

Origin of Botryoidal Dolostone of the Sinian Dengying Formation in Sichuan Basin, China*

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Abstract

The Dengying Formation (Sinian) is a thick succession (up to 1000 m), which is formed largely of finely crystalline dolostones and has high gas production in the Sichuan Basin, China. In some parts of the formation (mainly in Member 2 and 4) there are large, hard, variably shaped botryoidal masses of dolomite, up to 75 cm long, that are either parallel to bedding or cutting across bedding. Cross-sections reveal isopachous bands of various types of dolomite that developed as cements. Irregular-shaped cavities are still present in the central parts of some of the larger bodies. Although previously referred to as grapestone or prehnite, the botryoidal dolostone developed as various types of cements progressively filled cavities that formed as a result of subterranean dissolution that was associated with karst development. After the surrounding micritic dolostone originally deposited from seawater, the fact that each phase of cement is crystallographically and geochemically distinct indicates that each fabric probably formed at different times under different conditions: (1) the dolomitized automicrite in some samples was the 1st stage cement, which formed within the cavities due to various physiochemical and possible biological influences; (2) the 2nd generation fibrous dolomite had absolute ordering crystal structure and near-ideal crystal cell parameter, which may have originated from marine waters and adjusted to be ordered during the later diagenesis; (3) the 3rd generation fine-to medium crystal dolomite including traces of fibrous dolomite crystals formed near-surface meteoric environment after tectonic uplift; and (4) the 4th generation medium-coarse crystal dolomite primarily precipitated under burial environment and partially filled the central parts of the cavities. It is apparent that the Dengying Formation

was subject to multiple phases of diagenesis that included karst development, precipitation of various cements, and multiple episodes of dolomitization. Except the paleokarstification, all of the other processes critically reduced the porosity of the petroleum reservoir that developed in the Dengying Formation. The paleokarstification which related to botryoidal dolostone has crucial importance to the Dengying Formation reservoir. The study of botryoidal dolostone in the Sinian Dengying Formation conduces to understand the reservoir origin and evolution, the origin of Dengying Formation dolostone, and the Precambrian petroleum development of Sichuan Basin.

Introduction

Recent years, there were momentous petroleum discoveries in the Sinian Dengying Formation, Sichuan Basin, which brought the climax of Dengying Formation dolostone research (Hong et al., 2011). In the 2nd and 4th member of the Dengying Formation, there developed a dolostone with botryoidal structure. Because of the importance to the reservoir, the botryoidal dolostone was of concern by many researchers (Wang, et al., 2000; Cao, 2002; Shi, et al., 2011).

There are always different ideas about the origin of botryoidal dolostone in the Sinian Dengying Formation. Zhang, 1980 and Cao, 2002 considered they formed during the primary sedimentary stage; Liu et al., 1991b and Chen et al., 2002 took for the meteoric leaching origin during the diagenesis because the botryoidal dolostone cut through the beddings and some cave fillings simultaneously appeared. After detailed mineralogical, petrologic, geochemical, and crystal structure analysis on different stages in botryoidal dolostone, this paper considered that different stages of dolomites formed during different times and had their own origins. On the basis, the different origins of each stages of the botryoidal dolostone are discussed.

Introduction of Botryoidal Dolostone

The Dengying Formation (Sinian) is a thick succession (up to 1000 m), which is formed largely of finely crystalline dolostones and has high gas production in Sichuan Basin, China (Liu et al., 1991a). In some parts of the formation (mainly in Member 2 and 4) there are large, hard, variably shaped botryoidal masses of dolomite, up to 75 cm long (Figure 1a and Figure 1b). The botryoidal dolostone have three characteristics: (1) The botryoidal dolostones are either parallel to bedding or cutting across bedding; (2) Symmetry. The pore-filling dolomites grew from the margin to the center and formed symmetric zones; and (3) Gravitational effect. In the top of the cave there are overhanging dolomite cements.

Origin of Botryoidal Dolostone

Petrologic work, sequence study, and samples collection were done on the Xianfeng Section and the Jinkouhe Section, Southwest Sichuan Basin; Yangba Section, North Sichuan Basin; and some cores (sections and cores locations see Figure 2). After detailed petrologic and

mineralogic study on these samples, multi-generations were distinguished from the botryoidal dolostone (Figure 1c, Figure 1e, and Figure 1f). The surrounding rock is micritic dolomite. The 1st generation cement is automicritic dolomite. The 2nd generation cement is fibrous dolomite. The 3rd generation cement is fine-medium crystal dolomite. The 4th generation cement is medium-coarse crystal dolomite. These 5 kinds of dolomites separately formed in different times and different environments. Hence, the origin of botryoidal dolostone could not be treated as one stage but multi-stages.

