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## Lithofacies classification of fine-grained sedimentary rocks in the early Cambrian Qiongzhusi formation of Huize area, Eastern Yunnan Province

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# Lithofacies classification of fine-grained sedimentary rocks in the early Cambrian Qiongzhusi formation of Huize area, Eastern Yunnan Province

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**Abstract.** In recent years, the shale gas development boom around the world has made fine-grained sedimentary rocks become the focus and hotspot of sedimentological research. Lithofacies are rock types and assemblages formed in a certain sedimentary environment, and are important parameters in formation evaluation. The lithofacies classification of fine-grained sedimentary rocks is an important basis for the study of hydrocarbon source rocks, shale oil and gas and tight oil reservoirs. Anchored in the previous studies, the lithofacies classification scheme of fine grained sedimentary rocks in study area based on mineral composition was established in this paper. The results prove that the main lithofacies of Qiongzhusi formation in study area are mainly felsic clay rocks and clayey felsic fine-grained sedimentary rocks, and a small number of which are dolostone, limestone, felsic fine-grained sedimentary rocks, dolomitic felsic fine-grained sedimentary rocks, clayey felsic fine-grained sedimentary rocks, felsic dolostone, and dolomitic mixed fine-grained sedimentary rocks. This study can provide some geological basis for the evaluation and regional election of shale gas in this area.

## 1. Introduction

Fine-grained sedimentary rocks are composed of fine-grained sediments with particle sizes less than 62.5  $\mu\text{m}$ . Its complex composition mainly includes felsic minerals (quartz, plagioclase and potassium feldspar, etc.), carbonate minerals (calcite and dolomite), clay minerals (kaolinite, illite, montmorillonite and chlorite, etc.) and other authigenic mineral. Traditionally, mudstone, shale, clay and siltstone belong to the category of fine-grained sedimentary rocks [1-3]. Fine-grained sedimentary rocks are widely distributed, accounting for about 70% of the world's sedimentary rocks. As its sedimentation and diagenesis are more complex than other rocks, and subject to small particle size, difficult observation and ultra-microscopic experimental conditions, it is a weak field of geological research [2, 3]. Lithofacies are rock types and assemblages formed in a certain sedimentary environment. The Total Organic Carbon (TOC), brittle mineral content and physical properties of lithofacies are important parameters in formation evaluation. Therefore, the lithofacies classification of fine-grained sedimentary rocks is an important basis for the study of hydrocarbon source rocks,



shale oil and gas and tight oil reservoirs. In recent years, the shale gas development boom around the world has made fine-grained sedimentary rocks become the focus and hotspot of sedimentological research [4-7].

The early Cambrian Qiongzhusi formation ( $\text{C}_{1q}$ ) and late Ordovician Wufeng formation - early Silurian longmaxi formation ( $\text{O}_{3w}\text{-S}_{1l}$ ) in Sichuan basin and its peripheral regions are mainly shale gas exploration targets in China [8-10]. The major breakthrough of shale gas in Wufeng-Longmaxi formation has made China's shale gas reserves and output grow rapidly from zero, and become the third largest shale gas producer in the world [11]. The shale gas in Qiongzhusi formation has not achieved a major breakthrough yet, and the differential enrichment of shale gas has drawn the attention of petroleum geologists in China [12]. Qiongzhusi formation fine-grained sedimentary rocks in Qujing area of eastern yunnan province were studied on their reservoir geological conditions, reservoir characteristics and geochemical characteristics [13-16]. The research work in the study area is obviously insufficient and the lithofacies classification is rough, which restricts the exploration and development of shale gas. The mineral composition and lithofacies characteristics of Qiongzhusi formation are analyzed in this paper, in order to provide some geological basis for the selection evaluation of shale gas in this area. Qiongzhusi formation is approached with its mineral composition and lithofacies characteristics, with a view to providing geological basis for qiongzhusi formation selection evaluation.

## 2. Geological setting

Yunnan province is located at the junction of the Tethys-Himalayan tectonic domain and the Circum Pacific tectonic domain, and to the east of the collision zone between the Indian plate and the Eurasian plate. Huize area in eastern yunnan belongs to the southwest margin of the Yangtze block and is located in the northwest of Mile fault and the east of Xiaojiang fault. This area belonged to platform or quasi-platform from sinian to jurassic, and uplifted and denuded in yanshanian and xishanian, so the proterozoic-cenozoic strata were developed, with a dual structure composed of folded basement and sedimentary cover [13].

