THE KARST IN QINLING MOUNTAIN AREA, SHAANXI

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This excursion will take two days: the first day is for the trip from Xi'an to Zhashui; and the second day for visiting the peak-cluster depression and the outlet of Yudong Underground Stream below it in Heigou, Zhengan County.

Qinling mountain ridge stretching across the middle part of China is the geographical boundary between the south and the north. About 30 km north away from it is an outstanding tourism city in the world. It is Xi'an, the capital of Shanxi Province (Fig.1). Here there are many sites, such as the world well-known archaeo-logical site--Terracotta Army of Qin Dynasty (221-- 207 B.C). Every year thousands of people from home and abroad come here for sight-seeing. But karstworkers pay more attention to the Zhashui karst cave systems, the Heigou peak-cluster depression with the Yudong underground stream system underlying it, which are located in the southern part of Qinling area and found in recent years.

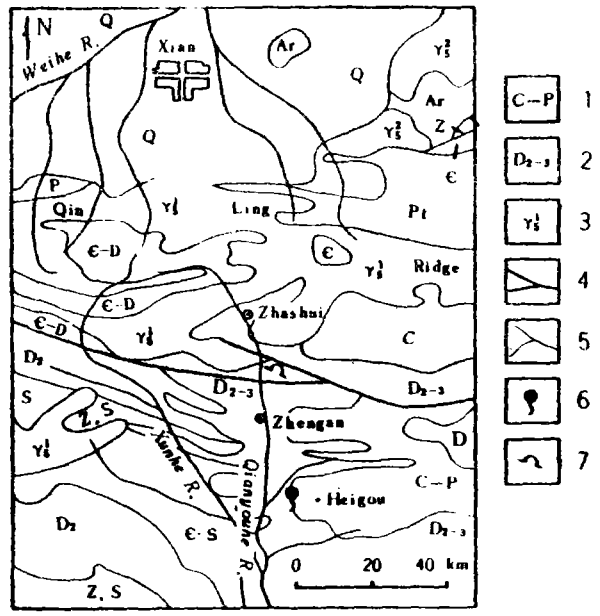

Fig.1 Geological Map of Mt. Qinling Ridge and its Vicinities
1.Carboniferous-Permian limestone 2.Devonian (through Ordovician) limestone 3.Gneissic granite 4.Fault 5.River 6.Outlet of Yuding Underground Stream 7.Zhashui Cave System
S, Є - D, Z, Pt, Ar refer to Silurian Cambrian - Devonian, Sinian, Proterozoic, Archaean strata respectively

Tectonically, the basement of Qinling Mountain Ridge was a Palaeozoic fold belt which was denudated afterward. During the Himalayan Orogeny it was uplifted into a mountain ridge with the elevation of 2000 to 3000 metres. Its

north slope is steep while south slope is very gentle and broad. Carbonate rocks are predominantly Late Palaeozoic, characterized by regional metamorphism in various degrees, which are distributed mainly in Mid-Qinling area and frequently intercalated or alternate with non-soluble rocks. The thickness of carbonate rock could be thousands of metres, but are subjected to changes both in thickness and facies. The annual precipitation in southern part of Qinling Mountain Ridge is generally 800 to 900 mm and sometimes up to more than 1000mm, while only about 600 mm in the north because Qinling Mountain holds back either southeast humid air current going northward or north cold current going southward. Accordingly, for those karst areas in south Qinling, there are not only plentiful of rainfall, but also abundant allogenic water deriving from non-soluble rock areas, along with warm climate with annual mean temperature of 18.4℃. Thus karst areas in south Qinling Mt. have peak-cluster depressions and relevent karst features, such as big caves with huge speleothem, underground stream, terra rossa, karren, and etc. The northmost peak cluster-depression in China, perhaps in the world so far known are distributed in this area at about 33° 20′--33° 40′ N. For the area is in the transitional zone with sharp contrast of climate between North China and South China, the karst developed in it is also important to us to understand the formation of karst in the transitional climatic zone. According to our investigation in situ, besides above-mentioned karst feature complex under humid climate, there are also other karst features, such as dry valley, normal shape mountain, and etc., which reflected the characteristics of karst under arid or semi-arid climate of North China.