Study Methods and Significances

Based on the multi-generations dolomites distinguished in rock samples and thin sections study, CL (Machine type: Elm-32), SEM (Machine type: Inspect S50), EPM (Machine type: EPMA1610), stable isotopic analysis (Machine type: DELTA V Advantage), strontium isotope (Machine type: TRITON), and X-ray diffraction (Machine type: X'Pert MPD) were used to analyze the trace elements' distribution, microstructure, isotopic characteristics, mineral compositions, ordering degrees, and crystal cell parameters. Micromill was used to separate the 4 kinds of dolomites (micritic dolomite, fibrous dolomite, fine-medium crystal dolomite, and medium-coarse crystal dolomite) in the samples. The above analyses were accomplished in the CNPC Key Laboratory of Carbonate Reservoir and Zhejiang Technology University. Data are shown in Table 1.

The ordering degrees of dolomites reflect the distribution of elements in the dolomites. In the past, many researchers just used the whole rock to analyze the ordering degrees. Because of the complex carbonate fabrics, the data may NOT reflect the ordering degrees of different generations in the rock. Zhang et al., 2014 analyzed the ordering degrees of different generations in botryoidal dolostone and found the differences among different dolomite types in botryoidal dolostone (Table 2, data XF1-11-a, XF1-11-b).

Crystal cell parameter is significant in identifying the forming environments of dolomite. The *c*-values differ in different environments as a result of the interfusion of trace elements with long ion radius (Lei et al., 1992). In this paper, after the tests of *c*-values in different dolomites, the dolomites formed in marine, meteoric, burial environments were distinguished.

Surrounding Rock Characteristic

The mineral composition of surrounding rock is micritic dolomite, which is located in the center of the botryoidal dolostone. Micritic dolomite (Md in Figure 1e and Figure 1f) was the earliest sediment, the basis of the growth of every cements and the residual of paleokastification. Four typical micritic dolomites were selected to do the isotopic analyses, and three typical micritic dolomites were selected to analyze the ordering degrees and crystal cell parameters. The results show that their ordering degrees are 0.64~0.832 (Figure 3a and Table 2), which are obviously

lower than the crystalline dolomites. In virtue of the long-term diagenesis, the ordering degrees are a little higher than the one of the Miocene primary dolomites in the South China Sea (0.33~0.40). The crystal cell parameters of micritic dolomites are a little low (Table 2), which reflect the characteristic of normal marine water. Former studies show that the increased salinity of sedimentary water medium could bring the positive excursion of carbonate carbon isotopes (Clayton and Degens, 1959; Keith and Weber, 1964). The injection of meteoric and terrigenous freshwater would cause the decrease of $\delta^{13}\text{C}$. The $\delta^{18}\text{O}$ value has close relationship with the burial depth and temperature. Increased Strontium isotope would be affected by the terrigenous Strontium. Except one datum with negative $\delta^{18}\text{O}$ value (GS1-1) because of the diagenetic alteration, all other data are positive excursion ($\delta^{13}\text{C}=1.59\text{‰}\sim 4.52\text{‰}$, $\delta^{18}\text{O}=-2.82\text{‰}\sim -4.82\text{‰}$). The Strontium isotope values (0.7080~0.7090, Table 1) are a little lower than the one of Sinian marine water (0.7087~0.7094) (Halverson et al., 2007), which reflect that the sedimentation of micritic dolomite suffered less influence of the terrigenous ^{87}Sr .

Based on the above data, the micritic dolomites should formed as primary precipitates in the sedimentary stage.

The Characteristics of Botryoidal Dolostone

Automicritic Dolomite

As the earliest cement on the surrounding rock, the automicritic dolomites are also very fine micritic dolomites, but they have three kinds of differences with the surrounding rock micritic dolomites: (1) Automicritic dolomites have laminated bands. Surrounding rock micritic dolomites have homogeneous structure. (2) Automicritic dolomites have light-dark color changes, a little coarse granularity and regularly arrayed. (3) Some automicritic dolomites are similar to the micro-stromatolite, but there is little evidence showing that there were microbial activities in the sedimentation of automicritic dolomites. Due to the destruction of later diagenesis, the automicritic dolomites cannot be observed in every botryoidal dolostone. This cement is labelled as an “automicrite” because available evidence indicates that it formed within the cavities due to various physiochemical and possible biological influences.

