

EVOLUTION OF KARST GEOMORPHOLOGY AND HYDROGEOLOGY IN SOUTH DUSHAN, GUIZHOU PROVINCE, CHINA

by

SONG LINHUA ¹

(3 figures)

RESUME. - Evolution de la morphologie et de l'hydrogéologie karstiques du Dushan méridional, province de Guizhou, Chine.

Mise au point des relations entre la morphologie et les caractéristiques hydrogéologiques. La morphologie connaît quatre stades d'évolution : celui des dépressions en entonnoir, celui des dépressions Fencong, celui des bassins Fenglin, et un stade consécutif au soulèvement tectonique régional et au rajeunissement consécutif du relief. L'hydrogéologie de la région est caractérisée par la coexistence d'aquifères de fissures et d'écoulements en conduits et par un profil nettement convexe du drainage souterrain. Une formule de calcul des réserves souterraines est proposée et l'exploitation des ressources en eau est brièvement discutée.

ABSTRACT. - The paper deals with the relationships between karst morphology and the characteristics of karst hydrogeology in the studied area. Four stages are described in the evolution of the relief. The main properties of karst hydrogeology are the simultaneous occurrences of a homogeneous fissure aquifer and conduit flow and the upper convex profile of the underground drainage. A formula is proposed to estimate the water storage and the management of water resources is briefly discussed.

INTRODUCTION

The main patterns of the underground drainage in karstic limestone terrains are the diffuse flow and the conduit flow (Ede, 1975; Atkinson, 1977). In the limestone regions of South China, because of high temperature and abundant rainfall, the landscapes of Fenglin and Fencong are well developed. The subsurface drainage systems consist of many types of flow : fissure flow, vein flow, conduit flow and cavern flow. In South China, the underground river is a special kind of cavern flow. Its hydraulic properties, shape of water channel and erosion and deposition features are very similar to those of surface rivers (Song, 1981). According to Guan Yuhya (1981), the siphon flow is sometimes circulating very deep beneath the conduit flow. The underground drainage patterns in a limestone terrain constitute the underground drainage system. Yuan Daoxie (1978) divided the limestone aquifers into four types : individual cave with water, very non-homogeneous, non-homogeneous and relatively homogeneous.

This paper will stress the relationships between the evolution of karst geomorphology and the characteristics of karst hydrogeology in South Dushan, Guizhou Province.

PHYSICAL GEOGRAPHY

The studied area lies in the link part of Dushan County, Guizhou and Nandan County, Guangxi, i.e. E107°20'-107°45' long and N25°13'-25°35' lat. (fig. 1). It is also the transition zone from Guizhou plateau to Guangxi basin. Topographically, it is higher in the northwest (1100 m a.s.l.) and lower in the south-east (400 m a.s.l.). Here is the watershed between the Hongshui He and Longjiang, tributaries of Pearl River.

It is in the subtropical climate zone with the annual average temperature 15°C and precipitation of 1313 mm (maximum : 1670 mm; minimum : 1090 mm). The rainfall in the wet season (April to October) takes account for 84 % of the year's total.

Neritic and littoral sediments deposited during the Carboniferous and Permian Periods are 2500 m thick, in which the pure limestone and dolomite make 84 % of the total thickness. Due to its location at the complex zone of Neocathaysian System, there are south-north tectonic elements, east-west elements and the west limb of Guangxi ϵ structure, and the tectonic fractures are very well developed.

¹ Institute of Geography, Academia Sinica, Beijing, China.

