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Effect of rock composition microstructure and pore characteristics on its rock mechanics properties

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ABSTRACT

This paper is to study the influence of composition, microstructure and pore characteristics on the rock mechanical properties. Five kinds of sandstone compositions were analyzed by using X-ray diffraction instrument. And the microstructure was observed by using scanning electron microscope. Then the pore distribution characteristic was investigated by using the low field nuclear magnetic resonance equipment. Finally, the uniaxial compression test was carried out to investigate the mechanical characteristics by using RMT150C mechanics experimental system and the uniaxial compressive strength, Poisson's ratio and elastic modulus were obtained. Compared to the analysis of the composition, structure and pore distribution and mechanical properties of the five kinds of sandstones, the relationship among composition, structure, pore distribution and mechanical properties was obtained. The results show that the composition, microstructure, pore distribution and mechanical properties of sandstone are closely related. With the decrease of feldspar and quartz particles, the compressive strength and elastic modulus increase, while the porosity decreases.

1. Introduction

Abundant high quality coal resources exist in the Ordos and Yulin coal fields, China, which have developed into an important modern coal production bases. However, the bedrock is relatively thin with low shear bond strength. This specific roof strata structure, as well as the high mining dynamic stress caused by the high strength mining. Severe dynamic disasters, such as large area roof falls and shield damaged were occurred by the high ground pressure. The specific physical and mechanical properties of the overlying strata are the internal factors causing the dynamic disasters. Therefore, the study of the physical properties of the overburden strata under this mining conditions is the fundamental research for the prevention of the dynamic disasters.

In recent years, many scholars have researched in this area with great success. Many valuable achievements on strata movement and control, and the microstructures of the shallow buried have been produced [1–12]. For micro-structure research, the relationship between micro-structure and rock mechanics properties has been analyzed [13–15]. Lindqvist et al. studied the effects of mineral composition, grain size, porosity and micro-fissures on rock mechanics properties [16]. Johansson confirmed that mineral composition, micropore porosity, grain size and shape as well as lamination are the most important factors influencing rock mechanics properties, He also summarized the different characteristics of various mineral composition and structure porosity as well as their effects on rock mechanics properties [17]. Tuğrul et al. recognized that the physical and mechanics properties of rock are functions of mineral composition and structure [18]. Přikryl concluded that the uniaxial compressive strength (UCS) of granite is closely related to its grain size [19]. Although many significant results have been obtained by numerous researchers in the past, there exist many problems in theoretical research and production process. Therefore the research on rock's mineral composition, structure and rock mechanics, especially the relationships among them are needed.

In order to study the effect of rock composition, micro structure and porosity on rock mechanics properties, five kinds of sandstones located at different depths were selected for this research. Their compositions were analyzed by X-ray diffraction instrument. The semi quantitative analysis of the components was carried out by using the Jade 6.0 analysis software. The microstructure characteristics were observed by using the scanning electron microscope of SM-6390LV. The pore distribution characteristics were investigated by using the low field nuclear magnetic resonance

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equipment. The uniaxial compression test was carried out to investigate the mechanical characteristics by using RMT-150C rock mechanics experimental testing system to obtain the uniaxial compressive strength, Poisson's ratio and elastic modulus. The compositions, structure, porosity distribution and rock mechanics properties of those five kinds of sandstones were systematically analyzed.

2. Laboratory facilities and test methods

2.1. Laboratory facilities

Composition analysis employed the X-ray diffractometer manufactured by Bruker Co. of Germany. For micro-structure analysis, model JSM-6930 all digital system with high resolution and high precision in variable focusing lens system made by Electronic Co. Ltd of was used. The low field nuclear magnetic resonance device made by Newman Electronic Scientific Co. Ltd was employed for analyzing the porosity distribution. The Model RMT-150 Crock Mechanics Testing system made by Wuhan Institute of Soil Mechanics was employed. All tests were performed with displacement-controlled at 0.002 mm/s.

Table 1
The stratigraphic column.