Fibrous Dolomite

The most common type of cements found in the cavities from Member 2 is the banded isopachous fibrous dolomite cements that are formed of fan-like crystal arrays. The banding in these cements, from 1 to 5 mm thick, is defined by color variations that range from white to dark grey. Even the thinner bands are commonly characterized by microbanding that is defined by color contrasts (Figure 1c). They can be divided to two kinds: white fibrous dolomite and black fibrous dolomite. The fibrous dolomite cements (Figure 1e and Figure 1f, fd) developed after the automicritic dolomites and formed the 2nd cement.

The topography of the individual bands is highly irregular with each band paralleling the earlier formed band. In many samples it is impossible to determine the morphology of the crystals that form these bands. In some samples, however, there is clear evidence of fan-like crystal arrays. In each case, the base of the fan-like structure is rooted on one of the growth surfaces and expanded as it grew towards the cavity center. Micromill was used to drill the fibrous dolomite to do geochemical analysis. The results show that the contents of potassium and sodium are 220~900 $\mu\text{g/g}$ (Table 3). Exceptional sample has 7788.1 $\mu\text{g/g}$ potassium and sodium content, which reflect the high salinity environment. Iron contents are low and the stable isotope values have no obvious negative excursion ($\delta^{13}\text{C}$ is 2.29‰~2.85‰, $\delta^{18}\text{O}$ is -2.63‰~-3.43‰). The strontium isotope values (0.7089~0.7090, Table 1) accord with the marine water strontium isotopic range (0.7087~0.7094) (Halverson et al., 2007). Sr/Ba ratios are all greater than 1 (Table 3) except the XF-2a-1 sample which suffered the meteoric water effects. Because the marine sediments are rich in strontium and poor in barium, other data of the fibrous dolomites show the characteristic of marine environment. Shi et al., 2011 considered that the fibrous dolomites from Southeast Sichuan Basin were meteoric origin, but we gained the opposite results. Maybe the samples from the Southeast Sichuan Basin are close to the Nanchuan-Zunyi fault zone and suffered meteoric water effects which were linked by faults. SEM images show that the fibrous dolomites have perfect rhombic crystal forms (Figure 1d; Xiang et al., 1998) and are composed of many coalescence ultra-micro dolomites which parallel to the c-axis. The above SEM characteristics show that they were rapidly crystallized from marine water. Absolute ordered structure (Ordering degree=1, Figure 3b) and crystal cell parameter c-value=16.01 reflect the long-term diagenetic alteration to adjust to ordered. CL show that the luminescence of fibrous dolomites show concentric ring (Figure 1e and Figure 1f), which reflect that the fibrous dolomites formed in a space that they can freely grow and the compositions of marine water were stable.

The morphology of fibrous dolomites is very similar to the marine fibrous calcite. Sibley, 1991 put forward the conception “mimetic crystal” in early stage of mineral symbiotic series and considered that the aragonite or calcite could be replaced by dolomite but the original crystal morphology could remain. Mei, 2012 used the “mimetic crystal” to explain the preservation of fine dolostone structures in Precambrian strata. But there is little proof to prove this kind of synthesis.

The above geochemical data show that the deposition of fibrous dolomite cements should relate to the marine composition at that time. Some researches show that the abundant contents of dolomites in Precambrian challenged the understanding on dolomites. The special marine water of Precambrian might be aragonite-dolomite sea and the dolomite can just directly crystallize from the “dolomite sea” (Hood et al., 2011). If direct deposition of dolomite is true, then it is significant to explain the preservation of the fine multi-structures of botryoidal dolostone.

Fine-medium Crystal Dolomite with Traces of Fibrous Dolomite

The fine-medium crystal dolomites developed after the fibrous dolomites. They are euhedral-subhedral with high ordering degrees (0.905~0.97) (Figure 3c and Table 2). The CL of fine-medium dolomites (Figure 1e and Figure 1f, cd) show dark orange color. BSE images (Figure 3d and Figure 3e) indicate that the fine-medium dolomites show lighter color than fibrous dolomites. The sodium and strontium contents are obviously

low and the manganese content is obviously increased (325~867 $\mu\text{g/g}$). The iron content is Fe 1873~2801 $\mu\text{g/g}$. The above data concurs with the BSE images' characteristics. The strontium isotopic value (0.709420~0.709799) is higher than the value of marine water at that time. The carbon isotopic value (1.8‰~5.4‰) obviously deviated the isotopic value area of marine water. Sr/Ba ratio is greater than 1 (Table 3). Maybe the sedimentation of this generation of dolomites was still affected by the marine water. Some residues of fibrous dolomites could be observed in the fine-medium crystal dolomites (Figure 1e and Figure 1f arrow pointing to). Some fibrous dolomites were observed to be unequally dissolved. This is the typical characteristic that crystalline dolomite formed in the phreatic zone after the fibrous dolomites were dissolved.

