DOI: https://doi.org/10.3986/ac.v53i2-3.13951

# INTERVIEW WITH PROFESSOR FRANCE ŠUŠTERŠIČ

# MAPPING THE UNKNOWN: THE IMPORTANCE OF BASIC RESEARCH IN KARSTOLOGY AND SPELEOLOGY

cunducted by Janez MULEC

Professor France Šušteršič, a distinguished geologist, is known particularly for his contributions to various aspects of karst science. His entire professional career has been dedicated to karst, caving, and speleology. After becoming an active speleologist at an early age, he transferred this passion to his scientific work, to liaising with other scientists, and to mentoring his doctoral students. Over the years he taught many courses on geology of the karst at the University of Ljubljana and gave occasional lectures on karst at universities and research institutes around Europe. As well as introducing geology of the karst as a regular subject within the Department of Geology at the University of Ljubljana, he had previously introduced a regular course on numerical methods. Through countless scientific and professional publications, his co-editorship of the journal Naše jame, and his extensive field research and guided excursions, he has made a major contribution to the promotion of karst in Slovenia and abroad. Among his many interests he is particularly fascinated by the theory of karst development, especially with respect to the formation and development of karst features such as dolines, and aspects of early speleogenesis. In the latter case his studies primarily concerned liaisons between the roles of structural controls and the processes of cave development. Alongside making use of already well-established research methods he envisioned and instituted several mathematical methodologies for demonstrating the evolution and geometry of some surface karst phenomena. During his professional life he acquired an abundant understanding not only of the Slovene karst, but also of karst throughout the Dinarides.

*Professor Šušteršič, your academic career has spanned several fascinating fields, particularly geology, speleology, and karst processes. Could you tell us a little more about your academic background and how your journey in these fields began?*

*Professor France Šušteršič (photo: Primož Jakopin)*

Thank you for your kind invitation to provide this contribution to Acta Carsologica. Before pursuing the matter further, I feel that I should underline that I consider myself to be primarily a karst geomorphologist, whose skills and abilities benefit from a strong geological background. As a natural scientist my perception of the karst probably differs from that of most readers of the journal. For me, the karst is a natural phenomenon, developed in the topmost layer of the Earth's crust, in rock that can dissolve almost entirely in precipitation water. Ultimately, the karst is in itself a topologically 3-D entity, in distinct contrast to most other geomorphic systems, which at planetary scale display a third (topological) dimension that is negligible. The perception of a karst geomorphologist is that surface and underground phenomena are of equal importance. Inevitably, sooner or later, the effects of permanent denudation (surface lowering), would bring originally underground phenomena to the land surface and blur the difference.

The years of my boyhood were spent with my family, and our time was shared between Ljubljana and Rakek (close to Postojna). Often, I accompanied my parents, who enjoyed walking in the outdoors, and even in the early days I realized the difference between the Sava (at that time an untamed Alpine river) and the incised

karst rivers. My formal education, which was based in Ljubljana, culminated in the achievement of a doctorate in karst-oriented mathematical geology. Additionally, I studied two years of civil engineering, and two years of geography. Later I improved my knowledge of karst geomorphology (working with Professor Jean Nicod, visiting various karst sites in France), and of geostatistics (with Professor John Davis, who was on a sabbatical from the USA). Earlier, much of my high-school training had been language-oriented, and I discovered that this grounding was a huge help when studying foreign literature. Perhaps surprisingly, the most valuable aspect was a knowledge of Latin, and not just because it made the Romance languages, especially Italian, more familiar to me. Much more important was that four years' experience of translating Latin texts helped me know almost instinctively how to recognize the essential points within a foreign-language publication.

I started my scientific career with the Karst Research Institute (Postojna) and later I switched to the University of Ljubljana. Besides the formal education and experience already described, I must mention one more-informal but also valuable aspect. This encompasses many exhaustive discussions over the years with my co-workers and friends, including those from the academic world, such as Dr Andrej Kranjc, Professor Jože *Čar,* Dr Andrej Mihevc and Dr David Lowe, plus the many caving friends who made my underground interests realizable.

