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LITHOLOGICAL AND MORPHOLOGICAL CHARACTERISTICS AND ROCK RELIEF OF THE LAO HEI GIN SHILIN-STONE FOREST (LUNAN, SW CHINA)

LITOLOŠKE IN MORFOLOŠKE ZNAČILNOSTI TER SKALNI RELIEF LAO HEI GIN KAMNITEGA GOZDA (LUNAN, JZ KITAJSKA)

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Martin Knez & Tadej Slabe: Lithological and morphological characteristics and rock relief of the Lao Hei Gin shilin-stone forest (Lunan, SW China)

The Lao Hei Gin stone forest is yet one more of the diverse and famed Lunan stone forests created from subcutaneous karren. The initial morphogenesis of the stone pillars started along almost horizontal bedding planes and mostly sub-vertical faults and cracks already covered by thick layers of sediments and soil. The forest's stone pillars stand individually or in groups. The dominant and most characteristic shape of the pillars is mushroom-like, with alternating lithological characteristics of the carbonate beds expressed in a vertical direction.

Key words: Lunan shilin-stone forests, lithology, rock relief, morphogenesis, SW China.

Izvleček UDK 551.435.8(510)

Martin Knez & Tadej Slabe: Litološke in morfološke značilnosti ter skalni relief Lao Hei Gin kamnitega gozda (Lunan, JZ Kitajska)

Lao Hei Gin kamniti gozd je še eden izmed raznovrstnih in znamenitih lunanskih kamnitih gozdov, ki so nastali iz podtalnih škrapelj. Inicialna morfogeneza kamnitih stebrov je namreč začela potekati vzdolž skoraj vodoravnih lezik in večinoma subvertikalnih prelomov in razpok že pod debelimi plastmi naplavin in prsti. Kamniti stebri v gozdu so posamezni ali gručasti. Prevladujoča in najbolj značilna oblika stebrov je gobasta, saj se v njej v navpični smeri odražajo spreminjajoče se litološke lastnosti karbonatnih plasti.

Ključne besede: lunanski kamniti gozdovi, litologija, skalni relief, morfogeneza, JZ Kitajska.

INTRODUCTION

Shilin-stone forests (Knez & Slabe in print) developed from subcutaneous karst karren where thick layers of sediments and soil covered the carbonate rock. They are composed of stone pillars and stone teeth (Song 1986), formed on various horizontal and mildly inclined rock beds (5–150), cut by vertical faults and cracks (Ford & Salomon & Williams 1996).

The central part of the Lunan stone forest covers over 80 ha, while larger and smaller stone forests spread over 350 km^2. Unique among the stone forests is Lao Hei Gin. The forest is composed of pillars, standing in groups or individually, that can reach up to 20 m in height. Most are lower, however, up to about 10 m. The dominant and most characteristic form of the pillars is a mushroom-like shape. Watercourses run through caves that occur some 20 to 30 m deep below the forests.

We have presented our research of the Lunan stone forests in more detail in descriptions and collected notes published in the book "South China Karst 1" (Chen *et al.* 1998) and elsewhere (e.g. Knez & Slabe 2001a, 2001b,

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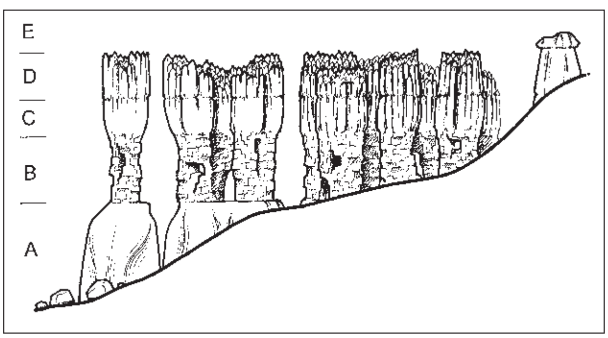
2002). In this article we are adding the results of our exploration of yet another stone forest, unique in its formation.

Figure 1: Lao Hei Gin stone forest.
Slika 1: Lao Hei Gin kamniti gozd.



The Lao Hei Gin stone forest (Figs. 1, 2, 3) lies 20 km north of Major Stone Forest. Individual stone pillars and larger rock blocks shaped by corrosion and erosion cover only about 2 km^2. Morphologically the stone pillars are similar to those in the Naigu stone forest.