According to the former researches (Lei et al., 1992), Dengying suffered large-scale uplift and secondary porosity developing: before long the Dengying Formation deposited, i.e. the fibrous dolomites crystallized, affected by the Tongwan movement, Dengying Formation strata was entirely raised to be exposed. The meteoric water dissolved some of the fibrous dolomite and brought about the secondary porosity. In study area, the bottom vadose silt and upper blocky dolomites formed geopetal structure (Figure 3d), which reflect the meteoric dissolution.

Medium-coarse Crystal Dolomites

Medium-coarse crystal dolomites (Figure 4a, red arrow pointing to the white dolomite crystals in the edge of the cave) were the 4th generation cement and filled part of the cave. They are subhedral-euhedral and the ordering degree is 0.93. Crystal cell parameter c-value is as high as 16.0623 (Table 2), which was caused by the entry to the lattices of metal ions with big radius. Geochemical data show that the highest iron content is as high as 7567 $\mu\text{g/g}$, which is the highest value in every kinds of dolomites (Table 3). The contents of potassium and sodium were too low to be tested, which indicated that the salinity was very low during the crystallizing process. The CL images are very dark or nonluminescence. The oxygen isotope data are very negative (as low as -9‰~-11‰), which reflect deep burial environment.

Origins of Botryoidal Dolostone

The present is the key to the past. Many researchers tried to use the present geological phenomenon to explain the past geological stories. Shi et al., 2011 tried to connect the Sinian Dengying Formation dolostone with the Great Bahama carbonate bank. Zhang, 1980 used the geological phenomenon that the gas field water from the Weiyuan stratigraphic well formed the botryoidal structure to explain the origin of botryoidal dolostone. In the present cave breccias, the multi-generational cementation is similar to the cements of botryoidal dolostone. Although they are not dolomitized, it can be imagined that after the primary deposition of micritic dolomites, the fibrous dolomites directly deposited from the marine water. After uplifting and exposure, the meteoric water dissolved some of the fibrous dolomites. In the phreatic zone, the fine-medium crystal dolomites including residuals of fibrous dolomites formed. During the deep burial stage, the medium-coarse crystal dolomites partially filled the pores. After burial diagenetic reconstructions, every dolomite fabrics turned to be stable and formed the present botryoidal dolostone.

After the micro-sampling and micro-fabric geochemical analysis, five different kinds of dolomites in different environments were distinguished: (1) primary deposition, (2) various physiochemical and possible biological influenced products, (3) directly deposited in marine water (later adjusted to be ordered), (4) meteoric environment, and (5) burial environment. Although many researchers considered that the dolostone were replacement origin. Huge thick dolostone series were hardly entirely replaced from limestone. Directly deposition of dolomites under special marine water still needs to be proved.

Significance of Botryoidal Dolostone Study

Significance to Dolostone Origin Study

There are other kinds of biogenic dolostones like stromatolite in Member 2 and 4 of the Sinian Dengying Formation (Zhang, 1980). Some researcher related the function of bacteria to the origin of botryoidal dolostone. If this is true, there should be traces of bacteria, but no traces of bacteria were found or reported in botryoidal dolostone. So there is not always a relation between the forming of botryoidal dolostone and algae. During the past researches, it is the hotspot of controversy that whether or not the dolomite were directly deposited. Not only the developed thick series of dolostone (including botryoidal dolostone) preserved the original structures, but also the limestone/calcite were seldom observed, which indicate that the formation of Sinian dolostones might have significant relationship with the special anoxic marine water rich in magnesium. The dolomite could directly deposit under aragonite-dolomite sea (Hood et al., 2011). There are many different generations of dolomites in botryoidal dolostone. Different generation of dolomite formed in different environments. So the origin of dolomites cannot be explained by a single model. Different fabrics of dolostone should be divided to analyze every generation's origin. The forming and later changes of dolomite are an endless process. More attentions should be paid on the fluid characteristics and later changes of dolomites.

Significance to Petroleum Exploration

There are multi-cementation in the macroscopically developed pores/caves related to the unconformities. After the sedimentation of fibrous dolomites, there was obvious dissolution. So there are dissolved traces of fibrous dolomites in the crystalline dolomites. The geochemical analysis on this stage of dolomites have proven that it is related to the paleo-karstification, which is commonly in the top of Member 2 and 4 of the Dengying Formation. These two main paleo-karstification are the indications to distinguish the meteoric leaching.