- *Was there a particular experience, or event that inspired you?*

What inspired me to do what I did? During my preschool years at Rakek, just a glance from the window towards the top ridge of the Javorniki. Even now, if I close my eyes, I can recall the highly regular profile of the upper-elevations, which provided a sharp contrast with the brook- and rivulet-dissected hills that I could see around Ljubljana. Plus, of course, it was inevitable that I would be impressed by the solution dolines that we had (and still have) around our house at Rakek. Some later outings to the Rakov Škocjan valley and Ravnik taught me that something dark, dangerous-looking, but still mesmerizing, was lurking in the forest, to say nothing of the river rising and re-sinking beneath our feet. The die was cast; there was no way back and, in the years that followed, my curiosity and my ambitions just simply increased.

- *In this context, can you identify one or more individuals who have had a notable impact on your professional path?*

Several people gave positive boosts to my interests, and taught me different aspects of the craft, but among them four individuals deserve particular recognition.

My father's long-time friend, the late Stanko Likar, was the one who first made me believe that the karst is something attractive, simply by introducing me to an unknown world, as well as providing me with a more sophisticated scientific access. At that time, he was the local polymath at Rakek and above all a great lover of nature. Under his "aegis", excursions to Rakov Škocjan were not just physical activities amid unspoiled nature; they also provided a cosmopolitan education about anything and everything that we might encounter during the trip. All of that was presented in a way that must have attracted and nurtured the interest of early-teenage boys. He also supplied me with copies of popular books about karst, as well as topographic maps that were not exactly freely accessible at that time.

Another mentor was my secondary-school teacher, Pavel Kunaver. At a time when I could have turned in other directions, he discovered my deep interests. Effectively he encouraged me and set me more firmly onto the right track, as previously indicated by Stanko Likar. My third mentor, Pavel's son Jure, is of course a (university) professor. At first we become caving friends and later he continued along his father's route, helping to pave my way into the scientific realm.

For all of that, my most important scientific mentor was the late Professor Ivan Gams. Though he was never my formal teacher – originally just a member of "my" caving club – we established scientific contact and rapport very early, keeping them active until eventually he moved into a retirement home. During frequent tea-table meetings we discussed more or less every aspect of modern karst geomorphology and speleology. More than just teaching me, he revealed problems within the then currently accepted wisdom. He loaned me books that he believed I would find interesting. On a regular basis he would present me with offprints of his latest publications, of which there was never a shortage! He also had many international acquaintances, and he soon introduced me to the "gang". Beyond all that, and perhaps most importantly, at a very early stage in our dialogues, he convinced me that my early ideas about what was to become "The Pure Karst Model", were essentially correct.

One might ask why Professor Gams failed to place greater emphasis upon the practical effects of his own view that the main agent of karstification is aggressive water. After half a century the answer is clear. In "his" time, geomorphology was unable to recognize or demonstrate the difference between corrosion and shaping. Corrosion is a chemical process that operates at the atomic or molecular level, simply "enabling" solid calcite to move. The process, generating forms at the much larger scale that we describe as geomorphic, is the one that moves the

*Exploring Najdena jama, 2002 (photo: Metod Di Batista)*

solution in a repetitive and cumulative way, so leading to the development of karst forms.

Perhaps because our underlying training was basically dissimilar, our later ideas developed in different ways. Nevertheless, our relationship remained completely amicable and constructive to the very end.

- *You are not only a university professor, but also a field person, a speleologist, a critical mind and a source of valuable information for students and colleagues. Do you think that nowadays, when data processing and modelling are becoming more sophisticated and many people study karst from the laboratory and/or from the office, fieldwork is still essential to advance our understanding of karst?*

Absolutely. During the last decade "armchair caving" in the extreme and literal sense of the term, supported by radar, LiDAR, etc., has become possible. Yet, there is no caver in the world who would uphold such an activity as true caving. In the scientific field the situation is less clear-cut, but essentially the same. Natural science without nature simply wouldn't "work". Numbers acquired in labs or produced by computers are merely symbols that need the context of a physical setting in the background. At the moment, reflecting the technology available on the market, the natural sciences are still hovering between fieldwork and indoor activities.

At the end of the day, the simplest way to find something new is to install data loggers, and then, after an appropriate time, run the acquired data through hopefully adequate computer programs. Increasing the number of digits after the decimal point might only be a great contribution to our science if it has a tangible physical meaning, reflecting upon the development of the karst. Put more simply, going too far could be as pointless as measuring the towers of a great cathedral with a millimetre yardstick. In such situations the limits should be set based on the theoretical requirements – otherwise the process might expand to infinity. Perhaps a clearer example is provided by the Michelson-Morley experiment, whereby what was essentially a simple thesis, designed on the basis of pure theoretical deduction, didn't stand up to practical testing. The consequences are well known… Only nature can be the final arbiter in such situations.