Figure 2: Lao Hei Gin stone forest. Top view.
Slika 2: Lao Hei Gin kamniti gozd. Pogled z vrha.

Figure 3; Cross section of the Lao Hei Gin stone forest.
Slika 3: Prerez Lao Hei Gin kamnitega gozda.

LITHOLOGICAL CHARACTERISTICS OF THE STONE FOREST

The geological column is divided into 5 lithologically and morphologically diverse sequences: A, B, C, D and E (Figs. 3, 4, 5). Sequence A is built mostly of low-porous and grained late diagenetic dolomite, sequence B is of highly porous late diagenetic grained dolomite, sequence C is of slightly dolomitic limestone, sequence D is of low-porous grained late diagenetic dolomite and sequence E is of compact speckled dolomitic limestone. The total thickness of the researched geological profile (stone pillar) is 26 m.

SEQUENCE A

This sequence is 7 m thick. The lower part of the stone pillar is formed from highly re-crystalised dolosparite to dolomicrosparite of a grainstone type. The primary limestone had been highly diagenetically transformed – under a microscope we can observe subhedral to euhedral dolomite grains, which form a hipidiotopic to idiotopic structure. The dolomite grains are up to one-third of a millimetre in size. In diffused light they mostly have a slightly brown hue, whereas individual larger grains are exceptionally clean and almost totally translucent. Autogenous overgrowth is clearly visible in a small percentage of the dolomite crystals. The rock also contains a certain percentage of calcite. Secondary porosity is substantial.

SEQUENCE B

Sequence B is 8 m thick and does not mineralogically differ much from sequence A; on average, however, the rock does contain twice the amount of calcite as the rock from sequence A. The rock in this sequence is a grainstone-type dolosparite to dolomicrosparite. Grainstone-type dolomite (dolomicrosparite to dolosparite) consists of subhedral to euhedral dolomite grains that form a hipidiotopic to idiotopic structure. The essential difference of the rock from both sequences is that the rock in sequence B shows substantially more secondary porosity than the rock in sequence A. On average, the dolomite

Figure 4: Single mushroom-like stone pillars.
Slika 4: Posamezni kamniti stebri gobastih oblik.

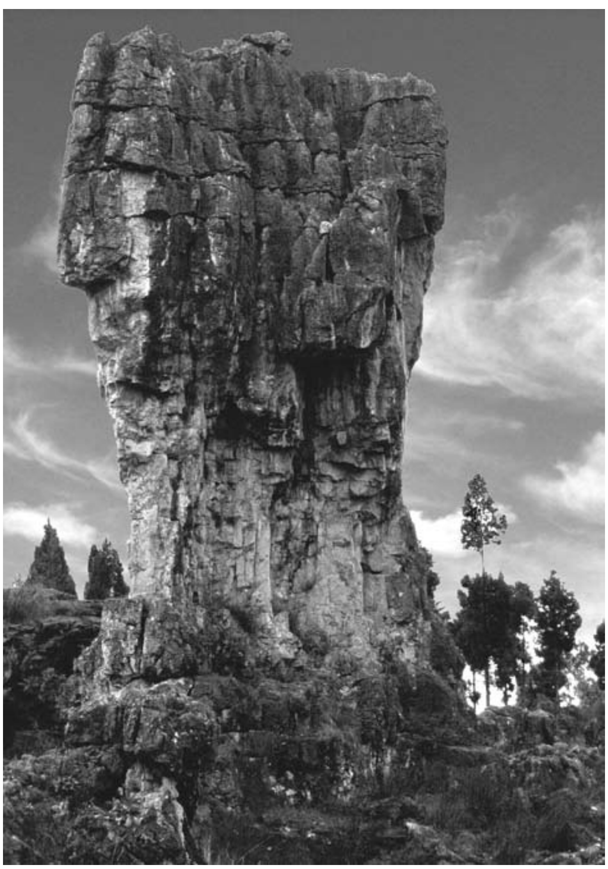


Figure 5: Stone pillar, which shape is dictated by rock.
Slika 5: Steber, katerega obliko narekuje kamnina.

crystals are smaller than the crystals in sequence A – in the upper part of the sequence even less than one tenth of a mm – and less pure.

