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Professor Herak's Contribution to Karst Geology and Hydrogeology

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The principal Croatian newspaper, the Zagrebian "Vjesnik" carried the following heading on 23 March 1972: "Our scientist on the top of the global list of karst researchers". It was a short review of a new book edited by Herak & Stringfield entitled "Karst - Important Karst Regions of the Northern Hemisphere". At that time, to gather together authors from thirteen "karst" countries each having different concepts and views on the karst, including the USA and USSR, was not only a scientific feat but also a tremendous organizational act. This bulky and enduring project was given to Herak who, after his long term effective and globally recognised karst research, became an outstanding connoisseur of karst geology. Therefore, we think that it is a most outstanding acknowledgement to our karst researcher.

But all this, as usual, started much earlier, when Herak became a member of the Geological Museum in Zagreb, under the directorship of Josip Poljak, a connoisseur, and in that time the only serious karst researcher in Croatia. With him, Herak had already in 1946 performed hydrogeological exploration in Gorski Kotar (HE Vinodol) and in 1947 around the Cetina river (the Peruća reservoir). Later, working in the area of the Zagorska Mrežnica river, Poljak, after Herak's argued influence, accepted the inundation of a karst spring, which facilitated the later construction of the Sabljaci reservoir near Ogulin. There, as Herak says, he realised for the first time that the karst hydrogeology may be understood only if the geological structure of the terrain studied is well known. Such an approach consists of, first of all, a scientifically proved geological basis that explains the hydrogeological consequences. Herak was convinced and tried to prove through many examples that the karst hydrogeology cannot be understood without a thorough knowledge of geological structure elements of the terrains studied, as the later hydrogeological practice confirmed it. Endeavours to formulate a general karst theory, as shown by Davis (1930), Grund (1903), Katzer (1909), Cvijić (1918) and Roglić (1972), became progressively more invalid as field investigations became ever more deci-

sive. Therefore, Herak's works in 1956 and 1957 on the geological problems of the Mala Kapela Mt. and on the geological basis of certain hydrogeological phenomena in the Dinaric Karst, are considered as a land-mark between the descriptive and scientific approaches to karst research. The application of his favourite saying "a peasant and water are not stupid; they always find the easiest ways" can be found in each of his works because water will flow only through the underground where the geological structure permits - but this structure has to be correctly understood. This "but" was most frequently a stumbling block and a basic misunderstanding between the geologists and the "consumers" of geology, and less commonly between pure geologists themselves. Herak insisted in the resolution of these misunderstandings by stubbornly and patiently drawing fundamental geology and its practical applications together.

He also introduced such an approach toward practical problems into his new lectures on hydrogeology and engineering geology, that he opened within the Technical Faculty in Zagreb, where he came from the Geological Museum in 1952. His continuous collaboration with the hydro-power engineers convinced him that such a practical approach is correct and gave him numerous wonderful examples needed for the education of students. The permanent impact of practical phenomena on fundamental investigations and vice versa stimulated him to introduce such an approach into his lectures. By that, he transformed the old term "the applied geology", that encompasses some segments of geology into "the application of geology", by which the entire geology with all its cognitions can serve for various practical uses. As a result, there is a saying about "The Zagrebian School of Karst Hydrogeology". On the basis of all this, he introduced the lecture "Karst Geology" within the faculty study and "Selected Chapters from Karst Geology" within postgraduation study.

His multiple, complex field investigations in late 1950's included Hvar island, the reservoir on the Gračsko Polje (Obrovac hydro power plant), the upper Kupa river basin (where a considerable allochthony of

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Palaeozoic deposits were discovered), the national park Plitvice Lakes, the Lika and Gacka rivers (Senj hydro-power plant), the Buško Blato, the Trebišnjica hydro-power plant and a series of hydrogeological studies and reviews within the area of the former Yugoslavia (Jamińska Kiselica, Drina river, Tara-Morača river system etc.). The experience gathered within such a large area convinced Herak that his opinion on the importance of tectonic elements in the explanation of karst phenomena was valid.

In 1965 Elsevier publishers requested that Herak write a book based on his karst exploration experiences, and this appeared. The book was published in 1972 as a significant contribution to the science of karst hydrogeology on the global level. After this event, Herak became a world known expert on karst hydrogeology which resulted in his invitation to the most prestigious meetings and help the resolution of the most complex hydrogeological technical problems.

