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KARST RESEARCHES IN YUNNAN PROVINCE, CHINA IN 1997

Between September 19 and October 3, 1997 members of our Institute, Mag. Janja Kogovšek, Dr. Martin Knez and Dr. Tadej Slabe, achieved the planned field work related to the project Study on Stone Forest Genesis, Functions and Structures of the Underground Karst Aquifers in Lunan, Yunnan Province, in co-operation with the Geographical Institute of Yunnan and sponsored by the Ministry of Science and Technology of Slovenia. They studied stone forests and carried out an underground water tracing test in the aquifer there. We would like to acknowledge the help of our Chinese partners for the successful work. A book about the research results is in preparation.

Study of Lunan Stone Forests

Stone forest is a special form of karrenfeld. Karren intersected by deep solutional channels, hollows or enlarged fissures on the surface of the rock are presented in the shape of pillars or teeth. Rock teeth are smaller forms. Pillars are from 5 to 50 m high; in the Lunan Stone Forest they are up to 35 m high and of various shapes. Their shape is controlled, as well as by past and present influences, by the lithology of the rock also, the extent to which it is bedded and crushed. A stone forest develops in thick-bedded, relatively pure limestones and dolomites; the strata are dipping 15^0 at the most and they are intersected by a network of vertical fissures.

In regard to location one may distinguish between two types of stone forest. Those in lowlands and valleys where large forests develop with interlying dolines and collapse dolines have underground water flowing beneath them; they are seasonally flooded or water flows through them. The second type develops on the ridges of mountains; their pillars are smaller (10-30 m), growing from a common base, and the sediment cover is thin. Stone forests appearing on the slopes present an intermediate form between the two described.

Usually a stone forest is described as a form of covered karst. The limestone where karren developed had been covered by thick sediments that decisively controlled the origin and the shape of the stone forest. Uncovered carbonate rocks are weathered by rainfall. Teeth are the first to appear, followed by a true forest.

Stone forests are a typical form of polytropical and subtropical climate.

The Lunan Stone Forest is one of the most famous. The central part (Shilin) covers about 80 ha, and bigger or smaller stone forests nearby are covering as much as 350 km^2. Tourist parts of the Lunan Stone Forest are visited by more than million visitors per year. This is a unique and integral natural and cultural landscape where the Sani minority lives mostly on tourism.

Below the forest a complex system of water conduits developed. The shape of pillars and their height are controlled by the type of rock and by their topographic location.

The central part of the forest - Shilin - lies between 1625 to 1875 m a.s.l. It is located in a shallow lowland with underground water close to the surface and the water level rises by 10 m after heavy rain. Most of the rain, from 70 to 80%, from the total annual amount of 936,5 mm, falls from June to October. The average temperature is 16,3^0, varying from -2 to 39^{0}C. The pillars are highest in the central part of the lowland, there where the superficial waters flow underground; at the borders there are more sediments. In the lower part the water flows on the surface and in the rainy season it floods the tourist footpaths among the pillars.

The central part of the Lunan Stone Forest developed in thickly-bedded and vertically jointed Lower Permian carbonates of the Maokou period.

First the limestone was covered by a Permian basalt and tuff and later by Eocene (Miocene) lacustrine sediments. Thick layers of lateritic soil were deposited above them.

The stone pillars in the central part of the stone forest, which is located in lowland, are up to 30 m high; the spaces amon g them are mostly 1 to 5 m wide. In the central part the pillars are closely packed together; further out they stand separately also. They are relics of rock between the spaces and their shape corresponds; they may have either square or triangular cross-sections, and there are also elongated and narrow shapes. Pointed and blade-like shaped pillars with sharp peaks prevail. The more the limestones are homogeneous, the sharper are the shapes of the pillars. On such carbonates the effective rainwater has incised outstanding rock features.

The Naigu stone forest lies 20 km east of the central forest and is an important tourist destination also. The pillars are from 20 to 30 m high, tower-like with square cross-section often having several smaller, pointed peaks. The pillars are frequently connected into series between distinct fault areas and often they may be described as large rock masses with numerous sharp peaks. Some higher rock pillars stand separately, some are very slim. The tops of pillars that form a vast pillar area are at the same level. Many pillars are mushroom-like especially single ones. The edges of pillars are frequently rounded; only the crests between flutes are sharp. Their rock surface, specially in the smaller rock features, is less distinctive due to inhomogeneity of the rock, and the rock surface is rough.

