# DISCUSSION ON THE FORMING FACTORS OF DOG-TOOTH CRYSTAL AND STONE CORAL IN FURONG CAVE, CHONGQING CITY, CHINA

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**ABSTRACT:** The forming factors of dog-tooth crystal and stone coral are discussed for the first time on the basis of comparative analysis of microscopic characteristics, chemical features of pool water, elemental contents of speleothems, and field work. Such conclusions are drawn: dedolomitization, which is functioned by gypsum in the overlying stratum, is of great significance for the forming of rare cave landscapes. Dog-tooth crystal and stone coral is closely related with it and different degrees of dedolomitization lead to different landscapes. In a dog-tooth crystal pool, the crush belt promotes dedolomitization, providing enough Ca ions and removing quantities of Mg ions, which can satisfy calcite to deposit continuously. Consequently, full grown crystals form in the shape of long columns or fibers. In the coral pool, dedolomitization is weaker because there is no fault and the pool is farther away from the gypsum source. Less Mg ions are removed, not enough Ca ions are provided. Meanwhile some of the Ca ions are consumed with the deposition of calcite, so Mg/Ca increases during crystallization of calcite. When it reaches a certain value, crystallation is interrupted, thus, stone coral is shaped by short columns and accumulates multiple layers. In other places away from the gypsum, almost no dedolomitization occurs, Mg/Ca maintains high levels and no calcite crystals can form. Only aphanitic $CaCO_3$ (stalactite, stone column, stalagmite) forms. All these explanations above conform wonderfully with the geological feature, microscopic characteristics and geochemistry of water and rock, which is of great importance to understand the evolution dynamics of landscapes, to learn their outstanding universal value, and to protect landscapes.

**Key words:** dog-tooth crystal; stone coral; dedolomitization; forming factors of landscapes; Furong Cave

## INTRODUCTION

In recent years, cave landscapes in karst areas have evoked people's attention with the boom of tourism. In order to protect touring resources and make them develop constantly, experts and scholars have become interested in formation factors of cave landscapes (Frank 1965; Wells 1971; Yang and Tian 1994; Gentry and Deflandre 1998).

Furong Cave lies in Wulong county, Chongqing city, with a latitude and longitude of 29°14 N and 107°55 E. Different kinds of speleothems (ie. dripping, flowing, pool, and non-gravitational) all develop very well here. Stalactites, stalagmites, stone waterfalls, stone curtains, stone flags, soda straws, palm stalagmites, stone corals, flowstone dams, side stones, cave pearls, cavelolus, grape corals, dog-tooth crystals, raftcones, helictites, anthodites, and moon milk stone can all be found in this cave, from ancient to up-to-date, from carbonate to sulfate. They are plenty in quantity and pure in quality, and of course of great value to onlookers. Many kinds of pool deposits and some perfect non-gravitational water depositions are ranked as rare speleothems at home and abroad; naturally Furong Cave is ranked first-class in the world.

Two rare speleothems with high outstanding universal value appear in Furong Cave (Zhu 1994; Luo et al. 2004). One is shaped like dog teeth and is named the dog-tooth crystal, while the other looks like coral and is named stone coral. Both of them are so scarce that this type of dog-tooth crystal is also found in La Peyrére Cave, south of France (Anonymous 2004), and it is documented that only a few scattered stone coral of this type can be seen in several caves (Zhu et al. 2000; Yang and Zhu 2004), however none of them can compare to the beauty of those found in Furong Cave in both quantity and scale.

Furong Cave is now the first one to be nominated in the preliminary list of the world's natural properties because of its outstanding scientific and aesthetic values, and it is imperative that we explore its significant and scientific value, especially its outstanding universal value.

Up until now, most of the research work on the formation mechanisms of cave landscapes have been limited to stalagmites, soda straws, cave pearls, etc. (Fu 1993; Wang et al. 1998; Zhou and Li 2004; Yang et al. 2004). We find little published work detailing with the forming factors of dog-tooth crystals and stone corals, and it still remains a secret. Two reasons may contribute to this: (1) their rarity, and (2) measures to analyze the forming factors are often taken from studies in cave water, cave biology, and stimulating solutions (Fu 1993; An et al. 1994; Wang et al. 1998; Zhou and Li 2004; Yang et al. 2004; Yan 2004). Some questions always puzzled us. What are their ingredients? Why are they so rare and what kind of special conditions are needed for them to form? Why do they develop so well in the two pools but in other places they do not? What kind of evolution dynamics are involved and what kind of special universal value does it stand for? What puzzles us more is that the distance between dog-tooth crystals and stone coral is only about 30m but two distinctive cave landscapes appear. The lacking of such research work restricts our understanding about the two speleothems, limits our further study on cave evolution dynamics, impedes our learning of universal value that Furong Cave owns, and blocks our scientific protection.