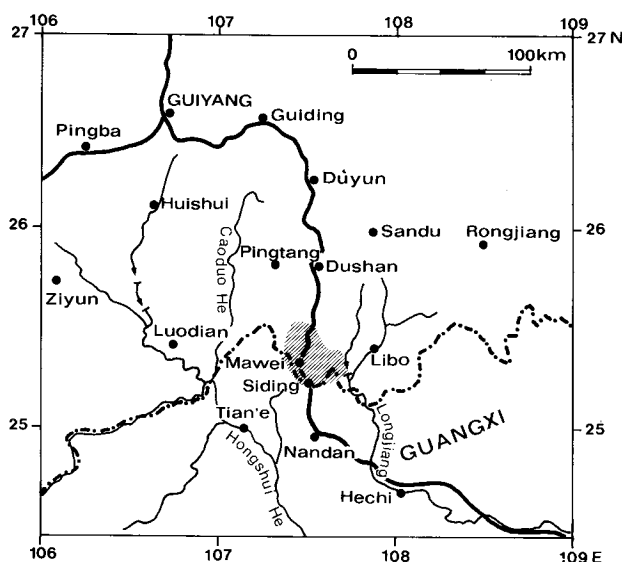


Figure 1. - Location map of the studied area.

Under the Tertiary tropical climatic conditions, the Fenglin geomorphology that developed has since Quaternary been uplifted at least altogether 500 m. The karst geomorphologic series in the area are the Fenglin-valley (not in all places), Fenglin-basin, Fengcong-depression, and Fengcong-canyon.

EVOLUTION OF KARST GEOMORPHOLOGY

The organic combination of conic Fenglin and Fengcong with basins, valleys, depressions, sinkholes and funnels has formed the special and magnificent karst geomorphologic landscape in the South Dushan County, Guizhou province. For example, the Xiasi-Mawei region, the upper reaches of the Huanghou underground drainage system, is typical Fenglin-basin landscape. In the basin, there are a lot of surface sections, of underground streams and deep karst ponds or lakes. In the middle reaches, the landscape of karst Fenglin basin gradually changes to Fengcong-depression. There are many deep sinkholes, shafts nearly several tens, or more than 100 m deep, and funnels in the basin with the dry flood-valley generally without water at all except during storm period. The Fengcong-depression about 50-100 m deep appears near Monguo. In the lower reaches, the Fengcong depression and trough, or canyon landscape, dominates, and the resurgence of the underground drainage system is hanging on the slope of the canyon about 100 m above the local erosion base.

The characteristics of karst geomorphology have strongly forced us to rebuild the evolution history of karst geomorphology in the view of karst hydrology.

Dr. Sweeting (1978) recognized three main stages in South China karst lands: (1) Feng Tsung (Fengcong) stage; (2) Fenglin stage; and (3) Tu Feng stage. She is probably right for the Guilin area and most stages are

conformable with the evolution of karst land in south Dushan, but since Quaternary, Guilin is still under the control of tropical climatic conditions. The annual temperature averages 19°C and precipitations 2000 mm, and the earth crust is nearly stable. So karst land might evolve consequently in that way.

The environment of karst development in South Dushan was rather different from that of Guilin. In the studied area, the four stages may be recognized as follows:

1. Funnel or depression stage (fig. 3a)

The original surface was quite flat and fractured by the tectonic movements. The rainfall on the surface dissolves limestone along the fissures especially at the intersections. The mechanism of funnel development has been described by Williams (1983) in the view of hydrology. The funnel stage includes the young karst and "adolescent" karst explained by Grund (1914).

2. Fengcong stage (Fig. 3b)

The funnel with the highest capacity of draining water enlarges and deepens at a fast speed and at the same time gradually captures other funnel drainage systems. The limestone block among the big funnels is very slowly eroded, so it keeps relatively high elevation. A lot of hills stand on the same base, and the distance between the peak and depression is about one third of the total hill height. All the water belonging to the drainage system is discharged underground through the depression bottom.

3. Fenglin stage (Fig. 3c)

With the developing of Fengcong, the bottom of the depression goes down to almost the groundwater table. After storms, the depressions are flooded, or exotic waters flow into them, strongly and laterally eroding the hill foot and sometimes forming foot caves. As a result, the hill slopes will draw back and the depression will expand. Finally, the base separates from the hills and takes the isolated feature known as "Fenglin". Depressions linked together play an important part in forming the flat big basins and valleys. Respiration of vegetation and decay of organic material increase the CO₂ content in both soil atmosphere and groundwater which strongly corrodes the limestone, enlarges the openings and forms the fissure waternet.

