Research on Microscopic Characteristics of Carbonate Reservoir Fracture fillings Based on Microscopic Infrared Spectroscopy

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Abstract. The characteristics of hole and seepage of carbonate rocks depend on the structural components of carbonate rocks and the combination relationship with these structural components under multi-scale. The quality of filling in reservoir fracture is an important part of fracture description. In this paper, the method of microscopic infrared spectral imaging was used, and the spectra cubic database was established by means of spectral imaging experiment. Each single band image which characterizes the related substances was extracted and the microcosmic characters of the filling in carbonate reservoirs fracture from Wumishan formation in Renqiu oilfield were studied. The spatial distribution maps of different chemical composition and groups in the core sample were obtained. The distribution of different hydrocarbon in the fracture of the reservoir and the connectivity of the pores etc. were better revealed
Keywords. Carbonate reservoirs; fracture; microscopic infrared spectral image.

1 Introduction

In the process of oil and gas exploration and development, fracture-cavity filling and connectivity in fracture-cavity carbonate reservoir is an important research topic [1-3]. The classic techniques commonly used are optical microscopy and X-ray diffraction, and often supplemented by scanning or transmission electron microscope. Although these detection methods have some achievements in the research of micro morphology, the common deficiency is that they can not distinguish the homogeneous or determination of partially ordered degree and other phase information, mainly because they stress on the spatial morphology analysis and lack of energy spectrum (mainly spectrum) analysis [3]. In the research of fracture fillings, the experimental method named imaging spectroscopy technology is urgently needed, which has the ability of spatial resolution and spectral resolution. The carbonate reservoir fractures of buried hill in Renqiu and microscopic characteristics of its fracture fillings were researched by microscopic infrared spectral imaging method, which provides a new way to fully grasp the physical properties of reservoir.

2 Imaging spectroscopy

In recent years, newly developed imaging spectroscopy system has combined spectroscopy and imaging technology organically [3] .The basic principle is to make spectrum (λ) for each pixel space site (X, Y) of the target, to form a so-called spectral cube (X, Y, λ), as shown in Fig.1.

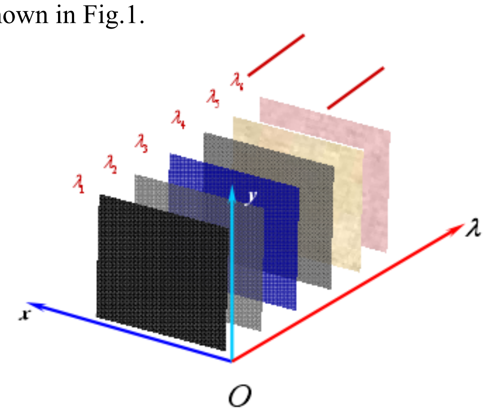

Fig.1 The sketch map of spectrum cube in imaging spectrum

It is can be seen from Figure 1 that the core of the imaging method is the integration of spatial information and spectral information of the target, which can analyze and identify the target in two aspects of the spectrum and space [3].

Fluid inclusion is one of the most important research objects in the study of fracture fillings[5,6]. Because of the mobility of fluid itself, it is only has high requirements of spectral resolution to keep the uniformity of the space in the range of entire fluid inclusions (especially fluid inclusions device of artificial simulation).

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3 The microscopic characteristics of carbonate reservoir fracture fillings in Renqiu Oilfield

3.1 General geology of the study area.

Renqiu oilfield is located in the transitional area between northern Central Hebei Depression Raoyang Sag in the west of Bohai Bay Basin and Baxian Depression area. It's a buried hill oilfields with Lower Palaeozoic and Middle-Upper Proterozoic Erathem carbonate as reservoir, the second and third segments of lower tertiary of Shahejie formation as hydrocarbon source rock, and the first segment of Shahejie formation and the Dongying formation for cover. Renqiu oilfield is one of the large and high producing ancient buried hill oilfields in the world. Renqiu ancient buried hill is 30km from north to south, 7km from east to west, and the area is about 183km2. Jixian system Wumishan formation is the most important oil producing layer in Renqiu buried hill. The core samples taking from Ren 28 well of Wumishan formation in Renqiu oilfield were analyzed in this work.