SEQUENCE C

Sequence C is 4 m thick. Here the rock is mostly limestone with no more than 10% dolomite crystals. The boundary between sequences B and C is sharp and immediately

Figure 6: Subcutaneously shaped stone teeth.
Slika 6: Podtalno oblikovani kamniti zobje.

transforms into biopelintramicrite to biopelmicrosparite in the vertical direction. The fossil remains are generally less preserved; only occasionally did some foraminiferas and thick-shelled gastropods have better undergone the diagenetic processes. Secondary porosity is barely present.

SEQUENCE D

The thickness of sequence C is 5 m. The upper part of the pillars forms a highly re-crystalised and grained dolosparite to dolomicrosparite. The boundary between sequence C and sequence D is often blurred and difficult to determine visually and macroscopically. The primary limestone was highly diagenetically altered. Under a microscope we can observe subhedral to euhedral dolomite grains, which form a hipidiotopic to idiotopic structure of the rock. The dolomite grains in this sequence are also about one-third of a mm in size. In diffused light the dolomite grains mostly have a slightly brown hue.

SEQUENCE E

Sequence E is up to 2 m thick. Massive dolomitic limestone is characteristic for the upper part, which we found only on some pillars. On the outside it has a coarse and speckled appearance, characteristic of a large part of the Naigu stone forest (Knez & Slabe 2001a). Because of the bulginess on the rock surface, coarseness and subsequent algae overgrowth, the dolomite fields are dark grey. On the rock surface we can see them as dark grey to black spots, which gradate into lighter limestone fields in all directions. In most parts of the sequence, the percentages of the surface, as well as volume, of non-dolomitic limestone and dolomitic zones are equal.

SHAPE OF THE STONE FOREST

The larger groups of stone pillars consist of several tens of pillars (Figs. 1, 2, 3, 4). Between them are corroded fissures or narrow passages. The smaller groups of pillars, composed of ten or fewer pillars, are most often cut only by cracks and corroded fissures. Over a relatively large area of the stone forest we find only individual pillars and stone teeth. Individual pillars are relatively large, broad and high, or else they are low and wide.

The bedding is reflected in the form of pillars mainly because of the diverse composition of the rock. Below the soil, as well as on the surface, the B beds decay and decompose faster, and subsequently the individual thinner and tall pillars are unstable. The tall pillars are generally mushroom-shaped. The beds of sequences A, C and D are more resistant and extensive. In some areas the upper parts of the pillars have disappeared, and only low pillars formed in rock sequence A are preserved. Subcutaneous tubes transformed by rainfall dripping down the pillars frequently hollow the porous rock of the beds B. The rare pillar tops that form in such rock are often diversely shaped.

THE ROCK RELIEF OF THE STONE FOREST

We find three distinct types of rock forms on the pillars: subcutaneous forms, forms created by rainfall and combined rock forms. The creation of these rock forms and their uniqueness is defined mainly by the rock itself, especially where it is exposed. The subcutaneous forms are less explicitly defined by the rock.

SUBCUTANEOUS ROCK FORMS

These forms are divided into those that were formed below the deposits and the soil as the result of water flowing at the contact of the rock and the soil, and forms created by water percolation through the soil that only partially covers the rock, and the rock forms that formed at the level of the soil or deposits that surround the rock (Slabe 1999).

The first group of subcutaneous rock forms are subcutaneous channels of various sizes that were formed by continuous water-flow at the contact of the rock and the deposits that covered the rock and filled the fissures in the vertical cracks. The diameter of the larger channels can reach up to several metres (Fig. 6). They dissect all different rock sequences. At the tops of the higher pillars they were transformed by rainfall, while the B beds decompose too quickly for the channels to remain preserved on them for a longer period. They are therefore mainly a characteristic of the lower parts of the pillars and stone teeth. Subcutaneous scallops that form on the relatively permeable contact area of the rock and the deposits are preserved mostly in beds A, C and D or on the B beds that had been exposed for only a shorter period. Also the walls of the largest subcutaneous channels could be dissected by them.

The more extensive pillar tops and teeth are segmented by mid-sized and smaller subcutaneous channels and subcutaneous cups (Slabe 1999, 259) that were formed under the soil that partially covered the rock, therefore as the result of water percolation through the soil and its flow along the area where it touches the rock.

They have characteristic semi-circular cross sections or cross sections in the shape of the upturned letter omega. They are wider at the lower part of cross-section, their diameters can reach up to 1 m. They are usually linked into a branched network. The subcutaneous cups (Slabe 1999, 263) are of various sizes and diameters, from a few centimetres to a metre or more. They occur on the tops of large pillars and on the bottoms of funnelled notches in the walls below them. The most porous strata are fairly densely perforated by subcutaneous tubes of diameters ranging between a few centimetres and a metre or two.