The symbiosis of botryoidal dolostone and dolostone rich in algae like stromatolites and oncolite is very often. These dolostones rich in algae are very good source rocks. In the botryoidal dolostone, there are many kinds of reservoir spaces, including caves (Figure 4a), solution fissures, dissolution pores (Figure 4b and Figure 4c), inter-crystal pores etc. Botryoidal dolostone is a significant kind of reservoir rock. Combining with the later meteoric leaching and linking, it is propitious to the generation, migration, and reservation of petroleum. Former studies on the

reservoir forming of botryoidal dolostone show that the botryoidal dolostone is significant to study the petroleum exploration of the Sinian Dengying Formation. The presence of multi-paleo-karstification is very important to guide the Sinian petroleum exploration in the paleo-uplift area which suffered erosion.

Conclusions

After the surrounding micritic dolostone originally deposited from seawater, the fact that each phase of cement is crystallographically and geochemically distinct indicates that each fabric probably formed at different times under different conditions:

1. The automicritic dolomite in some samples was the 1st stage cement, which formed within the cavities due to various physiochemical and possible biological influences;
2. The 2nd generation fibrous dolomite had absolute ordering crystal structure and near-ideal crystal cell parameter, which may have originated from marine waters and adjusted to be ordered during the later diagenesis;
3. The 3rd generation fine to medium crystal dolomite including traces of fibrous dolomite crystals formed near surface meteoric environment after tectonic uplift;
4. The 4th generation medium-coarse crystal dolomite primarily precipitated under burial environment and partially filled the central parts of the cavities.

It is apparent that the Dengying Formation was subject to multiple phases of diagenesis that included karst development, precipitation of various cements, and multiple episodes of dolomitization. Except the paleokarstification, all of the other processes critically reduced the porosity of the petroleum reservoir that developed in the Dengying Formation.

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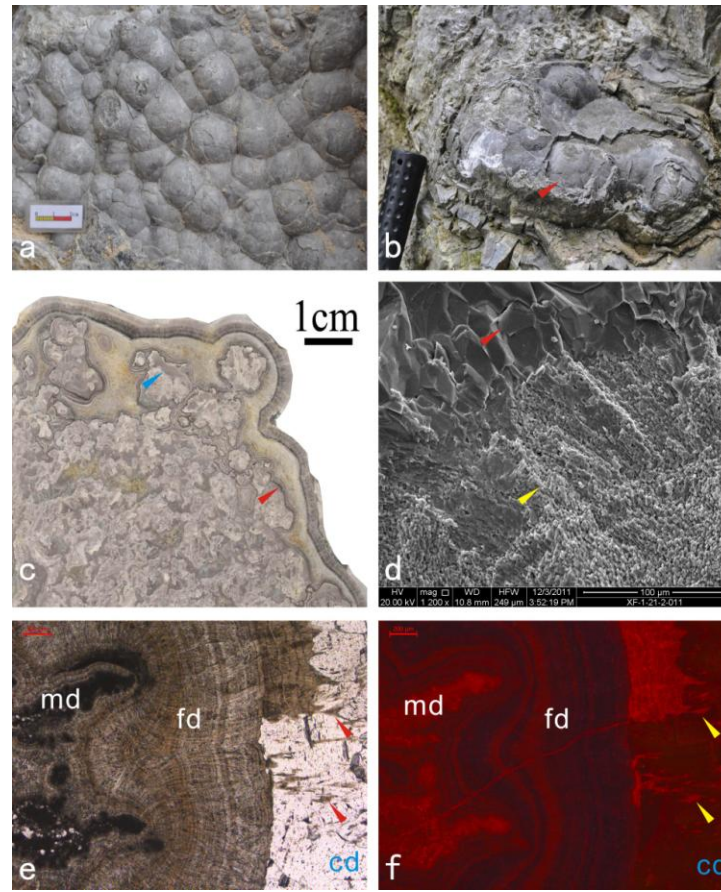


Figure 1. Petrological characteristics of the Botryoidal Dolostone in Member 2 of the Sinian Dengying Formation, Ebian Xianfeng Section, Sichuan Basin.