3.2 Infrared imaging spectrum experiment.

The sample used in the experiment came from Ren 28 well of Renqiu oilfield in Central Hebei Depression, which belong to the Upper Proterozoic-Jixian system-Wumishan formation layer. The well depth is 3227.9m and the mainly sedimentary facies is a shallow marine. The lithology is grey brown dolomite. The instrument used in this infrared spectral imaging experiment is Spotlight400/400N Fourier transform infrared / near-infrared imaging system which is produced by American perken-Aylmer company. The wavelength range of imaging mode is 7800-720cm-1, and the wavelength range of single point mode is 7800-600cm-1. In order to locate a sample area of infrared spectral analysis image in the infrared spectral imager, it is need to select and delineate on the black and white image displayed on a computer monitor visible with a red rectangular box. The results were shown in Figure 2. IR imaging experiment results of all sites in the sample area encircled by the red box in Figure 2 were stored in the computer, which forming the spectral cube database were shown in Figure 1. According to the need, it is easy to extract different information from the cube database obtained previously.

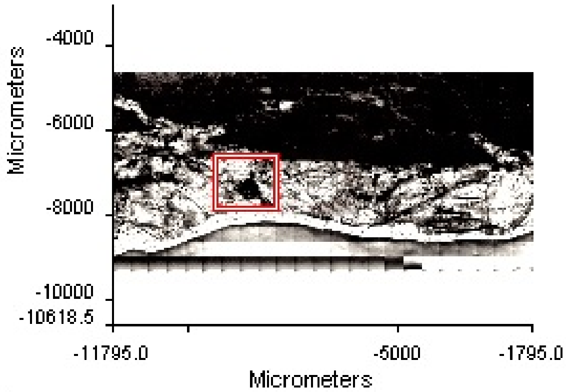

Fig.2 Visible black-white images of sample B008 of Ren28 (Red casing express the region of infrared imaging spectrum)

3.3 Experimental results and analysis

The infrared imaging spectral characteristics of the sample B008 of Ren 28 were studied as follows.

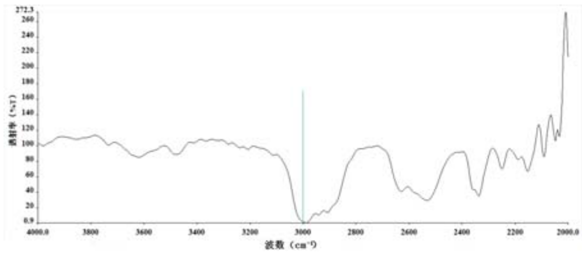

Fig.3 The infrared imaging spectrum of one space site of sample B008 of Ren 28

Figure 3 express the infrared spectrum of a certain C in the red box in Figure 2, i.e. the spectral intensity I（X_0，Y_0，λ）of a certain site（X_0，Y_0）in the spectral cube in Figure 1 changes along the wavelengthλ axis of the spectral cube. So the chemical composition of this site can be known. But it is only the spectral distribution of a certain site in the sample, which is not representative of the spectral distribution of various sites in the sample.

It is can be seen from Figure 3 that the infrared absorption spectrum (expressed by optical transmission spectra) of site C (shown in Figure 4) mainly includes symmetric and asymmetric stretching vibration absorption band of CH3–(methyl) and CH2–(methylene). It is indicates that the absorption of organic saturated hydrocarbons is in the dominant position of site C.

On the other hand, Fig. 4 indicates the absorbance spatial distribution of all the sites in the red region in Fig. 2. The absorbance intensity is expressed in a pseudo color, and on the right side of the diagram is a intensity scale. However, the absorbance of each site is the absorbance after spectral integration in the range of the entire measured spectrum, and the absorbance is the sum of all the substances in the sample. Since no spectral resolution, it is not known exactly what the chemical composition of the absorption. Therefore, it is necessary to seek the spectral images with spectral resolution according to the spectroscopy knowledge of the related substances.