In order to clarify the forming mechanism of the two speleothems, samples of cave water and spelethems were gathered and analyzed in the laboratory. At the same time, their geological section and microscopic characteristics were studied in detail, on the basis of which, the forming factors of dog-tooth crystal and stone coral are discussed.

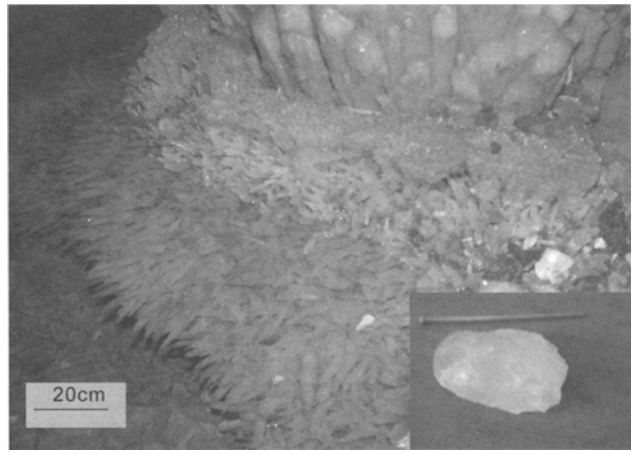


*Figure 1. Dog-tooth crystals in cave (lower-right picture: a speleothem after it was dipped in HCl).*

## SAMPLING AND EXPERIMENTS

### Studied Objects

Dog-tooth crystals and stone corals occur respectively in the dog-tooth crystal pool and the coral pool, which are located on both sides of a slope, with a 30m length and a 32° grading angle (Fig. 8).

Dog-tooth crystals lie in the dog-tooth crystal pool on the south of Huge Hall, about 1000m from the cave entrance. The pool water surface spreads along the cave wall, in a narrow shape. Clear water drops from the cave roof into the pool below. Pure dog-tooth (honeycomb) calcite crystal groups surround the pool. The crystals are characterized by a length of 5-15cm, a thickness of about 0.5m, vertical to the cave wall, and pure white in color (Fig. 1).

Stone coral occurs in the coral pool. The crystals are characterized by vertical crystallization, perfect development, in good order, and multiple layers. The crystals are about 1m in thickness. They are oxidized in appearance and slightly greyish-white. Crystals turn white and slightly greyish-green when the oxide is removed by dilute HCl (Fig. 2).


*Figure 2. Stone corals in the cave (lower-right picture: LEFT: original speleothem; RIGHT: appearance after sample is dipped in HCl).*

### Sample Gathering and Analyzing

Field investigation includes cave geological characteristics, tectonic characteristics, and cave sectioning. Samples of dog-tooth crystals, stone corals, other speleothems (stalagmites, pillars, stone knots, etc.), bedrock, and water were gathered.

The sample-dissolving work was done by Lu Yilun, a senior engineer working at the Institute of Geographical Sciences & Natural Resource Research, CAS. Samples were dissolved by HCl-$HNO_3$. Contents of As, Se, Hg, F were analyzed by Lu Yilun in the laboratory and the Atomic Fluorescence Spectroscopy (AFS) method was used. The contents of other elements were analyzed at the Institute of Geology and Geophysical, CAS, using the Plasma Emission Spectra method (instrument model is ICP emission spectrometer). The reporting limit is $10^{-8}$ mg/l and the relative error is 5%.

## ANALYZING RESULTS

### Identification of Contents

The methods used to identify the contents of the two speleothems are as follows:

*Microscopic characteristics.*– Both of the speleothems have almost the same microscopic characteristics: no color and transparent; rhombus cleavage; obvious twinkling; super white interference colors; twin crystals; twin striations parallel to the longer diagonal of the rhombus; symmetric extinction along cleavages The extinction angle of dog-tooth crystals is 55°- 65° and that of stone corals is 50°-60°.

*Hand specimen.--* The calcite crystal form can be seen when 5% HCl is used to remove the oxide. Dog-tooth crystals spread in long columns with perfect cleavage, while stone corals are in short columns. Dog-tooth crystals appear pure white while stone corals are slightly gray (Figs. 1, 2).

*Identification by dilute HCl.--* Both bubble when 5% HCl is dropped.

*Staining method.--* Both appear black after a former reaction with 10-12%$FeCl_3$ within 20 minutes, then washed with distilled water and a latter reaction with $NH_4S$. The dog-tooth crystal is a darker black than the stone coral.

From the characteristics mentioned above, both speleothems are calcite crystals.

## Microscopic Characteristics

The dog-tooth crystal is characterized by a long column or fiber shape; well developed crystals; perfect crystal forms; no grains and euhedral-granular; rough appearance; obvious cleavage shape; and nonclastic crystalline texture (Fig. 3). Stone corals have radiation or short columns; regular boundary between grains; perfect crystalline forms; twin crystals and mosaic structures between grains; varied growing orientations of crystals; and medium-grained crystalline textures (Fig. 4). Such speleothems as stalagmites, stone columns and stalactites by the shapes of crumb or speckle; aphanitic texture, fine grains; non-crystalline agglutinating grains (Fig. 5). It seems to be such a fact that from dog-tooth crystal, stone coral to stalagmite and stalactite, and the crystal grains becomes finer and finer, the crystal forms turn from long column, short column to cryptocrystalline and the crystallizing degrees become worse.