4. Karst spring-returned stage (Fig. 3d)

After the Fenglin stage, there is an important uplifting of the earth's crust and the drainage base goes down because of the neotectonic movements, that promote vertical circulation of groundwater. Where the fissures are well developed in the basin, the new funnels and closed depressions are also growing. For example, there are about 20 funnels and sinkholes of different dimensions in the Huanghou area. Near

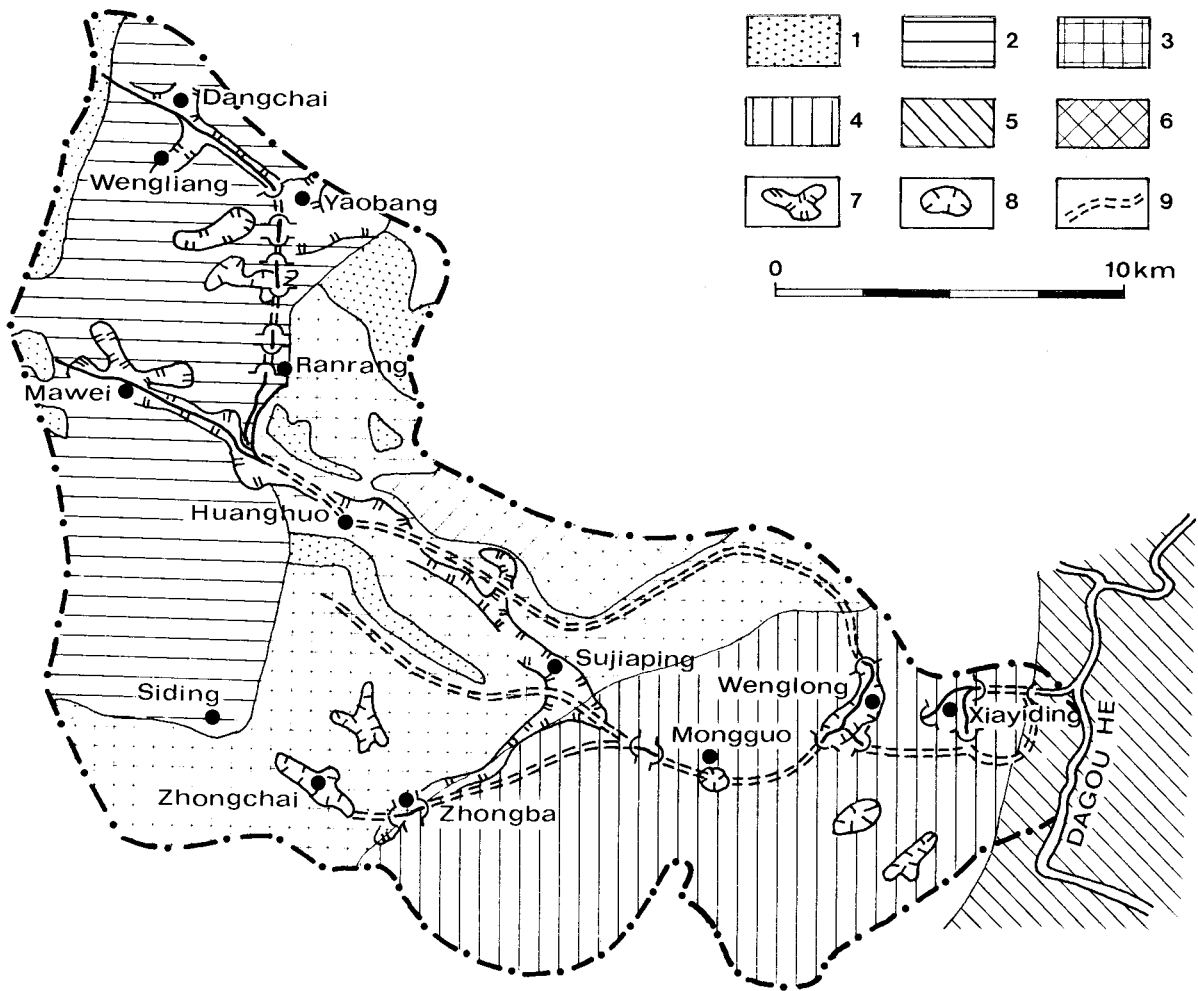


Figure 2. - Karst Geomorphology in Huanghuo Subsurface Drainage System Area.

1. Non-carbonate rocks; 2. Fenglin-basin; 3. Fenglin-basin and Fengcong-depression; 4. Fengcong-depression; 5. Fengcong-valley or canyon; 6. Erosion geomorphology; 7. Karst through; 8. Large depression; 9. Subsurface conduit and cavern flow.

Mongguo village, a closed depression about 100 m deep has developed since Quaternary. The landscape is very similar to that of the Fengcong-depression. But traces of Fenglin-basin have remained in some places.

The phenomenon of spring returned stage appears only in the middle and lower reaches of big drainage systems. The karstification remains the same, since it is not influenced.

KARST HYDROGEOLOGY

The characteristic of hydrogeology in limestone areas is that it is not only controlled by lithology, structure and fractures, but also by the evolution of karst geomorphology. The main properties of karst hydrogeology in the studied area are as follows :

1. Homogeneous fissured aquifer and conduit flow

Although the earth's crust is gradually uplifting, the head erosion of underground drainage system has not got to the place of the Fenglin-basin. The homogeneous and crossed solutional fissured aquifer formed by the evolution of karst geomorphology in the limestone terrains has developed. The movement and storage of groundwater with a uniform table in it is just like the fissure-net aquifer in other hard rocks. But in the areas not affected by the head erosion caused by the spring-return, the transmission and storage of groundwater are characterized by the concentrated flow. Such groundwater has the property of hydrodynamics as described by Chen Yushen (1965).

In the relatively homogeneous aquifer area, the uniform network flow and non-uniform conduit flow have developed together. In (big and flat) basins like