This forest developed in Qixia rocks and this is reflected in its shape and relief.

The shape of subcutaneous rock teeth is not controlled by the rock structure. They are roundly pointed as are the subcutaneous teeth in other rocks.

Below the stone forest there is a show-cave showing, by its rock surface, several phases of its genesis. Scallops of not very distinctive shapes give evidence for a water flow of 0,5 m/s that flowed through the flooded passages. The scallops were covered by fine-grained sediments that filled the cave. On the roof there are big above-sediment ceiling channels, several metres across, and anastomoses. Above-sediment ceiling features give evidence of a long duration of cave formation by water flowing above the fine-grained sediments. The cave in the middle of the park shows cavernous karst underground below the stone forest and indicates the periods of fast water outflow from the surface transporting sediments that covered the limestones. But also relatively long were the periods when the cave was filled by fine-grained sediments and the surface above it was probably flooded. This shows the development of the stone forest in stages.

Examples of outstandingly mushroom-like pillars, from 35 to 40 m high, are found in Lao Hei Gin, 20 km NE from the "central park". The highest pillars are in the lowest part of the forest. They may be divided into huge rock masses intersected by narrower spaces and having several smaller pointed peaks and single pillars; among them are vast patches of sediments. Single pillars are square towers or like mushrooms. Often they consist of more squares, these are relics of rock layers between bedding-planes and fissures. The central part of the pillar is weathered and disintegrates strongly. The rock weathers in grains and the rock surface is rounded, being angular only below thin scales. The rock is very porous and the middle part of the pillars is intersected by numerous channels, from 1 cm to 1 m and even more across. Rainwater shapes the rock surface on the peaks of the pillars and at their foot, at the section of more resistant rock. So the rock surface reflects the structure and joint frequency; the rock was shaped below the soil and later transformed by rainwater.

Between pillars, dolines are frequent and in them are caves. Through some of these caves water flows from 30 to 50 m below the surface, having a discharge up to 3 m^3 and only exceptionally from 4 to 7 m^3. Taking into account that the underground water network is well developed also in this stone forest, we infer that the outflow from the surface is fast, and not only limestone and dolomite but also sediments and soil are transported underground. At the foot of single pillars there are big above-sediment channels incised deep into the rock. It seems that the entire aquifer was dammed. There had been enough rainfall and this is shown by above-sediment features in the rock. At that time water did not remove sediments from the surface and the growth of the forest was interrupted.

Martin Knez has sampled the rocks at some new locations in the stone forest and also at places already known, in order to establish, by later laboratory tests, the reasons for selective corrosion in three stone forests near Lunan. During this visit the geological investigations did not involve a regional overview of the landscape and geologic processes from the Paleozoic to now, but just detailed researches of the parent rock mostly in such parts of the geological profile where selective corrosion occurred during karstification. The work was undertaken in the field at macroscopic level and at home in the laboratory it will continue at microscopic level in order to find out the basic reasons that conditioned essentially stronger and sometimes locally characteristic karstification at some sections of the geological column.

Tadej Slabe completed researches on single rock pillars in low stone forests. The underground rock surface developed below the sediments and soil, and the peaks of pillars were transformed by rainwater; composite rock features occur at the foot of pillars, at the contact with sediments and soil. Slabe linked rocky features into rocky relief revealing the factors controlling the stone pillar formation and frequently providing evidence of the development of the stone forest. For development of a stone forest the lithology is very important too. He complemented or changed the previous explanations about origin of some rocky features that he had found in literature; obviously the study must continue and several assumptions must be checked. He intends to make a research model of a stone forest in plaster of Paris.

Janja Kogovšek studied stone pillar solution in the Stone Forest and solution during the rainwater percolation in karst.