- a. The outcrop photo of small type botryoidal dolostone. The sizes of each knurl are 0.5~3 cm.
- b. The outcrop photo of big type botryoidal dolostone with multi-generational cementation. The sizes of each knurl are tens of centimeters.
- c. Polished surface photo of botryoidal dolostone with complex generational cements. Red arrow points to the borderline of micritic dolomite. Light yellow-grey minerals are the fibrous dolomite cements. Blue arrow points to the 1st stage automicrocritic dolomite with lamination structure.
- d. SEM photo of botryoidal dolostone. Yellow arrow points to the fibrous dolomites, which show automorphic dolomite crystals but show fibrous structure. Red arrow points to the powder to fine to coarse crystalline dolomites.
- e, f. The center of botryoidal dolostone is surrounding rock - micritic dolomite (md). The 2nd cement is fibrous dolomite (fd). The 3rd cement is fine-medium crystal dolomite (cd). Arrow points to the typical dissolved fibrous dolomite. The CL characteristic of remnant dissolved fibrous dolomite is light orange, as same as the one of the latest fibrous dolomite zone. E is the PPL photo and f is the CL photo.



Figure 2. The sampling locations of the Botryoidal Dolostone of the Sinian Dengying Formation, Sichuan Basin.

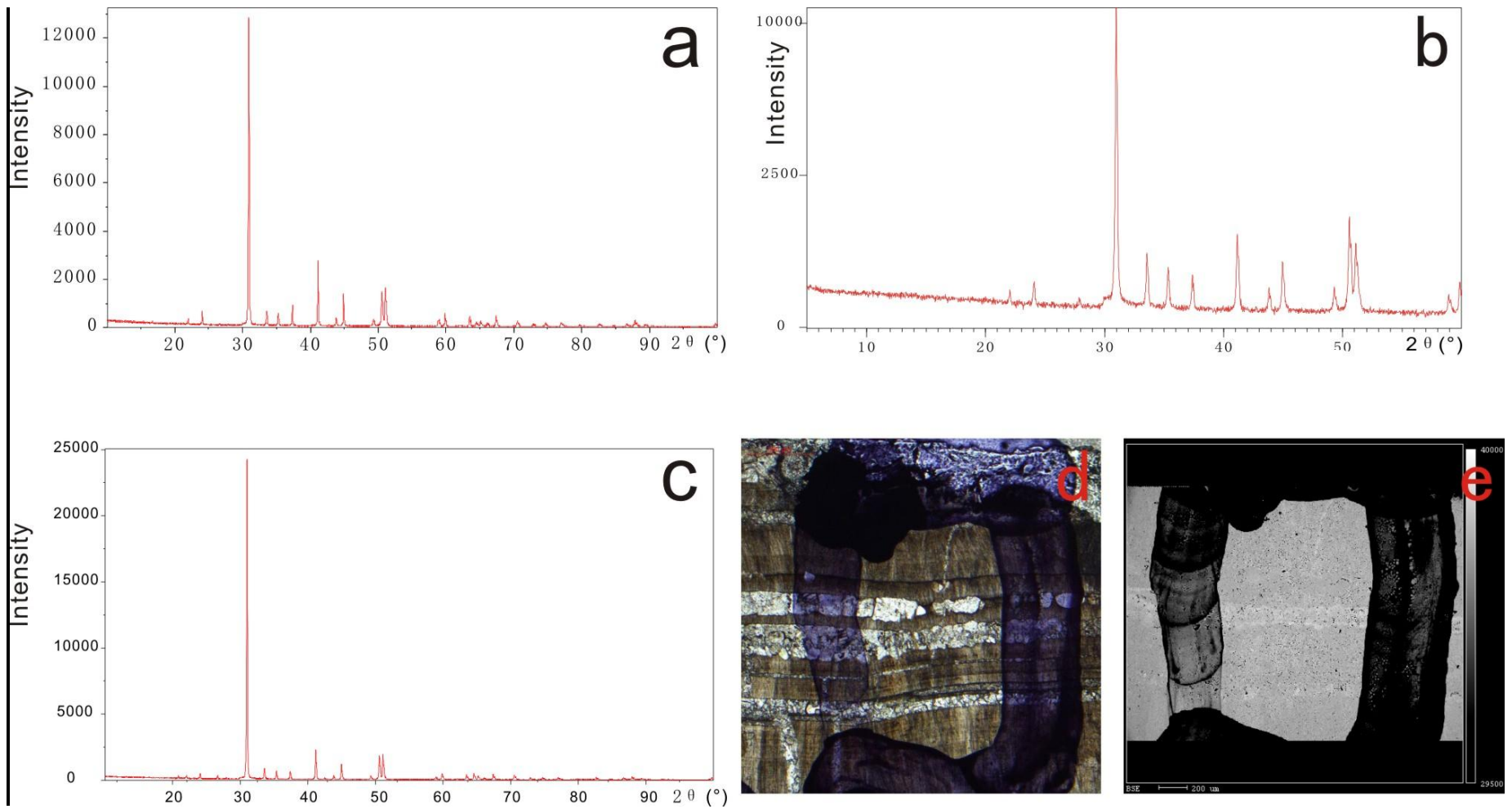


Figure 3. The XRD and BSE characteristics of different generational dolomites in Botryoidal Dolostone in Member 2 of the Sinian Dengying Formation, Ebian Xianfeng Section, Sichuan Basin.