The pillars in the B beds are generally distinctly undercut below the ground, which is visible from the overhanging lower parts of the pillars that have developed on these rock strata.

COMBINED ROCK FORMS

These are the larger channels in the upper parts of the pillar walls. They develop as the result of water flowing from subcutaneous channels, which appear on the larger pillar tops, or by water dripping from the funnelled notches. Subcutaneous cups occur at the bottom of the latter or else were once present there. They thus have larger or smaller funnel-shaped outlets at the edges of the tops, which have in most cases been transformed by rainfall. They are especially noticeable in the beds of the A, C and D groups, or, if the top is in the D beds they reach to the B beds. Their distribution and shapes, relatively narrow and deep, are defined by how crushed the rock is, how serrated the rims of the rock are, and also by the composition of the rock.

Rainfall transforms, mainly deepens, the former subcutaneous channels and cups that criss-cross the wider tops. Such rock formations therefore exhibit traces of subcutaneous dissolution of the rock and of the rainwater, which can gradually, with the denudation of the rock, completely take over. Below the soil the channels and cups are relatively evenly shaped with smooth walls, but as they become exposed their shapes become distinctively uneven with many branches and segmented rims.

Half-bells are formed on the more durable levels of soil and deposits that surround the pillars (Slabe 1999).

ROCK FORMATIONS CARVED BY RAINFALL

These types of rock formations, especially the smallest flutes and cups, do not occur on this type of rock. The exceptions are the more limited highest zones of the stone forest, where the tooth tops are created in the dolomitic limestone of the E beds. Segmentation of most of the tops is therefore defined by the composition and diversification of the rock (Fig. 7). Rock exposed to rainfall is coarse and contains only rock formations that do not exceed the size of the individual segmentation of the coarse surface. The solution pans with distinctly segmented and coarse surfaces are developing from subcutaneous cups; only the bottoms of solution pans that are covered by thin layer deposits and are overgrown remain even and relatively smooth.

Figure 7: The top of stone pillar carved by rainfall.
Slika 7: Vrh kamnitega stebra oblikovan z deževnico.

On the steep walls the segments resemble channels, usually very narrow but relatively deep and angulated, with diameters that measure 1–10 cm and are 2–3 m long.

At the highest section of the stone forest we find dolomitic limestone on the pillar tops, with flutes carved in them (Fig. 8). Smaller channels of a diameter of 1–2 cm appear on the limestone where there are fields of dolomite in the limestone, which generally protrude a centimetre or two from the wall and do not exhibit other rock formations.

Figure 8: Dolomitic-limestone stone teeth.
Slika 8: Dolomitno apnenčasti kamniti zobje.

CONCLUSION

The stone pillars in the forest are either solitary or in groups within which there are only cracks and fissures. They were formed at various levels on nearly horizontal rock beds and in corresponding shapes. The exposed lower part of the geological profile or stone pillar is composed of fully dolomitised limestone, the middle part (sequence B) is composed of porous dolomite and the upper parts of the stone pillars are composed of more durable limestone and dolomitic limestone, resistant to erosion. Sequence B rock beds decay and decompose faster, below, as well as above the ground, and since they are generally covered by more durable strata, the pillars form characteristic mushroom-like shapes. The pillars are wider below the narrower parts if the lower dolomite strata are exposed.

The rock relief consists of various groups of rock forms: subcutaneous, those carved by rainfall and combined forms – their characteristics are defined by the composition of the various rock beds. The tops are sharp and well segmented around the cracks. Such are all the forms carved by rainfall – these are channeled rock forms and solution pans. Their surface is notably coarse. On limestone beds that occur only in some of the highest lying parts of the stone forest, the flutes and small channels are evenly shaped. On porous and faster-disintegrating beds, there are no distinct rock formations carved by rainfall, except at the beginning on exposed rock covered by more rounded parts of the subcutaneous rock relief. These are distinctly formed on all different types of rock beds. Only their surface is mildly coarse.

In our research we have observed (Knez 1998; Slabe 1998; Knez & Slabe 2001a, 2001b) that the lithological composition and tectonic properties of the rock play a decisive role that corresponds to the morphological picture of the stone pillars and that are essentially important in selective corrosion and erosion.