First day: Xi'an-->Shangjiwo-->Qinling Watershed-->Niubeiliang Nature Preserve-->Yingpan-->Zhashui (Fig.2)

(1) Shangjiwo: Located in northern slope of Qinling Mt., with Gneissic granite. Spherical weathering feature on the rock is very clear. Fissure groundwater is flowing in gneissic granite gorge. For the water is from the granite, the carbonate hardness and total dissolved solid in water are all very low. There are many collapsed stone blocks in the gorge. These reflect that the physical weathering of rock in the area is very strong.

(2) Qinling Watershed: Located in Qinling Mt. Ridge, 2020 m asl in altitude. It is not only the hydrological divide but also the boundary of climate, geology and karst in Central China.

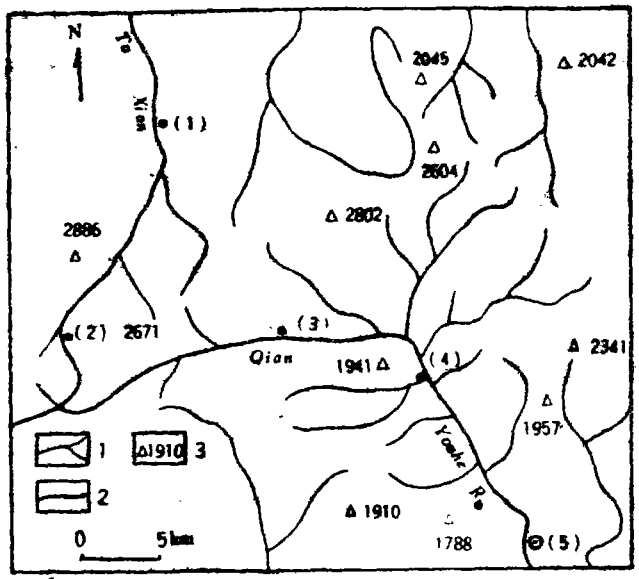

Fig.2 The Sketch of First Day Excursion in Mt. Qinling Area

(1)--Shangjiwo (2)--Qinling Watershed (3)--Niubeiliang Nature Preserve (4)-Ying-pan (5)--Zhashui

1--Stream 2--Highway 3--Altitude (m)

(3) Niubeiling Nature Preserve: It is a national nature preserve, and located in the southern slope of Qinling Mt. Ridge, about 1900 m asl in elevation. Here is a dense forest frequented by panda.

(4) Yingpan: 1540 m asl, it is the source of Qianyouhe River, which will be seen later. This is an area of non-carbonate rock, so the water in the gullies is strongly aggressive to the carbonate rocks of the lower reach. For example, according to in-situ measurement in September of the year 1990, the pH-value of water in the source area is 7.05 and the carbonate hardness only 1.8 in German degree, so the saturation index of calcite calculated from these data is as low as -1.69.

(5) Zhashui karst Cave systems: Located 18 km to the south of Zhashui County (Fig.1), Shaanxi Province, and 164 km away from Xi'an City. Geomorphologically, these cave systems are in the medium-high mountain area. Qianyouhe River, with mean discharge of 2.7 m^3/s, stretchs across the area, and flows southward.

The area is transitional between cool sub-tropical zone and warm temperate

zone, with annual mean air temperature 18.4℃ and annual mean precipitation 692 mm. Here, the weather is pleasant with no severe winter and no swelter summer. Although no big forest but there are weeds and bushes in the area.

The karst caves in the area is mainly developed in Middle-lower Ordovician limestone. The folds, faults and strata are all basically E-W oriented, as controlled by Qinling latitudinal tectonic system. But it is influenced by the late NE and NW tectonics. The three major tectonic directions with their relevant structural features have clear influence on the development of karst.

On the vertical profile,the caves are characterized by multi-layer. They concentrate mainly on the altitude of 800 m, 920 m and 1200 m asl, which reflect that the area has gone through three stages of neotectonic movement--intermittent uplifting and relative stable stages between them. Tiandong Cave and Foyedong Cave which we will visit are the examples of the first layer.