## Chemical Features of Pool Water

The analyzed results of element contents in the water of the two pools are shown in Table 1. The current water temperature is 16.3°C, the pH in dog-tooth crystal pool is 7.84°C while that in the coral pool is 7.87°C. Ca and Mg are the dominating elements, with contents of 31.05mg/l Ca and 29.15mg/l Mg in the dog-tooth crystal pool, and those of 44.43mg/l Ca and 33.26mg/l Mg in the coral pool. Contents of Al, K, Na, Si are over 0.1mg/l, those of Ba, Cu,

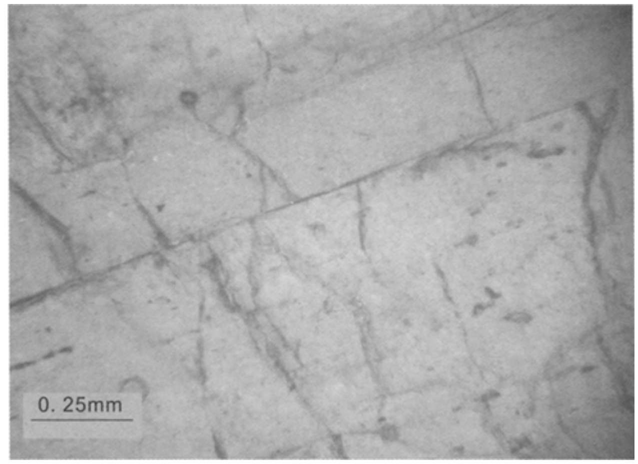


*Figure 3. Photomicrograph of a dog-tooth crystal.*

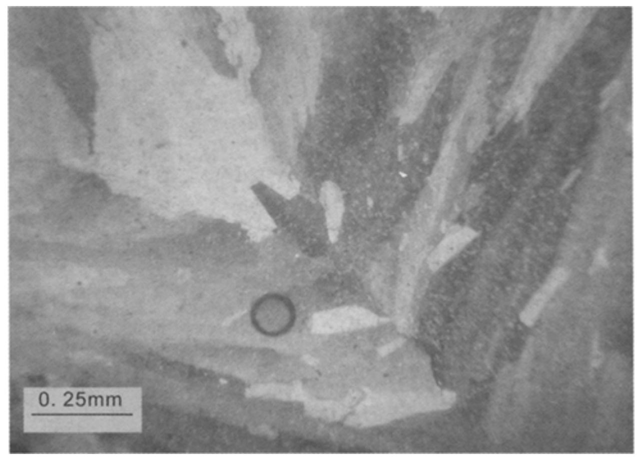


*Figure 4. Photomicrograph of a stone coral.*

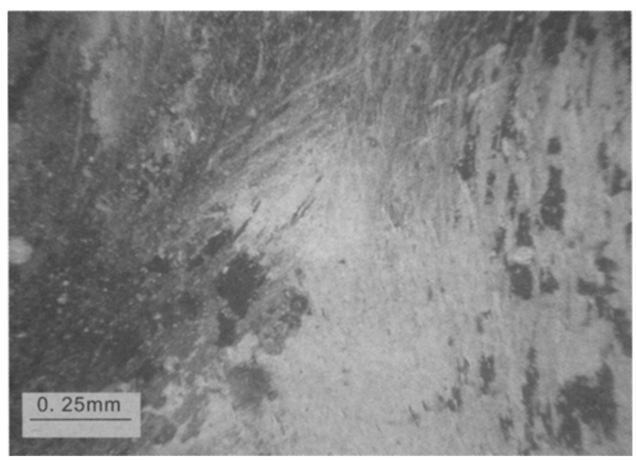


*Figure 5. The aphanitic texture of a stalagmite as viewed under a microscope.*

Table 1. Element contents of water in the dog-tooth crystal pool (Fr-9) and the coral pool (Fr-8).

| | Al | B | Ba | Ca | Co | Cr | Cu | Fe | K | Mg | Mn | Mo | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fr-8 | 0.76 | 0.06 | 0.03 | 44.43 | 0.0002 | — | 0.02 | 0.001 | 0.90 | 33.26 | — | 0 | 1.12 |
| Fr-9 | 0.75 | — | 0.01 | 31.05 | — | — | 0.04 | — | 0.50 | 29.15 | — | 0.008 | 0.89 |
| | Ni | P | Pb | Si | Sr | Ti | V | Zn | F | As | Se | Hg | |
| Fr-8 | — | — | 0.02 | 2.20 | 0.06 | 0.01 | 0.03 | — | 0.03 | 0 | 0.24 | 0.002 | |
| Fr-9 | — | 0.005 | 0.04 | 2.58 | 0.03 | 0.01 | 0.02 | — | 0.01 | 0.84 | 0.22 | 0 | |

Concentrations in mg/l except (As, Se, Hg) which indicate ug/l.