During qiongzhusi stage in early Cambrian, the depocenter of eastern yunnan was located in the area of huize - qujing - Malone, and the black rock series composed of black-grey-green shale, silty shale, carbonaceous shale and argillaceous siltstone were deposited [14].

## 3. Samples and experiments

Samples were collected from Laolin village, Dahai township, Huize county. The Qiongzhusi formation outcrop section is well developed with few overhangs. 21 samples were taken from bottom to top, depending on the color, structure and structure of the rock. In the sampling process, fresh rocks with weak weathering alteration should be selected to minimize or eliminate the influence of sampling difference and mechanical differentiation on the mineral composition of sediments.

According to the standard (SY/T 5163-2010), these samples have completed X-ray diffraction (XRD) experiments in Henan Polytechnic University (HPU): experimental method was XRD full spectrum fitting; qualitative recognition software was HighScore Plus; quantitative analysis system was Rockjack; experimental instrument was bruker D8 advance diffractometer (Germany); and whit the experimental conditions of  $5^{\circ}\sim 65^{\circ}$  scanning angle,  $1^{\circ}/\text{min}$  scanning speed, 40 kv voltage and 40 mA electric current.

## 4. Results and discussion

### 4.1 Mineral composition

According to the results of XRD analysis, the research sample mineral composition was given priority to with quartz, clay mineral, followed by calcite, dolomite, potash feldspar and plagioclase, also contains a small amount of halite, anatase, spinel and typical supergene minerals jarosite formed by oxidation of pyrite, individual samples containing a certain amount of gypsum (figure 1).

#### 4.2 Lithofacies classification scheme

Due to the limitation of existing data and characterization methods, lithofacies classification schemes of fine-grained sedimentary rocks at home and abroad vary greatly, and there is no unified standard [17, 18]. The essence of the existing lithofacies classification is based on one or several indexes, such as color, grain size, sedimentary structure, biological fossils, organic matter content, geochemistry and mineral composition. There are some problems in these schemes, such as expanding the lithology range of "shale", failing to establish a reasonable discriminating process, and lacking quantitative constraints on discriminating indexes. Therefore, several basic concepts need to be clarified here. Fine sediment refers to clay and silt sediments with particle size less than  $62.5\ \mu\text{m}$ , and its composition mainly includes clay minerals, silt, carbonate, organic matter, etc., in which the group with particle size less than  $4\ \mu\text{m}$  is divided into clay, and the material with particle size between  $4$  and  $62.5\ \mu\text{m}$  is silt. Argillaceous is mixture of clay and silt in general. Fine-grained sedimentary rocks may also be called mudlike rocks, of which those developed in foliation are called shale and those not developed in foliation are called argillaceous rocks. Clay rock is a fine-grained sedimentary rock composed mainly of clay.