Number	Lithology	Buried depth (m)	Thickness (m)
A	Fine sandstone	143.70–146.10	2.40
B	Fine sandstone	314.10–320.00	5.90
C	Fine sandstone	345.50–347.60	2.10
D	Fine sandstone	200.60–201.70	1.10
E	Siltstone	119.50–122.20	2.70

2.2. Sample collection and preparation

Five kinds of sandstones, *A*, *B*, *C*, *D*, and *E*, located at different depths were selected for this research, The five groups of samples collected from the mine site were first divided into two parts. One part is for composition and SEM analyses, while the other for nuclear magnetic resonant analysis and rock mechanics testing. One sample from each kind of sandstone was made for composition and SEM analyses. The sample for composition analysis was ground to powder, while the SEM sample was made to a disk with a size of 0.5 cm × 0.5 cm × 0.5 cm. Samples for rock mechanic property and nuclear magnetic resonant tests were finished to standard cylinder test size with 50 mm in diameter by 100 mm

Table 2
Component analysis.

Sample	Mineral components (%)										
	Quartz	Feldspar	Kaolinite	Dolomite	Calcite	Gypsum	Micas	Pyrite	Chlorite	Clinochlore	Analcime
A	24.4	42.8		4.9	4.5			10.6			12.8
B	36.0	42.9	0.1				7.8	4.7		6.3	2.2
C	21.7	44.5	5.4				6.0	7.1	13.5	1.8	
D	47.2	27.8		0.2	7.5	17.3					
E	23.7	32.8		35.6			4.7				3.2

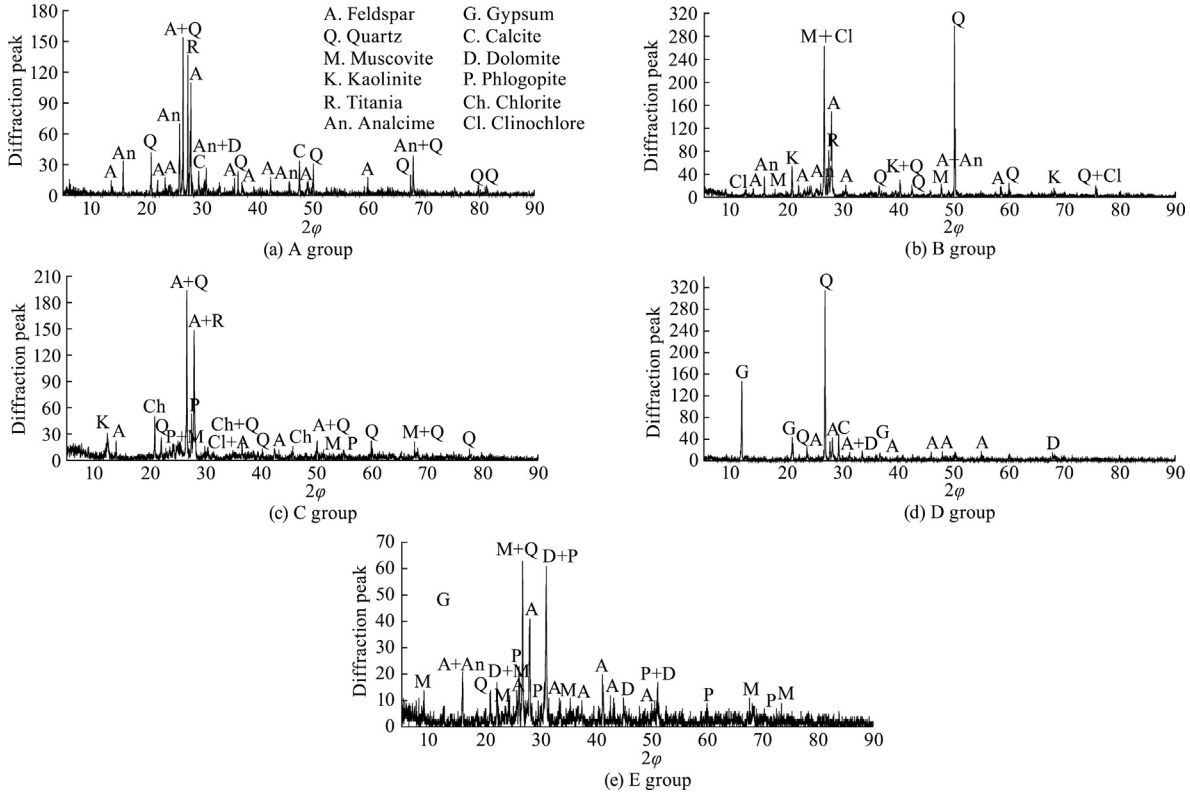

Fig. 1. X-ray diffraction analysis of sandstones.

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