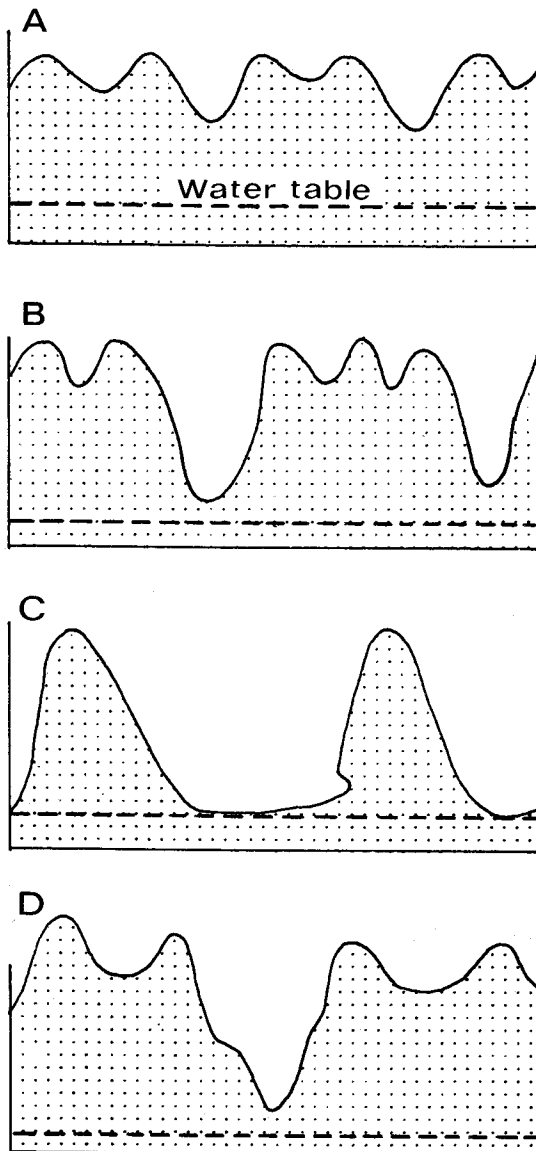


Figure 3

Stages of Karst Geomorphology in South Dushan, Guizhou.

A. Funnel and depression stage; B. Fengcong-depression stage; C. Fenglin-basin stage; D. Spring-returned (Fengcong-depression or canyon) stage.

Zhongzhai basin, the homogeneous limestone aquifer often exists. Therefore, it is very easy to dig wells anywhere in the basin. The groundwater with low hydraulic gradient flows out and floods the basin near Mawei after storms. However, the situation in the limestone block between two basins is quite different. Here, the conduit or cavern flow dominates. For example, the groundwater in the Zhongzai and Xiazhai basin flows into the conduit through the sink at the end of Xiazhai basin and comes out through the Dingquodong (cave), a cave more than 20 m wide and 10 m high on the boundary of Zhongba basin. Such features of karst hydrogeology will surely make a failure building up any surface reservoirs in the basins. The best example is Ranrong reservoirs; three dams have been constructed since 1958, and serious leakage made them lose their

effectiveness. But if simple dams were built on the conduit or cavern flow exactly on the top of the knick points, underground reservoirs would be formed. Such a method always succeeded. In south Dushan, 28 subsurface reservoirs have been successfully constructed. It is a good way to build the pumping station to utilize the karst groundwater, lake or pond water in the basin on the upper reaches of subsurface drainage systems.

2. The upper convex profile of the drainage systems

Since the Quaternary, the strong uplifting of Guizhou plateau and descending of the drainage base fosters the vertical karstification. The rate of such karstification decreases from the drainage base to the watershed, and forms the convex hydraulic profile of subsurface drainage system. The intermittence of earth crust uplifting makes the vertical karstification develop in stages starting in the direction from the drainage base and upwards. The beginning of vertical karstification upstreams constitutes the turn point-knick point of hydraulic gradient. Apart from the lithology and structure factors, the number of knick points of subsurface drainage indicates the number of the crust raising. There are three main points in Huanghou system.

3. Strong binding of surface water with groundwater

In the study area, karstification has undergone four evolution stages. The rainfall on limestone surface is almost totally absorbed into groundwater. In the Fenglin-basin area (above the first knick point) the groundwater table remains near the surface, (generally below 3–20 m), feeding a lot of karst lakes and ponds. Ceiling collapses expose former conduit flows to the air at some places. The ratio between surface flows and underground flows may reach up to 3.2. The water table varies annually within the range of only three to six meters.

In the middle reaches (between the second and third knick points) of subterrain drainage system, due to the effect of vertical karstification caused by the spring-return, conduit or cavern flow dominates. The water table is about 60–100 m below the surface and fluctuates very much. Many new sinkholes, shafts and funnels develop in the basins and depressions. During the rainy seasons, rain water quickly percolates through the vertical karst features. But in some places these are full of water after heavy rain because the discharge capacity of conduits and caves is limited. Groundwater thus overflows through the shafts and windows and floods the basin. It occurs every year in the zone from Pig cave to Sugaping basin. In the lower reaches, the groundwater rushes down in the high hydraulic gradient on the slope of canyon into the river at the local drainage base.

4. Assessment and exploration of karst water resources

The characteristics of karst hydrogeology are

very different from those of other kind of aquifers. Therefore we have to use special techniques to value the water resources. The methods of making use of an homogeneous aquifer may be employed to estimate the water resource in the karst basins where there is no influence of the spring-return.

$$V = F \times H \times U$$

where V - the static storage of groundwater;
F - the area of carbonate rocks;
H - the thickness of aquifer;
U - the storage coefficient.