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POVZETEK

Lao Hei Gin kamniti gozd (Sl. 1, 2, 3, 4) je nastal iz podtalnih kraških škrapelj. Karbonatne kamnine so bile namreč pokrite z debelimi plastmi naplavin in s prstjo. Kamniti stebri in kamniti zobje so se razvili v raznovrstnih, skoraj vodoravnih ali položnih skladih kamnine, ki so jo razkosali navpični prelomi in razpoke. Gozd sestavljajo stebri, ki so gručasto strnjeni ali pa posamezni in dosežejo do 20 m višine, večina je nižjih, visokih do 10 m. Prevladujoča in najbolj značilna oblika stebrov je gobasta. 20 do 30 m globoko pod gozdom so jame, skozi katere se pretakajo vodni tokovi. Lao Hei Gin kamniti gozd leži okrog 20 km severno od Shilina. Posamezni kamniti stebri in večji korozijsko in erozijsko preoblikovani bloki kamnine zavzemajo le okrog 2 km^2. Morfološko so kamniti stebri podobni tistim iz Naigu kamnitega gozda.

Glede na litološke in morfološke značilnosti smo geološki stolpec razdelili v 5 sekvenc: A, B, C, D in E (Sl. 3, 5). Sekvenca A je zgrajena večinoma iz slabo poroznega zrnatega poznodiagenetskega dolomita, sekvenca B iz zelo poroznega poznodiagenetskega zrnatega dolomita, sekvenca C iz rahlo dolomitnega apnenca, sekvenca D iz slabo poroznega zrnatega poznodiagenetskega dolomita, sekvenca E iz kompaktnega marogasto dolomitiziranega apnenca. Skupna debelina raziskanega geološkega profila (kamnitega stebra) je 26 m.

Večje gruče kamnitih stebrov so sestavljene iz več deset stebrov. Med njimi so špranje ali pa ožji prehodi. Manjše gruče stebrov, ki jih sestavlja deset in manj stebrov, pa sekajo največkrat le razpoke in špranje. Na razmeroma veliki površini kamnitega gozda so le posamezni stebri in skalni zobje. Posamezni stebri so razmeroma veliki, široki in visoki ali pa so nizki (1-2 m) in široki.

Skladovitost kamnine se v obliki stebrov odslikava predvsem zaradi različne sestave kamnine v posameznih plasteh. Skladi B tako pod tlemi kot na površju preperevajo in razpadajo hitreje in posamezni tanjši ter visoki stebri so zato neobstojni. Visoki stebri pa so praviloma izrazite gobaste oblike. Skladi A, C in D so namreč obstojnejši in obsežnejši. Ponekod zgornjih delov stebrov ni več, ohranjeni so le nizki stebri, ki so oblikovani v kamnini A. Porozna kamnina skladov B je pogosto prevotljena s podtalnimi cevmi, ki jih preoblikuje deževnica, polzeča po stebrih navzdol. Redki vrhovi stebrov, ki se oblikujejo na takšni kamnini, so največkrat neenotnih oblik.

Skalni relief sestavljajo vse značilne skupine skalnih oblik, podtalne (Sl. 6), tiste, ki jih dolbe deževnica in sestavljene skalne oblike, jim pa značilnosti v precejšni meri določa sestava različnih skladov kamnine. Vrhovi so ostrih in ob razpokah drobno razčlenjenih oblik, takšne so vse skalne oblike, ki jih dolbe deževnica, to so žlebovom podobne skalne oblike in škavnice, njihova površina pa je izrazito hrapava (Sl. 7). Na apnenčastih skladih, ki se pojavijo le na posameznih najvišjih delih kamnitega gozda, so žlebiči in žlebovi pravilnih oblik. Na poroznih in hitreje razpadajočih skladih ni značilnih skalnih oblik, ki jih dolbe deževnica, le sprva, po razgaljenju kamnine, jih prekrivajo zaobljene oblike podtalnega skalnega reliefa. Te se namreč izrazito oblikujejo na vseh različnih skladih kamnine. Le njihova površina je drobno hrapava.

Pri naših raziskavah vse bolj ugotavljamo (Knez 1988; Slabe 1988; Knez & Slabe 2001a, 2001b), da se tudi najmanjše litološke razlike v kamnini zelo jasno odražajo v morfogenetskem razvoju kamnitih gozdov.