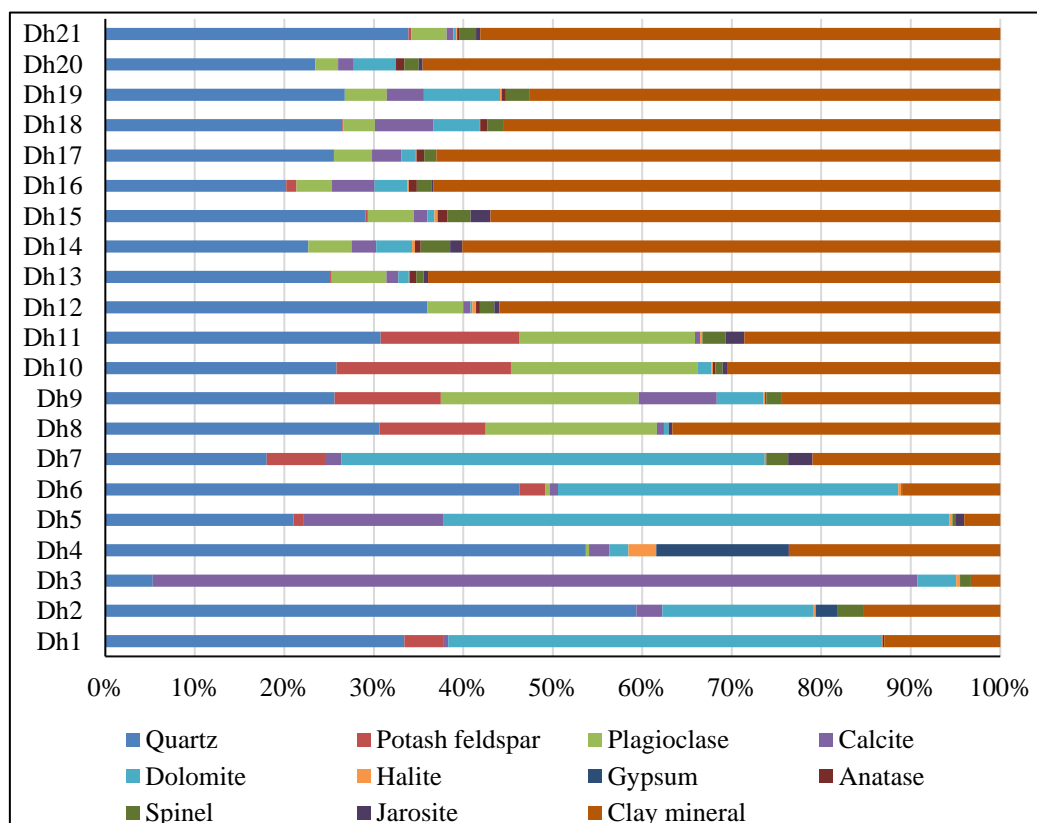


Figure 1. Mineral composition of Qiongzhusi formation in study area

As the mineral composition is the basis of the study of fine-grained sedimentary rocks, it affects the pore types, physical properties, brittleness and other characteristics, and should be the most important indicator of lithofacies classification [19]. In addition, XRD analysis can quantitatively determine the mineral composition of complex fine-grained sedimentary rocks. On this basis, the discriminant chart of fine-grained sedimentary rocks can be standardized and unified. Based on the research results of Lihong Zhou et al. [3], a lithofacies classification scheme for fine-grained sedimentary rocks is established (table 1).

In this lithofacies classification scheme, felsic minerals, carbonate minerals and clay minerals with generally high content in fine-grained sedimentary rocks are taken as three elements, and their relative contents after homogenization are used to divide the lithofacies: That with a content of more than 50%

are placed before the “fine-grained sedimentary rocks”, and that with a content of 25%~50% are placed

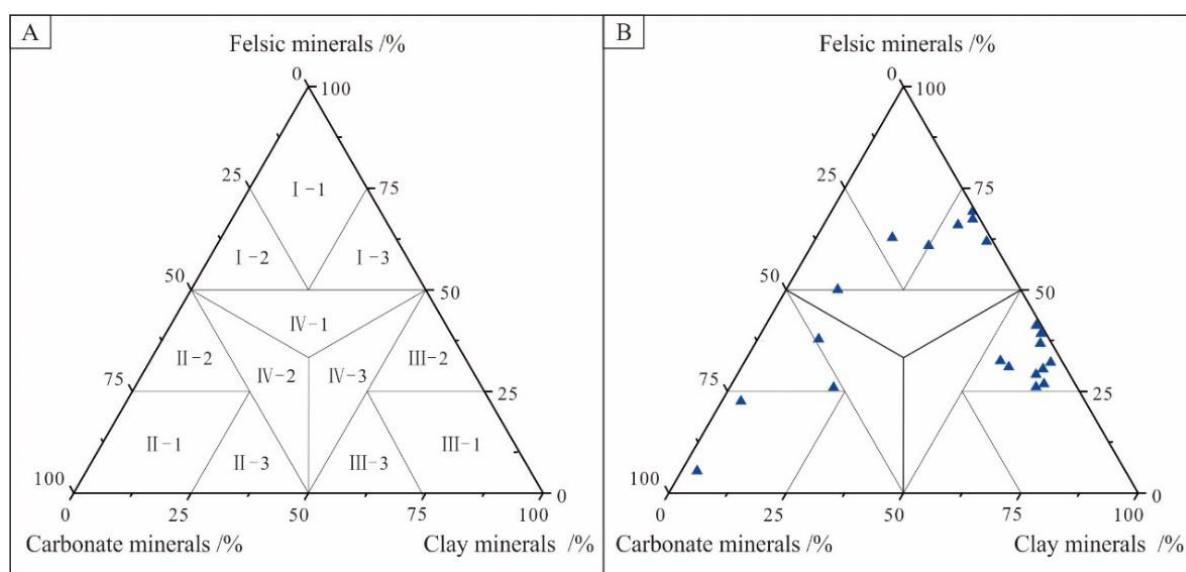
Table 1. Lithofacies classification scheme of fine-grained sedimentary rocks in study area