Processing of results of karst water properties obtained at the first visit to the Yunnan karst in July 1996, reflecting the process of carbonate solution, indicated a need for additional analyses at the surface and also in conditions when rainwater percolates through the vegetation and a thinner or thicker layer of soil and rock. In September 1997 she analysed the rainwater, which is the input parameter in the solution process in karst, and also the water that had, by trickling down variously tall bare rock pillars, already dissolved a certain amount of rock. Solution of rock pillars when the soil and vegetation are removed is controlled by the intensity of rain; the thickness of the water film that pours down the carbonate pillars depends on the amount of precipitation. The amount of limestone dissolved by a certain amount of rain trickling down the pillars depends on their height and on the length of the trickling way; usually equilibrium is not yet restored at the foot of a pillar. The rate of solution by a gentle rain in a warm season is the biggest and gerater effects of solution may be expected. The decisive factor in dissolving the limestone is the amount of rain, as has already been shown in the Slovene karst; in China there is also a high strength of solution. But already a small amount of rain causes the impermeable base at the foot of pillars to accumulate, and hold water; this water is still aggressive and capable of further solution of the rock at the contact, intensified by the influence of soil. Presumably the contact of pillars with soil and rainwater accelerates the solution effects and this may contribute to the explanation of some rocky features, which, however, must still be studied.

We analysed the percolation water in detail in the Baiyun and Jiuxiang caves where we sampled most of the abundant trickles and drips underground; this not only complemented our previous results but also provided new perceptions. The surface above the Jiuxiang cave is covered by soil and overgrown by grass and dense bushes. The water in the cave reflects dolomitic structure of the rock; Ca/Mg ratio was about 1, but there was also a percolation water with higher magnesium level compared to calcium showing relatively complex rock structure of the cave roof. The highest hardness levels during our researches in the Chinese karst were established; they exceed the levels measured in Slovenia by more than 15%. Baiyun cave lies in Naigu Stone Forest where the surface is bare and vegetation scarce. In supersaturated percolation water controlling recent flowstone deposition, calcium prevails, the Ca/Mg ratio being from 3 to 5. The stream flowing through the cave is very interesting, for it contains as much dissolved carbonates as the other percolation water and deposits flowstone. The cave managers felt justified, in leading this water to a nearby stalagmite with a weakened inflow and into nearby gours.

Water tracing test in the Lunan area

Water tracing tests in karst are used to discover and to prove the underground water connections. The method is widely used all over the world in order to protect water in karst and in particular to assure healthy drinking water. Already at the beginning of our co-operation, our Chinese colleagues expressed their wish to carry out such a test in their karst as in a dry season they are lacking water not only for drinking but also for irrigation; they planned to construct an underground reservoir. Before starting this they wanted to check the underground water flow by a water tracing test. By the first successful water tracing in July 1996 we established two main directions of the underground flow and measured its velocities at certain points. The sampling was carried out at 9 sampling sites, the tracing test was quantitatively evaluated and 55% of returned tracer was established. A directly useful result of the first water tracing was the conclusion that a layer of sandstones, previously supposed to be an important barrier for karst waters, is not so important to justify a construction of a big reservoir, for it only reduces the flow.

The relatively low quantity of returned tracer in the first tracing test indicated the possibility that water flows in another direction also. Unclear results obtained by natrium chloride, which is not a good tracer, in the southern part of the area, dictated the use of a more appropriate tracer. We therefore carried out another combined water tracing test in September 1997.

At the point Wayaodong on September 26 we injected 1 kg of Uranin, and on the point Qinhuadong 200 kg of Natrium chloride which was the only possible second tracer. At both points the discharge was higher than during the first tracing test; the sampling was organised on all the sampling sites of the first test and at one additional site in the northern part of the aquifer. We contributed a plan of water tracing and this time samples will be analysed at the Geographical Institute at Kunming where they expect a new luminiscence spectrometer. At the same time as the water tracing test was carried out, we sampled the water of the whole area and determined its basic parameters (temperature, specific electric conductivity and pH) in the field and analysed the levels of carbonates, calcium, magnesium and chlorides. We shall process the hydrological data gathered and the results of fluorescence analyses of the water tracing test, together with basic water characteristics, and we shall synthetise the results and assessments of our researches in a common Slovene-Chinese monograph related to studies in China.