Pb, Sr, Ti, V, F are 0.01~0.1mg/l and As, Se, Hg in µg/l contents. Such elements as Cr, Mn, Ni, and Zn (were not analyzed).

We can draw the conclusion from water chemical features that salinity in the dog-tooth crystal pool is lower than that in the coral pool. The previous research (Zhu 1994) reported that the dog-tooth crystal pool has 153.53mg/l salinity while the coral pool has a 193.49mg/l value. Although Mg content in the coral pool is higher than that in the dog-tooth crystal pool, the Mg/Ca value (0.75) is obviously lower than that (0.94) of the dog-tooth crystal pool. Therefore Mg ions in the dog-tooth crystal pool are richer compared with Ca ions if we synthetically reference salinity and Mg/Ca values. The Ba content in the dog-tooth crystal pool is clearly lower than that in the coral pool and is as much as one third of that in the coral pool. Sr content is just half of that in the coral pool. Dog-tooth crystal pool water has lower contents of K, Na, V, F but higher contents of Cu, Pb and As, than coral pool water, and Al, Mo, Si, Ti and Hg are almost equivalent in both (Table 1, Fig. 6).

### Element Content Characteristics of Speleothems

Elemental contents of dog-tooth crystal and stone coral are listed in **Table 2.** Ca and Mg are dominate. The dog-tooth crystals are characterized by contents of 226709.7 ug/g Ca and 498.5183ug/g Mg, and the stone coral by 166229.7ug/g Ca and 8178.318ug/g Mg. Contents of Al, Ba, Fe, Na are 100~500ug/g, those of B, Cr, Mn, Mo, Ni, Si, V, Zn are 1~10ug/g, and those of K, P, Pb are 10~100ug/g.

Several differences between the elemental contents of the two speleothems can be drawn from the logarithmic curve (Fig. 7). Firstly, dog-tooth crystals have a higher level content of Ca which is as much as 136% of stone coral but a clearly lower level content of Mg which is just only as much as its 6%, which indicates that Ca relatively enriches but Mg seriously deficits in dog-tooth crystal compared with stone coral. Secondly, Ba is richer in dog-tooth crystal and reaches as much as 15 times that of stone coral. Thirdly, Fe and Mn contents of dog-tooth crystals are lower than those of stone coral. And lastly, Sr content is distinctly different, and that of dog-tooth crystal is only as much as 4.9% of stone coral.

The content characteristics of water and speleothems can reflect such facts: (1) Mg/Ca in dog-tooth crystal pool water is higher than that in coral pool water but Mg content in dog-tooth crystals is lower than that in stone corals. This means that in the dog-tooth crystal pool, Mg runs off more directly to pool water, depositing less in speleothems than in the coral pool. (2) Ba, which is strongly related with $SO_4^{2}$, is lower in the dog-tooth crystal pool but deposits more in

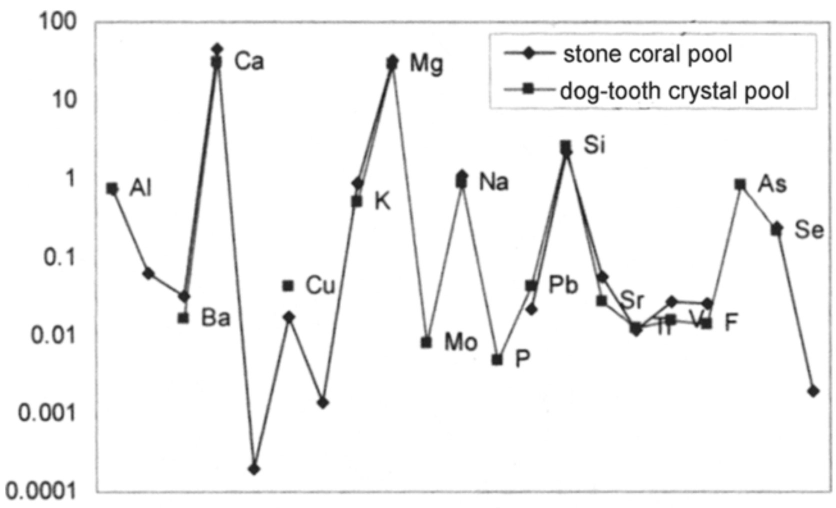


*Figure 6. Logarithmic curve of elemental contents of the water in the dog-tooth crystal pool and the coral pool.*

Table 2. Elemental content features of dog-tooth crystals (Fr-43) and stone corals (Fr-47).