a. X-diffraction spectrogram of micritic dolomites. The ordering degree is 0.64.

b. X-diffraction spectrogram of fibrous dolomite. The ordering degree is 1.

c. X-diffraction spectrogram of crystalline dolomite. The ordering degree is 0.97.

d, e. The fibrous dolomites were gone through by later fluid and fine-medium crystal dolomites were crystalized. PPL (d) and BSE images (e). These two photos reflect the differences of trace elements in different kinds of dolomites.

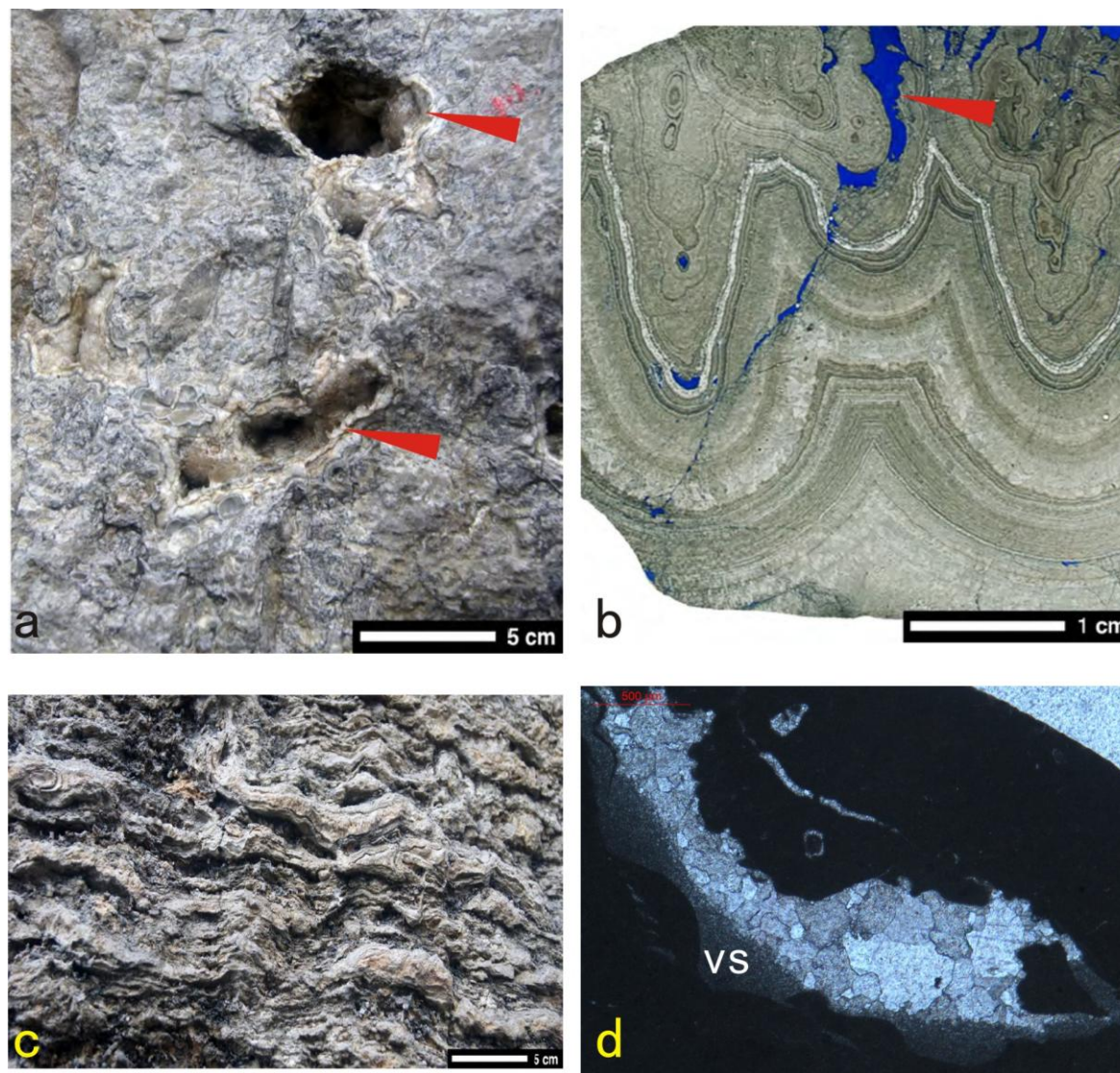


Figure 4. The reservoir types of Botryoidal Dolostone in the Sinian Dengying Formation, Ebian Section, Sichuan Basin.