Main category	Code	Lithology	Code	The relative content of minerals (%)			Annotation
				Felsic minerals	Carbonate minerals	Clay minerals	
Felsic fine-grained sedimentary rocks	I	Felsic fine-grained sedimentary rocks	I <sub>1</sub>	≥50	<25	<25	
		Dolomitic / calcareous fine-grained sedimentary rocks	I <sub>1</sub>	≥50	<25	<25	
		Clayey fine-grained sedimentary rocks	I <sub>1</sub>	≥50	<25	<25	
Dolostone / limestone	II	Dolostone / limestone	II <sub>1</sub>	<25	≥50	<25	Dolomitic or dolostone indicates relatively high content of dolomite mineral; Calcareous or limestone indicates relatively high content of calcite mineral.
		Felsic dolostone / limestone	II <sub>2</sub>	>25	≥50	<25	
		Clayey dolostone / limestone	II <sub>3</sub>	<25	≥50	>25	
Clay rock	III	Clay rock	III <sub>1</sub>	<25	<25	≥50	
		Felsic clay rock	III <sub>2</sub>	>25	<25	≥50	
		Dolomitic / calcareous clay rock	III <sub>3</sub>	<25	>25	≥50	
Mixed fine-grained sedimentary rocks	IV	Felsic mixed fine-grained sedimentary rocks	IV <sub>1</sub>		<50		Felsic minerals are the most abundant
		Dolomitic/calcareous mixed fine-grained sedimentary rocks	IV <sub>2</sub>		<50		Calcite minerals are the most abundant
		Clayey mixed fine-grained sedimentary rocks	IV <sub>3</sub>		<50		Clay minerals are the most abundant

before the main name. That with all three elements less than 50% are called “mixed fine-grained sedimentary rocks”, and the one with the highest content is placed before the main name, and that with a content of 25%~50% placed in front of the name of the rock; anyone less than 10% does not appear in the name of the rock. For the special minerals with high content, they are named as the fourth component besides the three elements.

#### 4.3 Results of lithofacies classification

According to the results of lithofacies classification (Figure 2), the main lithofacies of Qiongzhusi formation in study area are mainly felsic clay rocks and clayey felsic fine-grained sedimentary rocks, and a small number of which are dolostone, limestone, felsic fine-grained sedimentary rocks, dolomitic felsic fine-grained sedimentary rocks, clayey felsic fine-grained sedimentary rocks, felsic dolostone, and dolomitic mixed fine-grained sedimentary rocks.



Note: the meanings of classification codes refer to table 1.

Figure 2. Lithofacies classification plate (A) and results of lithofacies classification (B)

## 5. Conclusion

The lithofacies classification scheme of fine-grained sedimentary rocks in the study area was established. Felsic minerals, carbonate minerals and clay minerals with generally high content in fine-grained sedimentary rocks are taken as three elements, and their relative contents after homogenization are used to divide the lithofacies: That with a content of more than 50% are placed before the “fine-grained sedimentary rocks”, and that with a content of 25%~50% are placed before the main name. That with all three elements less than 50% are called “mixed fine-grained sedimentary rocks”, and the one with the highest content is placed before the main name, and that with a content of 25%~50% placed in front of the name of the rock; anyone less than 10% does not appear in the name of the rock.

The main lithofacies of Qiongzhusi formation in study area are mainly felsic clay rocks and clayey felsic fine-grained sedimentary rocks, and a small number of which are dolostone, limestone, felsic fine-grained sedimentary rocks, dolomitic felsic fine-grained sedimentary rocks, clayey felsic fine-grained sedimentary rocks, felsic dolostone, and dolomitic mixed fine-grained sedimentary rocks.

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