In 1959 Herak visited the Kharga Oasis in western Egypt where deep wells were drilled in order to extract groundwater. After this, he went to Iran firstly to review the geology of the Mashabad area, where a hydro-power dam was to be constructed, and later as a consultant of the Iranian government which allowed access to the research centers within the Iranian karst region. Herak's regional geological knowledge was utilised in the resolution of water problems at the Nabatich reservoir in Lebanon and followed by other reservoir projects in Lebanon, as for example reservoir in the Litany river valley. These links with Lebanon later resulted in a Lebanese student obtaining a PhD from the University of Zagreb. In Turkey, Herak explored the Taurus Mountain area, which together with the reevaluation of the geology of the Manavgat river valley resulted in the construction of a big reservoirs.

In 1967, Herak visited Jamaica as an expert of the United Nations (FAO) for two months where he helped to determine the catchment areas of major coastal karst springs. After resolving the basic geological structure of the island, the catchment area was discovered to be ten times larger than previously thought. This resulted in Herak's election as the UN FAO chairman of a group in charge of groundwater in fissured rocks. In 1969 after renewal of this post, as a president of the expert group, he visited Mediterranean countries to check the activity of UN development programmes related to the use of karst groundwater. He also collected the local karst terms in use in Turkey, Greece, Tunis, Alger, Spain and which together with those from Germany, France, England, Italy and Croatia were published in a multilingual dictionary in 1972 by the UN and UNESCO. In 1980 Herak undertook his final task for the UN when he helped in the exploration for karst groundwater in the Molai region of the Peloponnese. There, he proved irrefutably the decisive role played by overthrust tectonics in the occurrence and flow of groundwater.

Personal experience, scientific interpretations and research approaches to the karst exploration Herak presented on numerous international conferences on karst hydrogeology, as Dubrovnik, Moscow, Canary Islands, Montreal, etc. Between 1956 and 1986 he published 39 scientific papers related to the karst. From the first published paper in 1956 "O hidrogeološkim problemima Male Kapele" (On hydrogeological problems of the Mala Kapela Mt.) till that one published in 1986 "Geotektonski okvir zaravni u kršu" (Geotectonic framework of karst plateaux) which, we do believe, will not be his last paper on the karst. During this time period Herak developed, complemented and refined his initial concept. As time passed he became progressively more interested in geotectonics and his work on the karst consisted ever more of interpretation based on his broad knowledge and understanding of regional geology and geotectonics. His opinion on the hydrogeological function of karst terrains and on the spacial conditions in the occurrence of karst aquifers achieved a final form in the "Osnova hidrogeološke karte Dinarskog krša" (The basis of the hydrogeological map of the Dinaric Karst), scale 1:500,000, that was prepared by him and his collaborators in 1974. This map later became the basis for the hydrogeological map at the same scale of the former Yugoslavia.

The paper published in 1977 entitled "Tecto-genetic approach to the classification of karst terrains" (Tekto-genetski pristup klasifikaciji krških terena) represented the condensation of all Herak's knowledge. He remained consistent to himself and set geological conditions as the basis for understanding the origin of the karst medium and all tectonic changes to which the karst terrains were exposed. These two explicitly "geological" elements can always be reconstructed in regional frameworks and by means of available geological methods. His division of karst terrains into the epi-orogenic karst (formed in tectonically stabilized terrains without later significant tectonic deformations) and orogenic karst (formed in tectonically mobile terrains with later considerable tectonic deformations), will remain despite possible changes related to the geotectonics and variations in terminology, because it was based on the most elementary and unchanged geological thought. The divisions within these two main karst types (tabular, homoclinal, folded, basin-type and deep ones in the epi-orogenic karst, and lenticular, folded, dissected and accumulated ones in the orogenic karst) can be partly modified, but they will remain recognizable for their basic characteristics and applicable in the classification of karst terrains.

In this way, Herak marked the path for future scientists to follow. He significantly changed the approach to karst exploration, surpassing his predecessors and becoming the central figure among the karst explorers of this century. Herak deserves our sincere gratitude for everything that he achieved in this field of science.