| | Al | B | Ba | Ca | Co | Cr | Cu | Fe | K | Mg | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fr-43 | 322.33 | 3.74 | 599.81 | 226709.7 | — | 2.80 | 10.48 | 296.78 | 84.45 | 498.52 | 4.69 |
| Fr-47 | 169.33 | 5.8 | 39.89 | 166229.7 | — | 2.85 | 9.86 | 492.45 | 46.27 | 8178.32 | 8.55 |
| | Mo | Na | Ni | P | Pb | Si | Sr | Ti | V | Zn | |
| Fr-43 | 1.30 | 229.56 | 0.44 | 49.19 | 31.33 | 6.91 | 591.20 | — | 1.67 | 14.16 | |
| Fr-47 | 0.47 | 140 | 0.22 | 44.91 | 25.47 | 10.80 | 28.78 | — | 1.04 | 7.80 | |

**Concentration in ug/g**

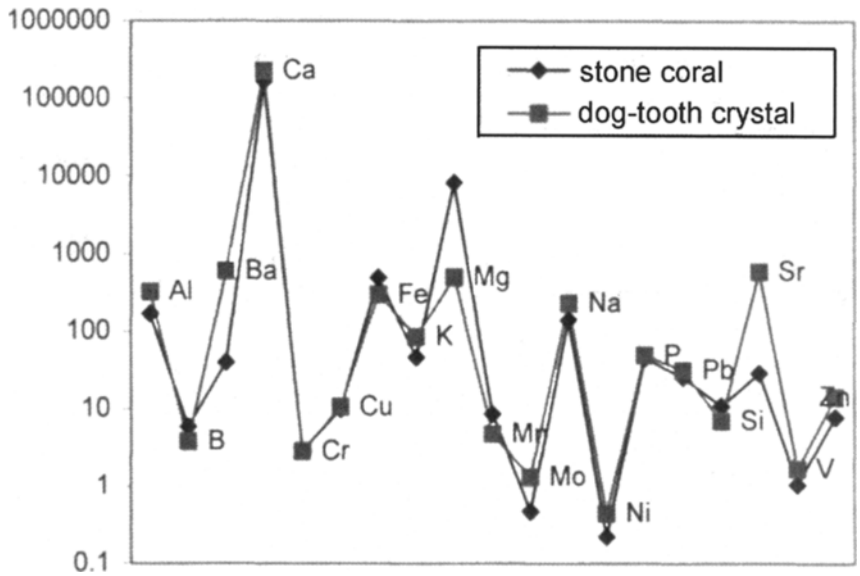


*Figure 7. Logarithmic curve of elemental contents of the dog-tooth crystals and the stone corals (ug/g).*

speleothems. (3) Fe and Mn, which often act as isomorphs of dolomite, are lower in dog-tooth crystals. (4) Sr contents in both pool water and speleothems are greatly distinct.

## DISCUSSION

### Influence of Mg Ions on $CaCO_3$ Deposition and Crystallization

In statistical evaluation of Ca and Mg contents of different types of speleothems in Furong Cave, it can be seen that from dog-tooth crystals, stone corals, aphanitic $CaCO_3$ (such as stalactites, stalagmites, stone columns, etc.) to carbonates, accordingly, Mg contents become higher, and they change from 498.52ug/g, 8178.32ug/g, 25579.32ug/g to 81179.32ug/g. Mg/Ca values have the same increasing tendency, which change from 0.002, 0.049, 0.1 to 0.383. Meanwhile, from dog-tooth crystals, stone corals, aphanitic $CaCO_3$ to carbonates, the shapes of $CaCO_3$ crystals change from long columns, to short columns and to cryptocrystalline, and the crystals form from perfect to imperfect, and the grain from coarse to fine (Figs. 3, 4, and 5). These facts may support a deduction that Mg ion content is closely related with crystalline $CaCO_3$ of cave speleothems, Mg can restrain the enlargement of crystals, and the degree of Mg removed has a great effect on cave landscapes and crystal forms.

In fact, Mg ions can prevent the enlargement of calcite crystals during recrystallization. This has been observed by many authors (James 1972; Khalifa and Abu El-Hasan 1993; Khalifa 2005) when diagenesis was studied and even tested by experiments, which has been widely accepted, and this fact seems to also take place in caves. Mg may be one of the main factors affecting the formation of the cave landscape. It is the Mg ion that controls the crystal forms of speleothems and the types of cave landscapes.

Moreover, we can roughly give such a scale: (1) $CaCO_3$ crystals often develop very well and form perfect calcite when Mg/Ca is less than 0.01, (2) it forms calcite crystals but, always in the short column shape when Mg/Ca is 0.01~0.06, (3) while when Mg/Ca is more than 0.06, its form is cryptocrystalline with an aphanitic texture.