By this method, 821 million m³ of water storage has been estimated.

The dynamic storage of groundwater in the basin can be valued with the discharges of conduit flows just at the lower reaches of the basin.

In the conduit flow area, the dynamic storage may be assessed roughly by the sum of springs and the underground runoff coefficient, it is :

$$Q = Q_{s1} + Q_{s2} + \dots$$

$$\text{and } Q = M F$$

where Q is the dynamic storage, 1/s; Q_{s1}, Q_{s2}, ... are the discharges of spring 1, 2, ...; M is the underground runoff coefficient, 1/s.km²; F is area of underground drainage system, km².

According to the calculation with the coefficient method, the dynamic storage of Huanghou system is 1550 l/s and controlling area 460 km², the coefficient is 3.36 l/s.km².

The method of developing groundwater resources is very different according to the different hydrogeologic units. In the area of relatively homogeneous limestone aquifer, one may directly pump the water from karst lakes, ponds and wells. On the conduit or cavern flows between the karst basins, dams can be constructed to form the reservoir or build the ground hydraulic power station like the Wangou station. In the conduit or cavern flow area, it is very difficult to pump water and build any dams, for the water table is too low and hydraulic gradient too steep. For the purpose of water supply, the better way is to explore and develop the perched water or make artificial ponds. But attention must be paid to develop the hydrodynamic energy for the gradient is high. Now a hydraulic power station has

been set up on the resurgence of Huanghou drainage system.

CONCLUSION

The karst geomorphology in South Dushan has experienced 4 stages of evolution. Since the end of the Tertiary, the Guizhou plateau was strongly and intermittently uplifted. In the upper reaches of underground drainage system not affected by the karst spring-return, the geomorphology is still at the Fenglin-basin stage. In the lower reaches vigorously influenced by the spring-return, it is undergoing the Fengcong-depression or canyon stage. In the middle reaches, the spring-return makes a number of funnels, sinkholes and shafts emerge, but the Fenglin-basin landscape has not been seriously damaged. Thus, the Fenglin-basin and Fengcong-depression (fourth stage) appear together.

In Fenglin-basin area, the relatively homogeneous fissured aquifer in the basin is well developed. Between the basins, the conduit or cavern flows are distributed. In other areas, the conduit or cavern flow, sometimes underground rivers, dominate. The water resources should be explored and used so as to make benefit to the people.

BIBLIOGRAPHY

- ATKINSON, T.C., 1977. Diffuse flow and conduit flow in limestone terrain in the Mendip Hills, Somerset (Great Britain). *J. Hydrol.*, 35 : 93-110.
- CHEN YUSENG, 1965. On the movement of karst water. Paper Selection, The First National Symposium of Hydrogeology and Engineering Geology (Special for Karst).
- EDE, D.P., 1975. Limestone drainage systems. *J. Hydrol.*, 27 : 297-318.
- GRUND, A., 1914. Der geographisch Zyklus im Karst. *Zeitschr. Ges. Erdkunde*, 52 : 621-640.
- GUAN YUHUA, 1981. Preliminary study on the karst siphon flow. In : Paper Selection, the Second National Karst Symposium, Geology Society in China.
- SONG LINHUA, 1981. Progress of karst hydrology in China. *Progress in Physical Geography*, 5 : 563-574.
- SWEETING, M.M., 1978. The Karst of Kweilin, Southern China. *Geogr. Jour.* 144 : 199-204.
- WILLIAMS, P., 1983. Karst Geomorphology. A Talk in Guilin Karst Research Institute.
- YUAN DAOXIE, 1978. On non-homogeneous characteristics of karst water. *Selections of Karst Geology 2*, Guangxi Hydrogeological and Engineering Geological Team.