



Figure 2: Cave Register - archive of Slovenian caves data at Karst Research Institute ZRC SAZU.

In Slovenia in 2019 over 13,000 caves were registered in Cave Register (Karst Research Institute and Speleological Association of Slovenia). There are 93 caves longer than 1000 m, nine cave deeper than 1000 m and 60 caves deeper than 300 m. The deepest is cave Čehi 2 (depth 1505 m), and the longest is Cave system Migovec (length over 42 km).

Institute collects documentation of all known and documented caves in Slovenia. Exploration results (surveys, cave maps, reports) are collected by the national Cave registry, which is jointly operated by the Speleological association of Slovenia. Cave registry consists of texts, maps and photographs.

New entries are made on the base of new documents received (checking of existing data and new data for the cave from the same area). Institute, according to of the Cave Protection Act (Articles 8 and 9), has authority for the collection, technical verification and reporting of data on caves to Ministry of the Environment and Spatial Planning,

which is responsible for nature conservation. Part of the data is included in a digital database, which is the base for state cave identification. Basic data of caves are public. Electronic database on caves required for reporting to the Ministry shall comprise base data which are: registration number, name of the cave, coordinates (location), length, depth and basic plan (map) of the cave. The number of last listed cave in April 2019 was 13.004. The number of new caves increases for 290 a year and in the electronic database was done 1.900 changes or corrections a year.

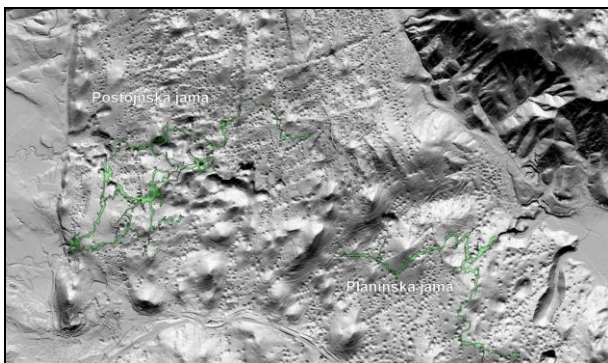


Figure 3: Karst surface with dolines and collapse dolines above cave passages of Postojnska and Planinska jama. Source of Lidar data: Geodetski oddelek ARSO.

Everyone can access to those data through Slovene Agency for environment web page (www.gis.arso.go.si/atlasokolja); on the same platform also a digital model of relief of whole Slovenia (DMR) from Lidar data is available since 2015. Lidar data can be used for detection and determination of various geological and karst features, using for visualisation of the caves spatial distributions and locations; and even for searching for new caves.

3. KARST AND CAVES PROTECTION PROJECTS

The characteristics of the karst underground make it an extremely sensitive and vulnerable system that is highly susceptible to influences from the surface. Human beings represent a severe threat to nature through their way of life and frequently ill-considered interventions in the environment (PRELOVŠEK; ZUPAN HAJNA, 2011).

Population and compact settlements pose a significant risk for pollution of the underground caves and of drinking water in karst areas, mainly due to the inflow of large quantities of municipal sewage, and large amounts of various kinds of waste. The threat is also mass tourism in karst areas

and unregulated show caves as also carelessly caving. Such interventions can destroy the natural balance in the environment, affect biodiversity, water quality, destroy interesting geological features and information and various karst formations.

In Slovenia for example, the karst and the karst underground are already protected by various acts: e.g. National Environmental Protection Programme; Environment Protection Act; Cave Protection Act; Rules on the designation and protection of valuable natural features; Nature Protection Act; Decree on special protection areas (EU Natura 2000 areas); Water Act; Rules on criteria for the designation of a water protection; Water Directive; The definition of protection belts for karst springs and measures for their protection; Cultural Heritage Protection Act. All caves in Slovenia, even those in privately owned quarries, are state property and are protected by the Cave Protection Act since 2004. The Act regulates the protection and use of caves in Slovenia, setting out protection regimes, protection measures and other rules of behaviour including the renovation of caves that are polluted and damaged.

Water monitoring

As a result of karst and water drainage characteristics, karst aquifers are extremely vulnerable to the consequences of various sources of pollution. The extent to which the effects of pollution on the karst surface are reflected in karst springs depends on the characteristics of the transfer of substances with water through karst rock. Water from the surface percolates rapidly underground, where it flows through open conduits. The rate of self-cleaning is thus dependent on the rate of flow and the type of pollution, but in general, is extremely low or non-existent in karst areas. Negative impacts are therefore able to spread rapidly into the underground, where they affect caves and conditions in them, altering the habitats of underground organisms and also have an effect on the water. Water and pollutants can enter the underground in several ways (e.g. PETRIČ, 2010), in dispersed form through bare or covered karst surface with precipitation; and in concentrated form through ponors. Once underground, they move freely through open karst conduits, where the rate of self-cleaning is very low or non-existent. The residence time of water in the karst underground is mostly concise, from a few hours up to a few days. Karst areas are characterised by large karst springs with a large catchment area (from tens to hundreds of km²).