Tiandong Cave (Fig.3): 798 m asl, it is 130 m long, 1~8 m wide and 2~10 m high. It is developed in Middle-lower Ordovician limestone, with double-layer structure: there are a lot of stalagmites in the upper-layer ; and well-developed rimstones in the lower-layer. According to the measurement in situ,

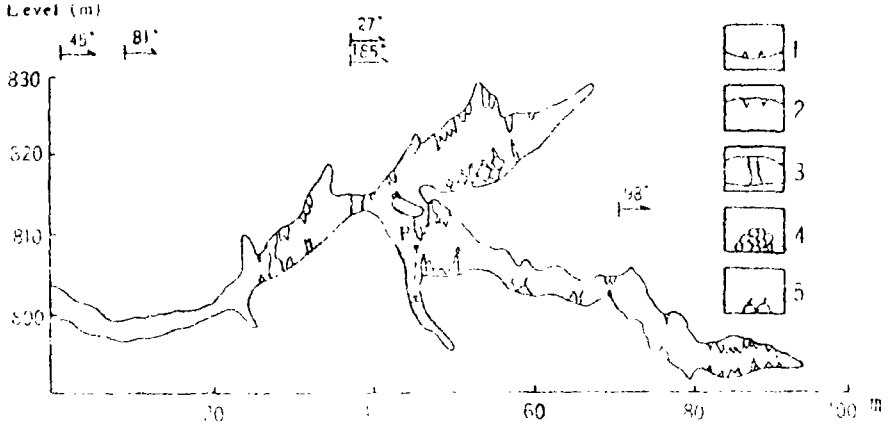

Fig.3 The Profile of Tiandong Cave
1.stalagmite 2.stalactite 3.column
4.collapsed stone blocks 5.rimstone

pH-value of dripping water from the top of cave (point P in Fig.3) is 6.52, the carbonate hardness of the water is 16.8 German degree, and the saturation index of calcite calculated based on these data is -0.45, so it is aggressive to calcite. This can be proved by the dissolution features on the stalactite where the water is dripping. However, the karst forms such as stalactite, stalagmite, column, soda straw, cave flower, rimstone, and etc. are still well developed. This shows that the aggressivity or saturation is variable, which possibly reflected the change of climate induced by natural or artificial factor.

Foyedong Cave (Fig.4): 840 m asl, it is around the same layeras Tiandong Cave. 240 m long, 30-40 m wide and 4-35 m high. The speleothem in the cave is predominately dripstone and flowstone. Moreover, there are also many collapsed stone blocks. Some of the flowstones have evidently experienced corrosion of later stage. According to data obtained so far, the stalactite in the cave was possibly formed in the humid climate of interglacial stage in the late of Middle Quaternary.

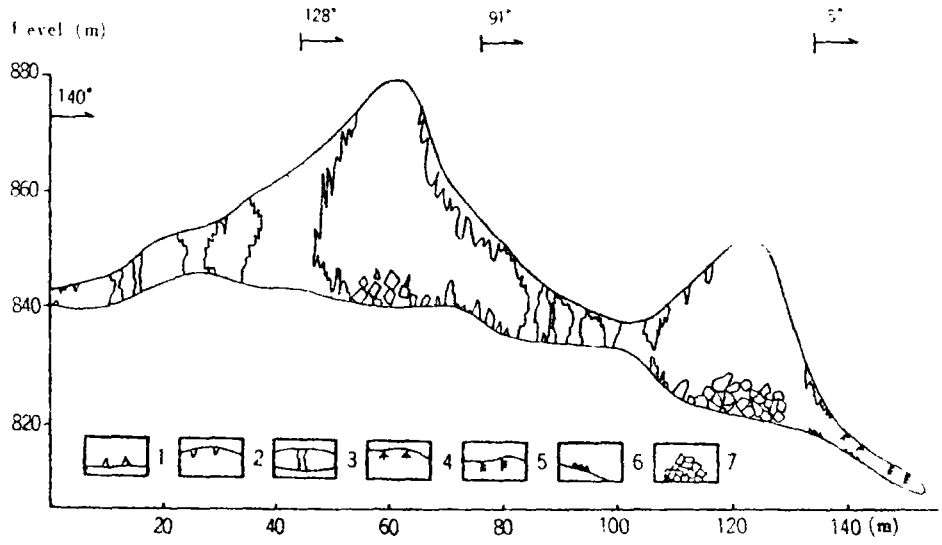

Fig.4 The profile of Foyedong Cave
1.stalagmite 2.stalactite 3.column 4. helictite
5.soda straw 6. rimstone 7.collapsed stone blocks

Tower karst: Looking westward at the distance from the entrance of Tiandong

Cave or Foyedong Cave, you can see the beautiful scenery of tower karst. Along with Qianyouhe River nearby, it constructs as beautiful hills and waters as Guilin.

