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THE DIVISION OF GEOLOGICAL AGE OF A STALAGMITE IN PANLONG CAVE IN GUILIN

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Combining with the predecessors studies[1~8] and based on the comprehensive investigation of the 60 caves such as Xiaoyan Cave, Taiping Cave and Heiyan Cave and their sediments, and comparing the dating of stalagmites and tufas, the stalagmite in Panlong Cave is rich in paleo-environmental informations, and its vertical profile is a typical and systematical one of Holocene.

1 BRIEF INTRODUCTION OF THE STALAGMITE IN PANLONG CAVE

The stalagmite, 122 cm high and 25~45 cm in diameter, is situated on the calcareous plate flanked by rimstone dams and cave pearl pools. It is characterized by clear lamina and structure on its vertical profile. To obtain enough evidences for age division, the layers with depositional cycles, rhythms and dark lamina resulting from the special deposition were selected for systematic dating.

1.1 Depositional (Growing) Cycle

Nine depositional cycles were identified by the staged changes in dropping water from cave ceiling. The stalagmite is mainly composed of yellowish white, grayish white and pure white calcite from bottom to top, and intercalated with some pink calcite lamina in the mid-upper section. It intercalates many dark layers, which are getting darker in colour and more in quantity upwards. The calcites change their size from fine to moderately coarse and then to moderately fine, and take the shapes of needle, pillar and gigantical crystals with ring-bedded structure and radiated structure. No. 1 and No. 2 cycles comprise the core of the stalagmite base with slow deposition; No. 3~No. 8 cycles build up its main body with rapid deposition intercalated with some short-term slow deposition and some breaks; No. 9 cycle constructs the top of the stalagmite with slow deposition, which is intermittently growing now.

1.2 Lamina Complex and Its Surfacial Structure

A batch of depositional laminas building up the stalagmite body of a certain stage is defined as lamina complex, and its surfacial pattern showing the surfacial characteristics of the lamina as surfacial structure . The depositional (growing) surface structure indicates the

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regime of dropping water. In the course of diagenesis, it is easily going on in water that the calcites were adjusted, moved and recrystallized to form coarser crystals which grow needle-shapedly along C axis and cut across the lamina to produce the radiated structure. Although argillaceous materials move or accumulate locally on the surface of calcite, the structure of the lamina remains reflecting the original deposition. The reason why the surfacial structure and lamina complex are very complicated is because the flowing regime of the dropping water is changeable. The surfacial structure of the lamina is of universal importance. For instance, their gentle surface, dip surface, and uneven surface manifest the dropping water scattered, flowing on one side and of several fixed position, respectively. The lamina complex and its patterns can show the regime of the drips of a certain stage.

1.3 The Isotopic Age of the Stalagmite

The composition, colour, lamina complex and structure of the stalagmite indicate the geological environment inside and outside the cave. There exist 8 dark layers, the synthetical reflection of the environment out of the cave (Tab. 1). There are differences in age, composition, structure and depositional properties between them. In them are found depositional breaks being the upper and lower limits of depositional cycles, i. e. the indicator to determine the geological age, especially in No. 1, No. 5 and No. 7 layers, they are very clear.

With few or no fossils in the stalagmite, U-series, ^{14}C, ESR, and heat luminescence are available for dating. To make as accurate dating as possible, the samples were taken at the tops of the lamina comprising the core of the stalagmite. The dating data about 40 lamina indicate that the ages of the core of its base is 36000 ± 1800 a B.P., 10 mm from the top of the stalagmite 1060 ± 80 a B.P., and the other 30 data between them all are in normal sequence. Calculating with these data, the lower limits of No. 1, No. 5 and No. 7 dark layers are 32375 ± 380 a B.P., 4296 ± 150 a B.P. and 2354 ± 140 a B.P., respectively, and their upper limits, and the lower and upper limits of other dark layers are listed on Tab. 1. These data can be taken as the basis of division of the geological ages because they are in line with the values measured.

2 DIVISION OF GEOLOGICAL AGE OF THE STALAGMITE

In the existing Quaternary researches in Guilin, the data of hundreds of boreholes were collected, meanwhile the studies on some profile were done, also much data about fossil, archaeology and isotopic dating were recently obtained through the special studies on the sediments in the caves and glacial vestiges. However, there is not a division with enough evidences for Quaternary, Holocene in particular.