In the karst science situation, a "mixed" procedure led to the recognition of previously overlooked unroofed caves. The appearance of an apparently unexplainable longitudinal depression on a motorway construction site triggered exhaustive debates around the tea-table. It turned out that the object in question was a cave that denudation had brought to the surface. Having reached this conclusion, the next step is obvious. If such features really are caves, then the parent rock around them, might tell us much more about the relationships between cave formation and the geological setting. Additionally, study of any sediments preserved within them could yield far more information about cave sedimentation in later times than is provided by the rarely preserved locations in accessible caves. Recent high-resolution studies of unroofed cave sediments have revealed not only rich, but also unexpected, insight into cave sedimentation. A less spectacular example is the recognition of the three zones in the slopes of solution dolines. The procedure began as an attempt to separate "noise" from "signal" by pursuing a pure mathematical modelling of the Dinaric doline slopes geometry. The "signal" so gained rendered it pos-

sible to reconstruct the "undisturbed" doline shape. Once achieved, the physical meaning of the pattern (three zones) became obvious, even to the naked eye.

- *As someone who has witnessed decades of progress in your field, what do you consider to be the most important advances in karst research,*

In the realm of speleogenesis two topics can be stressed: the Ford-Ewers "four stage" model of cave formation, and Wolfgang Dreybrodt's explanation of the "Atkinson paradox". However, they were not the only scientists working on these problems. Many people have contributed to further elaboration of the topics, investigating matters such as inception horizons and deep flow on long flow paths.

Directions that still need to be exploited fully include detailed study of the sedimentology of the fill in unroofed caves, along with more targeted investigations of the relationships between microstructural features and cave formation, and so on. In terms of surface karstification it appears that researchers based in the Anglo-Saxon world only accept and exploit the methods of the general systems theory extensively. Consequently, a number of correct field or lab data remain hanging in the air, simply because their theoretical basis has never been checked and updated. Half a century after Richard Chorley's pioneering systems theory publications, such a situation sounds rather astonishing. My personal estimation is that, at the moment, the critical mass of active researchers is insufficient to eliminate the old-fashioned notions.

- *and how do you think your work, particularly "The Pure Karst Model", has contributed to these developments?*

The basic idea of "The Pure Karst Model" has always been the axis of my interest. Since my boyhood I have asked myself repeatedly how the karst surface could be shaped without invoking something non-karstic. Later it became my permanent endeavour to apply Gams' idea – that corrosion is the only acceptable mechanism for bringing about the formation of the underground karst – to the surface of the karst.

During my few years spent working on the Speleological Map of Slovenija (a KRI team project) I came across a number of distinct karst features that could only be explained by application of the Gams idea. Additionally, I realized that, alongside the "fundamental karst process", other, corrosion independent, mass transport, processes might be at work. These are driven only by gravity, without any means of transport. They don't depend upon any master geomorphic system; they are simply determined by local structure and micro-climate. Consequently, I termed them cosmopolitan processes.

Following this line of thought, one can realize that under fluvial conditions water does not operate in the same way that it does under karstic conditions. In the former case mass transport may be enabled by any fluid that has *mechanical* properties comparable to those of water. In the latter, karst, case, however, transport can be enabled by fluids that have *geo-chemical* properties comparable to those of water. These statements have far-reaching consequences that, for brevity, are best skipped for now. The only thing we need to say is that the so-called "humid geomorphic system" does not exist. There are merely two competing systems (fluvio-denudational and karstic), both making use of the same chemical, but in radically different ways. Over time, permanent denudation brings underground features to the land surface, where they are definitively annihilated. And, not to be forgotten, the land surface provides the screen upon which the non-transportable sedimentary fillings of caves that developed within rocks that were removed long ago (now "phantom" caves) will accumulate.

In geomorphological terms, the most striking understanding inspired by the model is that the tower-like karst of the Dinarides is not a relic of a warm climatic period. Instead, it is a product of present day, or possibly Pleistocene, geomorphic activity under quite specific local tectonic circumstances. Geomorphological and speleological experience, together with theoretical considerations, have confirmed to me that this conclusion is valid and that the model is robust. The issue that remains open is the question of how to progress the concept to its final effect, i.e. how to reimagine a new generation of geomorphological maps on the basis indicated by the model. This question is by no means trivial, because it will include investigation of how best to design the detailed terrain and lab studies, possibly even including mathematical modelling. All this would be necessary because, having accepted such an approach, much of the existing methodology for producing geomorphological maps will become obsolete. Some landforms formerly considered "important" will become accidental, and – more importantly – other processes, including the cosmopolitan ones, must be studied in detail one by one. It appears that application of general system theory methods might provide a promising start point. Unfortunately, during the past half-decade, repeated attempts to publish something along these lines have failed to penetrate the impermeable barriers erected by reviewers and editors.