From the distribution of the above-mentioned caves, tower karst and Qianyouhe River, it is considered that the development of karst in Zhashui was influenced by the allogenic water from northern non-carbonate rock area. For example, after passing through the karst area of Zhashui Cave System, the pH-value and carbonate hardness of the allogenic water all increase evidently, being 8.17 and 7.0 German degree respectively, and the saturation index of calcite in the water is also increased to +0.60, which indicates that the hydrochemical feature is changing from an unsaturation state of allogenic water to a saturation state of karst water.

The Second Day: Zhengan-->Lianghe-->Longdongchuang-->Xigou-->Heigou-->Outlet of Yudong Underground Stream (Fig.5)

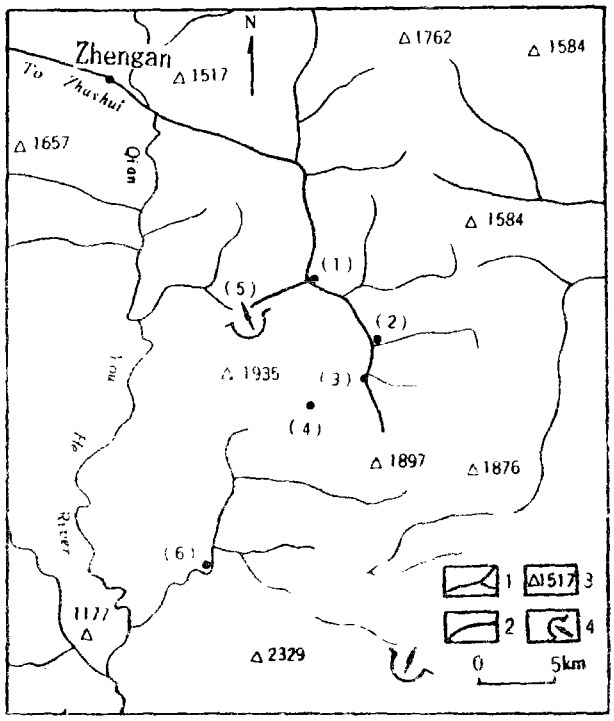

Fig.5 The Sketch of Second Day Excursion in Qinling Mt. Area
(1)--Lianghe (2)--Longdongchuang (3)--Xigou (4)--Heigou (5)--Outlet of Yudong underground stream (6)--Sunjiaao
1--River 2--Highway 3--Altitude(m) 4--outlet of underground stream

(1) Lianghe: River bed is 680 m asl, and water is flowing in a deep gorge. The area is rich in hydraulic energy because of steep gradient. This is favourable for local water power development.

(2) Longdongchuang hydropower station: It depends on a karst spring at about 1000 m asl. Though small in size, it provides enough electricity for local lighting and irrigation.

(3) Xigou: The area abounds in marble because of regional metamorphism. Here is a quarry and mill of pink marble. It benefits developing local ecnomics and improving the life of local residents.

(4) Heigou peak-cluster depression (Fig.6): It locates around Heigou Village, Zhengan County, 80 km south away from Qinling watershed, with the latitude of about 33° 20′ N. In the area, the altitude of the bottom of depressions is generally 1500 m, with the maximum 1800 m. The karstified rock is predominately Carboniferous-Permian limestone intercalated with coal measures. Most of the depressions are elongated, with the longer axis in NW, E-W or NE orientation, which reflects that the development of depression was controlled by the structural features of the same directions. There are terra rossa and karrens in depressions. Moreover, loess could be seen as well. This is the characteristics of karst in transitional climatic zone between humid and arid ones in China. Similar to the peak-cluster depressions of South China, there are also epikarst srings. According to analysis, the water from this kind of spring is highly aggressive, with pH-value as low as 6.06, carbonate hardness of 10 German degree, and saturation index of -1.35. This is because that firstly, the water in epikarst zone