### Dedolomitization and Its Effect on the Forming Factors of Dog-Tooth Crystals and Stone Corals

Dedolomitization is one of the most common types of diagenesis in carbonate areas (Von Marlot 1847; Qigrin and Feng 1978; Arenas et al. 1999). The increase of Ca ions is of great importance to dedolomitization, and the fact that dedolomitization is intensified by increasing the concentration of Ca ions (such as $Ca[OH]_2$ solution) has been proven by experiments (Deng and Tang 1998; Garcia et al. 2003). In nature, sulphate ions most ordinarily help dedolomitization, that is, sulphate ions combine with Mg ions of dolomite to generate magnesium sulphate and calcite, then magnesium sulphate dissolves and runs off (Lucia 1961; Wang et al. 1991; Arenas et al. 1999). In this way, Ca ions increase by the removal of Mg ions in dolomite, so dedolomitization can change Mg/Ca values as discussed above, and are thought to be one of the main factors affecting the crystallization of calcite. It can be expressed as the following equation:

$$CaMg(CO_3)_2 + CaSO_4 = 2CaCO_3 + Mg^{2+} + SO_4^{2-}$$

In fact, dedolomitization plays a great role in the formation of dog-tooth crystals and stone corals. Tan and Yang

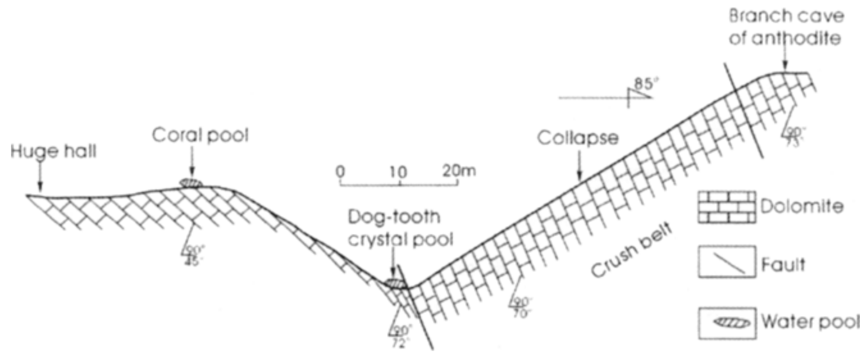


*Figure 8. Geological section from the coral pool to the dog-tooth crystal pool in Furong Cave.*

(1997) summarized the content characteristics of different causes of dedolomitization, and contents of Ca, Mg, Si, Fe, and Mn elements of both speleothems are characterized by gypsum dedolomitization. We found gypsum origins in the overlying stratum, where the Branch Cave of Anthodite develops (Fig. 8). On the one hand, the dissolved gypsum enhances the Ca concentration, while on the other hand, dedolomitization removes Mg ions from the dolomite. The Mg/Ca then becomes lower which is helpful for the calcite crystallization. The following explains the phenomenon. In this cave, calcite crystals only form in the dog-tooth crystal pool and in the coral pool. These pools are close to the gypsum-bearing stratum, while in other pools away from the gypsum, dedolomitization is weakened. Mg content and Mg/Ca values are high, and so aphanitic $CaCO_3$ forms, such as stalactites, stalagmites, stone columns etc., but no calcite crystals form.

There are several methods to demonstrate that dedolomitization in the coral pool is weaker than that in the dog-tooth crystal pool: (1) Mg/Ca in the coral pool is lower than that in the dog-tooth crystal pool while distinctly higher in stone coral than that in dog-tooth crystal, so we can say that more Mg ions run off and are released into the pool water during the forming of dog-tooth crystals. The stronger the dedolomitization is, the more Mg ions that should be liberated. (2) Ba content in the coral pool is obviously higher than that in the dog-tooth crystal pool, but that in stone corals is only as much as 1/15 of that in dog-tooth crystals, this may be due to the higher $SO_4^{2-}$ in the dog-tooth crystal pool generated by the stronger dedolomitization. The stronger the dedolomitization is, the more $SO_4^{2-}$ that should be produced. (3) Contents of Fe and Mn in stone corals are higher than those in dog-tooth crystals. This may be explained as: Fe and Mn often act as isomorphs, substituting Mg lattices in dolomite and are naturally deposited more in stone corals because of their weaker dedolomitization.