Combining the stratigraphical, paleontological and archaeological methods with the studies on the depositional cycles, the dating of the lamina and the depositional breaks at the tops and bottoms of the cycles , the stalagmite in Panlong Cave is believed to be formed in

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Tab. 1 Age table of dark calcite layers of the stalagmite in Panlong Cave

Number of layer	Location from the top (mm)	Thickness of the layer (mm)	Structure	Age (a)		Calculated lower and upper limit ages and their difference (a)		Depositional properties
				Top	Bottom	Top	Bottom	
8	90~114	2~19	Branched semi-ring-bedded	2265±80	2288±80	(23)		Depositional break at the bottom, intermittent deposition upwards
7	120~170	4~70	Conical semi-ring-bedded	2295±140	2354±140	2290±140 / 2295±140 (5)	2344±80 / 2354±140 (10)	Depositional break at the bottom, intermittent deposition upwards
6	270~300	2~18	Biconical semi-ring-bedded	3608±180	3905±150	(297)		Depositional break at the bottom, slow deposition upwards
5	344~400	4~56	Conical semi-ring-bedded	4219±190	4296±150	4172±150 / 4219±190 (47)	4162±150 / 4296±170 (134)	Depositional break at the bottom, slow and intermittent deposition upwards
4	468	1	Conical ring-bedded	5151±190	5481±190	(330)		Depositional break
3	520~540	1~18	Conical ring-bedded	5502±220	5510±220	5502±220 / 5517±220 (17)	5510±220 / 5522±220 (12)	Depositional break at the bottom, slow upwards and then intermittent deposition
2	739~750	4~11	Conical ring-bedded	5578±110	5581±110	5578±220 / 5457±110 (12)	5490±110 / 5581±220 (91)	Depositional break at the bottom, slow deposition upwards
1	956~1030	4~74	Conical ring-bedded	6461±250	32375±380	6383±110 / 6539±290 (156)	29437±650 / 32375±380 (2938)	Depositional breaks at both top and bottom, slow and intermittent deposition in the middle section

Note: In the Table the numerator means upper limit age; the denominator means lower limit age; the datum in the brackets menas the difference between them

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Late Pleistocene—Holocene. A detail division of age is made (Tab. 2). The comprehensive researches showed that the No. 2 cycle, i. e. No. 1 dark layer, is an indicator showing an violent climatic changes from cold to warm, which is a weathering crust-typed depositional cycle formed in a long-term depositional break. No. 2 cycle has an unconformable contact with underlying No. 1 cycle. In the transitional period from cold to warm after long-term depositional break, the dark lamina building up the low-mid section were formed. In Younger Dryas glacial period (11080±280 a B. P.), the parallel disconformity and unconformity were produced because of depositional break and intermittently slow deposition. With the intermittent hot deposition after the glaciation, the grayish white (intercalated with grayish black) calcite lamina were deposited to form the top cone of the core of the stalagmite base. When the depositional break came again, it contacted unconformably with overlying No. 3 cycle. Therefore, the intermittent depositions around Younger Dryas glacial period is classified into the dry depositional cycle after Dali glacial period. The lower limit of Holocene(Q_4) is 11080 ±280 a B. P., i. e. the time when Younger Dryas glacial period began[4]. Before Younger Dryas glacial period, the cold deposition building up the core of the stalagmite base may be included in the last stage of Late Pleistocene(Q_3^3); after Younger Dryas glacial period, the hot deposition building up the top cone of core of the stalagmite base in the early stage of Holocene (Q_4^1). It is difficult to further divide No. 2 cycle because it is only 5~74 mm thick, but its upper and lower boundaries are clear unconformable. Accordingly, it can be taken as the upper or lower boundary of other cycles. In a word, Holocene is subdivided into 4 stages by different depositional cycles, regime of dropping water and characteristic indicators. The stages are delimited by the dark layers and contact unconformably with each other. Their lower and upper limit ages are available. The division is nearly consistent with the ones of Pearl River Delta[5], loess of north China, the plain of north China[6], the glacial periods of China and Europe (Tab. 2).

3 CONCLUSIONS AND PROPOSALS

(1) Liking the ages determined by fossils and archaeology, the isotopic dating of speleothems is reliable and correct, sometimes, however, of multiple solutions. With the more systematical and definite properties, the comprehensive studies and systematical dating of the vertical profile of a stalagmite is one of the available and effective methods for the geological age division of Quaternary. To ensure the ages being correct and in normal sequence, the samples should be taken at the top of the lamina along the central axis of the stalagmite.

(2) The stalagmite has 9 depositional cycles showing its whole growth and 8 main dark layers indicating the rapid changes of deposition. No. 1 and No. 2 cycles build up the core of the stalagmite base with a very slow growth, No. 3~No. 8 cycles comprise the main body of the stalagmite with a quick growth, and No. 9 cycle makes up of the two cones of the stalagmite top. On the basis of the observation of the seasonal dropping water on the stalagmite,

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Tab. 2 The comparison of the ages of the stalagmite in Panlong Cave in Guilin with other regions