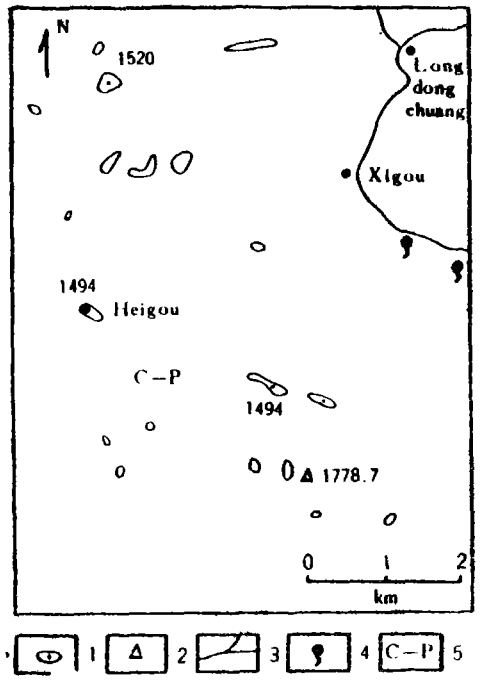

Fig.6 Distribution of karst depression at Heigou area, Zhengan County
1.peak-cluster depression 2.bench 3.River 4.karst spring 5.Carboniferous - Permian limestone

circulates near surface, and is closely related to soil, so dissolves large quantity of CO_2 from soil (the CO_2 content in soil in Autumn can reach 7000 ppm, and more in summer); secondly, there is coal measure, and the oxidation of sulphide in coal can produce sulphuric acid (according to analysis, the sulfate in the water is little higher, reaching 15 mg/l), which decrease the pH-value and increase the aggressivity of water. It is considered that the epikarst spring water may play some role in the development of depression.

(5) Yudong Underground Stream: This is the subsurface karst feature matching Heigou peak-cluster depressions. It links with karst depressions through the sinkholes. The outlet of the stream is 8 km northwest away from Heigou Village (Fig.5). The Yudong Underground Stream is 30 km long, with catchment area of 85 km^2 and flood peak discharge of about 10 m^3/s. In view of the coefficient of variation of its discharge (100 times), it is similar to that in south China karst area with humid climate.

Compared with epikarst spring water in the peak-cluster depression, the carbonate hardness of the underground stream (7.0 German degree) is lower, so is the water temperature (12.7 ℃ for epikarst spring, and 11.6℃ for underground stream), which assume an inversion hydrochemical and temperature profile being different from non-carbonate rock area. This case shows that, on the one hand, epikarst zone and underground stream are in different part of a karst system; on the other hand, this two parts have different structure of water-bearing media, i.e, the epikarst is predominately fissure form, and the underground stream is conduit form. The pH-value and saturation index of underground stream, being 7.81 and +0.15 respectively, are higher than those of epikarst springs. This shows that the aggressive capacity of water decreases from recharge area to discharge area.

(6) Sunjiaao tufa: It is 18 km south away from the outlet of Yudong underground stream. We will not be able to go there this time because of the the limitation of time,but it is very important to know it for a whole picture of karst feature complex in south Qinling Area. The tufa body is about 70 m high and 30 m thick. The deposition process began 8303 years B.P. (Carbon-14 Method) and is developing now, intergrowing with bryophyte. According to analysis and calculation, the main reason for the formation of tufa is, firstly, that the water on th top of tufa has been saturated with calcite, with saturation index +1.24 and the corresponding pH-value and carbonate hardness of water 8.40 and 12.6 German degree respectively; Secondly, the position of tufa is just on the steep slope from mountain to river bed. Because of strong disturbance, CO_2 in water escapes quickly. Correspondingly, pH-value of water increases (from 8.40 to 8.73), so does saturation index of calcite (from +1.24 to +1.51). So the stirring of water is favourable to the formation of tufa. In addition to above-mentioned two points, the function of organisms, such as the photosynthesis of bryophyte, is also important. The huge thickness of the tufa body may also be a record of long time of favourable climate.