What causes these differences of dedolomitization in the coral pool and the dog-tooth crystal pool? One factor may be the distance away from the gypsum-bearing stratum. The closer the dog-tooth crystal pool is, the stronger the dedolomitization is. Another factor may involve the crush belt. In our field work, we notice that the dog-tooth crystal pool just lies on a fault, and a huge crush belt with perfect cracks lies nearby. Here, the dip angle of rock stratum in the dog-tooth crystal pool suddenly changes to 72°, while that in the coral pool is 45°, which is concordant with that of the whole cave. According to the different elemental contents of dedolomitized calcite due to different causes summarized by Tan and Yang (1997), Sr content of dog-tooth crystals indicates a dedolomitization related to structural cracks but that of stone coral does not. Advanced research (Wang and Zhang 1996) has confirmed that rock bulk will increase by 12.7% because of dedolomitization. Faults and cracks can provide the space for this increased rock bulk and thus allow the needed space for dedolomitization. Research (Tan and Yang 1997; Deng et al. 2001) reports that different modes and processes of dedolomitization occur in fault belts and non-fault belts, respectively. In fault belts, replacement and calcite deposition occur synchronously, while in non-fault belts, replacement occurs formerly and space is left over, with calcite depositing later. Lab simulation and results (Ayora et al. 1998) demonstrate that it takes 500a to deposit 1m calcite where there is enough space while $10^5$a is needed where space is limited. Thus, the fault and crush belt close to the dog-tooth crystal pool greatly promotes dedolomitization. In this way, Mg is lost and Mg/Ca decreases, which is helpful for calcite crystalization, attributing to the evolution dynamics of landscapes. In the field, we also find huge perfect calcite crystals in the crush belt (Fig. 9).

In summary, crush belts and the distance from gypsum lead to the degree of dedolomitization in the dog-tooth crystal pool and the coral pool. This arouses the difference in calcite crystal forms and the degree of crystallization, and two completely different cave speleothems form.

## Discussion on the Forming Factors

Dedolomitization provides important dynamic forces for the deposition of $CaCO_3$ and the forming of cave landscapes. Gypsum and faults are of great importance to dedolomitization. From dog-tooth crystal, stone corals

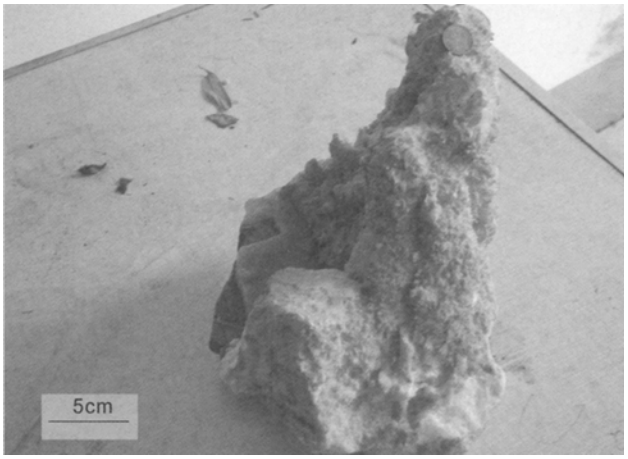


*Figure 9. Huge calcite crystal found in the crush belt.*

to the aphanitic $CaCO_3$ series, dedolomitization becomes weaker, less Mg ions are liberated, and Mg and Mg/Ca content in speleothems increases gradually (Table 3). Mg concentration affects the degree of calcite crystallization and leads to different evolutional directions of landscapes (Fig. 10).

In the dog-tooth crystal pool, the crush belt and the shorter distance from gypsum reinforce dedolomitization. Sr content of dog-tooth crystals is characterized by dedolomitization related to the fault. Quantities of Mg ions are lost and accumulated in the pool water, and vast $SO_4^{2-}$ are produced, which results in a low Mg/Ca and a high Ba content during the crystallization of calcite. The intensive dedolomitization causes Mg ion loss continuously and maintains a low Mg/Ca value. Thus crystallization of calcite becomes continuous too, and naturally the calcite forms dog-tooth shaped and perfect crystals. Meanwhile, the strong dedolomitization decreases Fe and Mn content in dog-tooth crystals, and the dog-tooth crystals appear pure white (Fig. 10a).

Dedolomitization is weaker in the coral pool because of the longer distance away from gypsum and no crush belt influence. Only part of the Mg ions run off and limited $SO_4^{2}$ is produced, consequently the stone coral have a lower level of Ba content but a higher Mg/Ca value than that of the dog-tooth crystals. Initially, $CaCO_3$ deposits continuously and calcite crystals form, but Ca ions are consumed with the deposition. Moreover, the weak dedolomitization provides

Table 3. The relationship between Ca, Mg contents, Mg/Ca values, and $CaCO_3$ crystal forms in Furong Cave.

| Crystalline $CaCO_3$ | | | | | | Aphanitic $CaCO_3$ | | | Carbonate Bedrock | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dog-tooth crystals | | | Stone corals | | | Stalactites, stalagmites, stone columns | | | | | |
| Ca | Mg | Mg/Ca | Ca | Mg | Mg/Ca | Ca | Mg | Mg/Ca | Ca | Mg | Mg/Ca |
| 226709.7 | 498.52 | 0.002 | 166229.7 | 8178.32 | 0.049 | $\frac{(2.2\sim2.8)\times10^5}{255589.7}$(9) | $\frac{(1\sim4)\times10^4}{(25579.32)}$(9) | 0.1 | $\frac{(2\sim2.4)\times10^5}{(211949.7)}$(4) | $\frac{(0.6\sim1)\times10^5}{(81179.32)}$(4) | 0.383 |

(Varying scope)/(Average), ( ) means the statistical sample number, concentrations in ug/g.