a. Residual cave in botryoidal dolostone with about 5 cm diameter.

b. The solution fissure in botryoidal dolostone connected the unfilled pores (blue).

c. The undulation of botryoidal dolostone layer. Half-filled pores developed along the layer.

d. Vadoso silt (vs) filled in the bottom of pore in dolostone. The upper part of the pore was filled by sparry dolomites. Geopetal structure formed.

Sample number	Layer	Dolomite types	$\delta^{13}\text{C}/\text{‰}$	$\delta^{18}\text{O}/\text{‰}$	Strontium isotopes
JKH-1	Member 2	Micritic dolomite	1.59	-4.82	/
GS1-1	Member 4	Micritic dolomite	2.30	-8.51	0.707989
Yb-b1-a	Member 2	Micritic dolomite	4.52	-3.58	0.708994
Yb-b2-f	Member 2	Micritic dolomite	3.49	-2.26	0.708951
Yb-b3-a	Member 2	Black fibrous dolomite	2.85	-2.63	0.709003
Yb-b4-a	Member 2	White fibrous dolomite	2.29	-3.43	0.708954
GS1-3	Member 4	Fine-medium crystal dolomite	2.94	-5.67	/
Yb-b3-c	Member 2	Fine-medium crystal dolomite	3.04	-9.89	0.709799
Yb-b1-b	Member 2	Fine-medium crystal dolomite	4.01	-9.42	0.709420
GK1-3	Member 2 of	Medium-coarse crystal dolomite	1.71	-8.77	/
JKH-3	Member 2	Medium-coarse crystal dolomite	0.93	-11.41	/
Yb-b4-d	Member 2	Coarse crystal dolomite	3.12	-10.28	0.710909

Table 1. The geochemical data of different dolomite fabrics of Botryoidal Dolostone in the Sinian Dengying Formation, Sichuan Basin.

Sample number	Layer	Dolomite types	Ordering degrees	C-value of crystal cell parameters
GS1-1	Member 4	Micritic dolomite	0.64	15.9907
XF1-11-a	Member 2	Micritic dolomite	0.832	16.0189
JKH-27	Member 2	Micritic dolomite	0.645	/
XF1-11-b	Member 2	White fibrous dolomite	1	16.0100
XF1-11-c	Member 2	Fine-medium crystal dolomite	0.905	16.0170
GK1-3	Member 2	Medium-coarse crystal dolomite	0.97	16.0154
JKH-2	Member 2	Coarse crystal dolomite	0.93	16.0623

Table 2. The crystal structure characteristics of different dolomite fabrics of Botryoidal Dolostone in the Sinian Dengying Formation, Sichuan Basin (Data JKH-27 is from Lei et al., 1992).

Dolomite types	Fibrous dolomite							Crystalline dolomite			
Sample numbers	JKH-1-3	JKH-1-5	XF-1-1	XF-1-3	XF-2a-1	XF-2b-1	XF-2b-3	JKH-1-2	JKH-1-4	XF-1-2	XF1-18-R-1
Na	185.4	210.2	419.7	304.8	7365	695.2	503.5	20.79	5.636	69.28	<
K	40.67	46.46	33.38	64.38	423.1	202.9	123.9	0.344	5.034	10.62	<
Mn	158.4	174.7	377.9	206.5	93.73	263.5	119.1	329.7	325.7	867	890.1
Fe	393.6	427.9	1915	1709	429	1116	547.7	1873	2533	2801	7567
Sr	56.52	53.48	51.82	65.33	74.32	49.82	44.45	46.91	37.53	40.15	26.95
Ba	6.43	6.322	2.361	3.092	429.7	3.373	11.82	0.7841	0.4589	2.482	0.8671
Sr/Ba	8.79	8.46	21.95	21.13	0.17	14.77	3.76	59.83	81.78	16.18	31.08

Table 3. The trace elements contents of different dolomite fabrics in Botryoidal Dolostone in the Sinian Dengying Formation, Sichuan Basin (Unit: 10^{-6} . < means lower than the detection limit or not detected).