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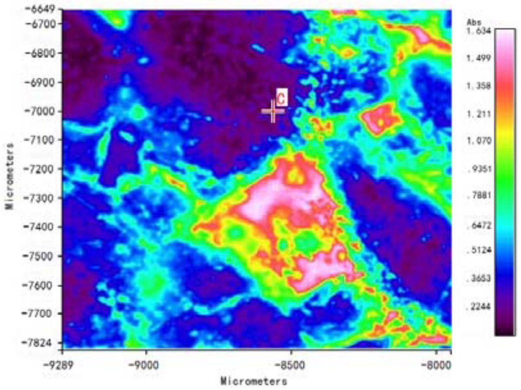

Fig.4 Space distribution imaging of infrared spectrum integral absorbance of sample B008 of Ren 28

As stated above, Fig. 4 is a pseudo color image using the integral value of the absorbance of the spectrum at the whole band. It is not only refers to the absorption of hydrocarbons, more are not the absorption of a specific chemical group in the hydrocarbons. It can not truly reflect the spatial distribution of oil and gas.

According to the spectral cube (as shown in Fig. 1) database obtained from the experimental measurements of infrared imaging spectra, each site (or pixel) of the sample select a specific chemical group in hydrocarbon, whose peak intensity of the absorption spectra or area integral value of absorption bands is performed imaging (in pseudo color). Fig. 5 and Fig. 6 express the spatial distribution of the sample at a single wavelength (or wave number).

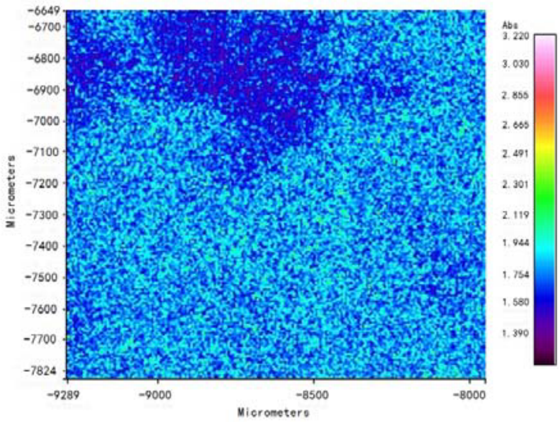

Fig. 5 Space distribution imaging of infrared spectrum single wave number（3000cm^{-1}）absorbance of sample

Fig. 5 is a single wave number spectrum imaging map, which characterizes CH_3–(methyl) and CH_2–(methylene) wave number of 3000cm^{-1}. It shows that there are only a few small area in the sample have the group.

It should be pointed out that the absorbance of the sample is proportional to the peak of the spectral absorbance or the absorption band area. Therefore the absorbance scale (in pseudo color) of all imaging spectrum (whether single wave number, or spectral integral) has only relative significance before standard sample calibration. But in the characterization of the absorbance (chemical composition) on the relative distribution of space it is meaningful.

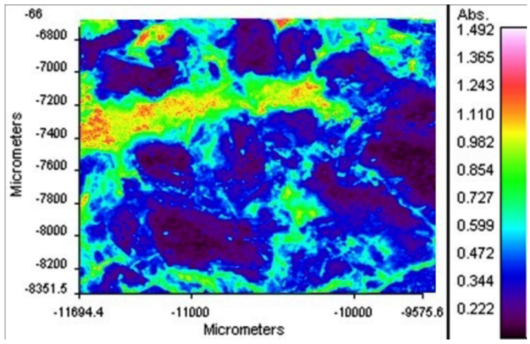

Fig. 6 Space distribution imaging of infrared spectrum single wave number（3500cm-1） absorbance of samples

Fig. 6 is a single wave number spectrum imaging map, which characterizes containing intermolecular or intermolecular association hydroxy wave number of 3500cm^{-1}. It has strong absorption, indicating the group is obviously existence in the crack area of the sample [4]. This indicates that there is hydrocarbon organic matter in the crack area of the sample. It can be speculated that there has oil gas migration in the crack.

4 Summary

Analyzing the spatial distribution of chemical composition of the fracture fillings can not only be judged by the spectral characteristics of several sites of the samples, or only depends on the absorbance spatial distribution of the spectral integral of the samples. It can be achieved with the help of the spectral cube database established by spectral imaging experiment, continuously extracting the single spectrum band images of characterizations of related substances. A new method for reservoir characterization is provided by the study of infrared spectral imaging characteristics of carbonate reservoirs fracture fillings.

Acknowledgements

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