Time	The growth of the stalagmite			Isotopic age (a, B.P.) (3)	Paleoclimate	The profile of Beizhuang, south of Weihe River (5) Zhou Minggao et al.	Pearl River Delta (6), Li Pingri et al. (1984)	Glacial and inter-glacial period (Yang Huairen 1985)		
	Composition	Stages	Cycles					China		Europe
Q_4^{4-2} ......(1) Q_4^{4-1}	Bi-conic for the top	V	⑨	479±80 1080±80	Warm Dry (cold)		1260±40 Q_4^4 ∫ Hot and Tem. 2350±110 (12) —2500	Late Holocene	Cool and Tem.	Sub-Atlantic period
~~(2)				2354±140						
Q_4^{3-2}	Main body: Upper	IV	⑧		Hum. and hot		2510±90 Q_4^{3-2} ∫ Cool 4950±250 (14) —5000	Mid-Holocene	Tem. and dry	Sub-north period
Q_4^{3-1}			⑦	4296±170	Dry (cold) Warm Dry and cold		5020±150 Q_4^{3-1} ∫ Tem.		Warm and Tem.	Atlantic period
Q_4^{2-2}	Mid	III	⑥ ⑤		Hum. and hot			(7) —0.6—		
....				5581±110						
Q_4^{2-1}	Lower		④ ③		Dry Hum. and hot Dry and cold Tem. and hot			Early Holocene	Tem. and dry	North period
Q_4^{1-2}	The core of base: Top-cone of the core	II	②	6461±250	Dry cold after glacial period	—8000 Warm —9000 Tem. —14000 Dry and cold —18000 Hum. —20000 —26000 —30000 Cold	—7500 8050±200(19) —10000 Q_4^1 ∫ 15000±150 Q_3^3 Cool —22000	Paleo-Holocene	Cold and dry	Pre-North period
Q_4^{1-1}				11080±280 (332375±380 temporarily)				—1		
Q_3^3	Bottom of the base	I	①	36000±1800 36400[U-Series(4)]	Very cold		Tem. 28220±2200 (9) Q_3^{3-2} 30000±2800 —32000 Q_3^{3-1} Cold 37000±1480 (6)	—3	Dali glacial period	Yumu glacial period

Note: (1). parallel ring-bedded unconformity of disconformity; (2). ring-bedded unconformity; (3). upper, lower limit and boundary ages; (4). U-series, the others for AMS ^{14}C; (5). the profiles of loess, paleosoil and sludge and traditional ^{14}C dating; (6). pollen and ^{14}C dating date, the amount of samples in brackets; (7). ^{14}C dating (ten thousand years); Tem. —temperate; Hum. —humid

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we found the stalagmite is still slowly growing as a result of the intermittent deposition of calcite.

(3) The stalagmite was formed in the period from the last stage of Late Pleistocene to Holocene, its main body in Holocene. It is suggested that the boundary between Late Pleistocene (Q_3) and Holocene (Q_4) would be Younger Dryas glacial period with the lower limit of 11080±280 B.P.. The time before Younger Dryas glacial period belongs to the last stage of Late Pleistocene (Q_3^3), and the one after that incorperate into Early Holocene (Q_4^1). The lower limits of Middle Holocene (Q_4^2), Late Holocene(Q_4^3) and the last stage of Holocene (Q_4^4) are respectively 6461±250 a B.P., 4296±170 a B.P. and 2354±140 a B.P., which can further be divided into early and late sub-periods by the unconformity and parallel unconformity or disconformity between the deposional cycles.

Seeing that the predecessors often took the time about 10000 a B.P. as the boundary between Late Pleistocene and Holocene, grounded on the specific properties of the stalagmite profile in Panlong Cave, the lower limit age of Holocene is defined as 11080±280 B.P.. It is difficult to further divide No. 2 cycle being too thin. However, it is demarcated by both upper and lower unconformities. The lower limit of Holocene would be defined by 20000 a earlier, i.e. 32375±380 a B.P., providing using the lower limit of No. 2 cycle as the one of Holocene. It must further be verified whether the viewpoint is available.

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桂林盘龙洞石笋地质时代的划分*

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摘 要

桂林盘龙洞石笋以9个沉积旋回为基础，以旋回顶底沉积间断面为标志。通过对该石笋的沉积旋回、纹层组合、结构构造、层面构造等沉积特征的研究，并配合化石成分、微(痕)量元素、同位素组成测试及40多个沉积纹层系统测年，结果表明，此石笋形成于晚更新世末—全新世，其间的新仙女木冰期发生在距今11080±80年前后，是晚更新世与全新世的分界，但石笋主体形成于全新世，可细分为早(Q_4^1)、中(Q_4^2)、晚(Q_4^3)、近(Q_4^4)四期，各期下限分别为11080±80年前、6461±250年前、4296±170年、2354±140年前。各时段(期)根据石笋沉积速率、滴水量及动态等差异、沉积旋回间的圈(壳)层不整合或平行不整合等，可再分为早、晚亚期(参见前文Tab. 2)，这是至今桂林地区全新世地层剖面工作最细、时代划分依据最充分的剖面，桂林地区宜以此作为标准剖面。

关键词 桂林盘龙洞 石笋 地质年代

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