To be frank, few people have openly refuted the general idea of The Pure Karst Model. Instead, the majority considered it merely as a curiosity – i.e., nothing more than the outcome of a mental experiment – and closed the drawer. Nevertheless, my firm belief is that the model's time is yet to come.

- *As climate change continues to impact geological processes, what do you think are the most pressing research questions regarding its influence on karst systems?*

Milanković cycles and huge volcanoes in Indonesia or Colombia are still there and continue as they did a million years ago. I don't believe that human activities may jeopardize the Planet significantly or can menace the karst directly. If we observe events in the past, we may recognize the amplitudes of former climate oscillations. Unroofed caves in particular might yield substantial amounts of useful information. The mania for "garbage in – garbage out" provides more and more data, but it doesn't seem to solve the Planetary problems.

- *And to conclude our discussion, looking to the future: what unresolved questions in karst research do you think are particularly exciting and should be explored further as they hold significant potential for groundbreaking discoveries?*

With a few exceptions, my knowledge about the karst globally is limited to various areas of interest. Perhaps I can say something more about the Dinarides.

Most groundbreaking discoveries become such only decades or even centuries after they have been launched. So, perhaps it is better to ask what can, or must, be done at this moment, to move the cart onwards without meeting major problems or dead-end streets.

Just to set the scene: the international terminology of karst features must be set upon a solid foundation of sound definitions and measurable parameters. These days too many potentially valuable determinations are based upon the inadequate observations, in some cases fabrications, and even colloquial expressions that were produced by the pioneers. Some other expressions are incorrectly understood: for example the Latin *forma* and *formation*, where loosely the former means *shape* and the latter means *creation*. In many European languages the difference has been forgotten and the terms are too commonly interpreted wrongly. Plus, there is a more local issue: Cvijić made a clear distinction between *dolines* "in general" and "true" *dolines*. Perhaps for linguistic reasons the difference has been forgotten and, ultimately, we are left with a total muddle in the understanding. Well – up to a point this is normal and to be expected, but the significance and validity of individual terms must be checked and possibly revised. And so, it goes on – and this is by no means the end of the list.

The key problem that must be addressed is that physical karst science has never entirely abandoned an initial approach, which can be termed "collecting", that produces just a few tiles isolated within a quite thinly filled mosaic. Of course, by the "final" or "productive" stage the mosaic must be reasonably complete. Clear relationships between karstic entities and fundamental natural laws need to be established, including the re-examination and revision of some seemingly "incontrovertible rules". An era of previously unachievable precision of field measurements and exact laboratory tests is on the way, and this will bring with it a mountain of information. In many cases the new data will sharply oppose existing knowledge or supposed "knowledge". Because the natural sciences are not mathematics, groups of scientists will do what David Hilbert achieved for mathematics in the early 20$^{th}$ century – provide a logical unification of the whole.

Thinking in terms of a long-term research project: in the Dinarides, one of the most outstanding problems remaining to be solved is the origin and total volume of the red fill that is found in tectonic fractures. Because the rock is intensively fractured (consider the walls of the Red Lake near Imotski), the quantity must be enormous. It appears that the sedimentation took place within a distinct time interval. If nothing else, this sediment might have played an important role in speleogensis.

Now is the time to rationalize what we already have in the drawer. Maybe produce a parent rock solubility map of Slovenia? Or perhaps identify and prepare the start-points for a revised, more complex, and better founded speleological map of Slovenia? But the latter undertaking is ambitious and would, perhaps, be a medium-length project.

Realistically, what can we do at this moment? Inevitably, after a time, the layers of the bedrock where the structural framework was once turned into a speleogenetic network (and finally to caves) under deep phreatic conditions, will appear at the surface. So, pick up a hammer, go into the field, and identify the caverns and other hollows in the parent rock that must have remained there ever since. And please don't forget how to document and present the observations. Good luck!

Thank you for providing this opportunity to present some of my ideas.