Water from karst springs is essential for the water supply; drinking water from karst aquifers supplies $\frac{1}{4}$ of the world and $\frac{1}{2}$ of Slovenia's population (ZUPAN HAJNA et al., 2015). The quality of the water from a spring depends on hydrological conditions and pollutants in the spring catchment area. The existing problems concerning pollution and protection of karst groundwater will not be solved merely through legal regulations (PRELOVŠEK; ZUPAN HAJNA, 2011; RAVBAR; ŠEBELA, 2015). Cooperation is needed between experts, regulators and operators for the sake of careful land use planning and protection of karst waters. However, it is also necessary to change people's attitude to nature and natural resources through education about the characteristics of the karst.



Figure 4: Example of dye tracing of ponor in Slovenia; tracer tests are essential to know the directions of underground water flows.

The results of hydrological monitoring performed as part of various projects, combined with the results of long-term observations from meteorological and hydrological stations, alongside the sampling of water quality during the flood pulses may provide appropriate assessments of the hydrological state of the analysed underground watercourses (ZUPAN HAJNA et al., 2015).

Tourist caves

People have been using and exploiting caves for various purposes since the dawn of their existence. Only recently, however, have people become aware of the fact that caves are also an essential part of natural heritage. Due to their specific characteristics (e.g. relatively constant humidity and temperature, fauna) caves are extremely sensitive to various external influences

and visits. In remote places, it takes a long time to repair, or the damage is even permanent. Easily accessible caves are the most vulnerable ones. Combined with careless behaviour unregulated cave tourism brings about various adverse effects, such as acts of vandalism, waste and sewage, which disproportionately increase the intake of substances and energy (light) in an otherwise poor environment and as well as the introduction of decaying materials such as wood, iron. In order to minimise these changes and damage, it is necessary to observe the laws of individual countries, the guidelines of the International Union of Speleology (UIS) and the International Show Caves Association (ISCA), and to educate new speleologists/cavers on the level of national organisations, societies and clubs.

Despite all listed, numerous caves are many times unfortunately damaged and sometimes used as landfill sites. Waste in caves is not visible on the surface: "out of sight, out of mind". To prevent such behaviour, it is necessary to protect caves and ensure their prudent and controlled use actively. Moreover, most of all, it is important to inform and raise public awareness about the importance of caves and their preservation.

Among the most common economic activities of cave exploitation is tourism. Its direct negative effect on cave systems range from morphology transformation (e.g. new cave opening, enlargement of passages), climate and chemical processes changes, threats to habitats and similar.

Due to the very slow natural processes towards recovering the natural state, anthropogenic alterations in the underground are virtually everlasting. The past and present utilisation of caves for tourism could be markedly more sustainable if it were more thought-out and in line with scientific guidelines. In line with the Slovenian Cave Protection Act, there is a proposal to arrange the custodianship of show caves that will define the scope and utilisation level as a necessary compromise between preservation and use for tourism. Karst Research Institute ZRC SAZU perform(ed) more projects and monitoring of tourist caves in Slovenia (e.g. ŠEBELA; TURK, 2011; ŠEBELA et al., 2013; GABROVŠEK et al., 2014; MULEC, 2014; PRELOVŠEK et al., 2018); the most important is UNESCO site caves Škocjanske Jame and Postojnska Jama. The findings of the impact of past and present tourist use, together with the indicators and guidelines, will be valuable for managers of show caves as natural sources, for sustainable cave use and for preparing long-term management plans.

One of the examples where Institute was evolved in the scientific presentation of the cave natural and tourist developments as a tourism product was the design and preparation of content for interpretative exhibition at show cave Postojnska Jama. In 2012 new concessionaire Postojnska Jama, d.d. Decided to invest in the interpretation of Postojnska Jama story. Before that, Postojnska Jama was historically famous show cave with various, numerous and famous visitors from all over the world, but without any permanent exhibition or interpretation on the cave.



Figure 5: The issue of “proper” lighting is a problem in all tourist caves; special lighting of Postojnska Jama on the 200th anniversary of a tourist visit in 2018.

The leading idea was to present cave regarding natural and tourist development and its significance in space and time with the use of innovative technologies and interpretation. There was a big challenge on how to provide enough information for the average visitor, without oversimplifying or overloading; to avoid this problem multi-levelled exhibition was set up. The exhibition was opened in 2015 by marketing name “EXPO Postojna Cave Karst” and in 2017 exhibition got the award for most creative and exciting achievements in Slovenian tourism “Sejalec 2017” from Slovenian Tourist Board.

4. CONCLUSION

Even the monitoring of the impact of karst springs, tourist visit in show caves is essential and needed, also as sustainable management or water supplies and show caves with such large visitor numbers is a big challenge, the base for understanding caves and karst is still their basic scientific research. It is also of vital importance that we realise that people can destroy or preserve karst landscapes, caves, water and fauna for many generations to come.

5. ACKNOWLEDGEMENT

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