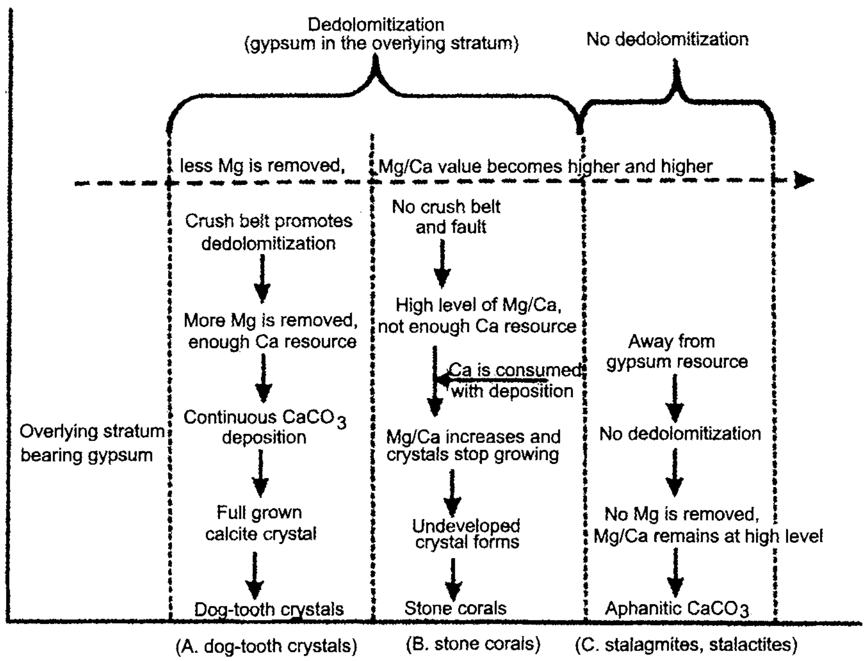


*Figure 10. Diagrammatic sketch of forming and evolutionary dynamic forces of cave landscapes in Furong Cave.*

insufficient Ca ions and removes less Mg ions, and Mg/Ca values increase with the calcite deposition. When it reaches a certain limitation, the crystallization ceases and the calcite crystals stop growing, and then deposition is interrupted and thus the crystals are often characterized by a short column shape. More Fe and Mn are brought into stone corals because of the weaker dedolomitization, causing the speleothem to be colored grey-white. Dedolomitization still occurs during the deposition interruption, and as the Mg/Ca increases and reaches another certain value, the deposition restarts and another new crystal accumulates on the former one. Multiple processes repeat and consequently stone corals are characterized by layers with a cloudy shape (Fig 10b).

Dedolomitization is very weak and holds almost no validity in other places in Furong Cave because of the long distance from the gypsum source. Mg content and Mg/Ca maintain high levels and there is not enough Ca for $CaCO_3$ to crystalize and often aphanitic $CaCO_3$ such as stalagmites, stone flags and stone columns form (Fig. 10c).

## CONCLUSIONS

Such conclusions can be drawn on the basis of the analyses above:

1) The ingredients of the dog-tooth crystals and the stone corals in Furong Cave are confirmed to be calcite crystals through the identification of hand samples and microscopic investigation. But dog-tooth crystals are characterized by full grown crystal forms and a long column shape, while stone corals are characterized by immature crystal forms and a short column shape.

2) The Mg element plays an important role for cave $CaCO_3$ deposition and crystalization. Mg content and Mg/Ca have an increasing tendency from long-column dog-tooth crystals, short-column stone corals to aphanitic $CaCO_3$, and accordingly with the crystal forms from full grown to incomplete, and crystal size changes from grain to fine. Mg ions can hinder the growth and enlargement of calcite, which may be the key factor of landscape evolution.

3) Dedolomitization is related closely with the forming factors of dog-tooth crystals and stone corals. In the dog-tooth crystal pool, dedolomitization is intensive and quantities of Mg ions run off because of the crush belt and the short distance away from gypsum, which provides enough Ca ions for calcite to crystalize continuously. Thus perfect dog-tooth crystals are produced. In the coral pool, dedolomitization is comparably weaker and only part of the Mg ions run off, which can not provide enough Ca ions for calcite to grow continuously and deposition interruption occurs. Stone corals with incomplete crystals form and a short column shape forms. This explanation conforms wonderfully to the microscopic characteristics of speleothems, chemical features of pool water, element content characteristics of speleothems, and layered characteristics of stone corals.

This paper begins to explain the forming factors of the two speleothems, yet this explanation may be only a tentative discussion. Further research should be performed, especially in the laboratory. The materials we presently collected strongly support our ideas, and we are eager for other experts' opinions.

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