Identification of clay minerals in reservoir rocks by FTIR spectroscopy

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Abstract. Clay minerals including kaolinite, montmorillonite and bentonite in oil and gas reservoir rocks are identified by absorption spectra obtained via Fourier Transform Infrared (FTIR) spectroscopy. Bands around 3695, 3666, 3650 and 3630 cm^{-1} and bands around 3620 and 3400 cm^{-1} are the most diagnostically reliable for kaolinite and montmorillonite, respectively; also absorption bands in the region of 1200…955 cm^{-1} are equally diagnostic for all the clay minerals studied.

1. Introduction

Currently the issue of studying the oil and gas reservoir rocks and clay minerals composing them becomes very important and relevant to in geology and oil and gas fields development. Clay minerals are formed as a result of alteration of such primary minerals as feldspars, micas, chlorides, etc., and as a result of their deposition as gels from colloid and true solutions. Clay minerals of montmorillonite, kaolinite and hydromica groups and mixed-layer formations prevail in a lot of clay rocks [1].

The structure of clay rocks including their size, shape, surface texture, structural elements quantitative and spatial relation and structural relation type is the main factor that determines clay rock properties. The clay rocks microstructure is a sensitive indicator of the rock formation environment and various combinations of microstructure features are in strong relation with the rock properties. The most important property of clay rocks is their swelling ability, i.e. an ability to expand when interacting with water and water solutions [2]. Clay rocks composed by clay minerals with a more elastic crystalline structure (like montmorillonite) and a less elastic crystalline structure (like kaolinite) show off the most swelling and the least swelling ability, respectively. Such clay minerals significantly impact the filtration properties of reservoir rocks and this has to be taken into account when designing oil and gas production methods.

It is a rather complicated task to identify clay minerals that compose reservoir rocks. For this purpose various methods including Mossbauer spectroscopy, thermo luminescence, thermal analysis, SEM investigation, X-ray diffraction, infrared (IR) spectroscopy and other are used [3]. Such methods are mutually complimentary and should be used in combination.

In this paper an IR spectroscopy was used to identify minerals by their characteristic absorption spectra [4].

2. Research methodology

The IR absorption spectra were recorded with a spectrophotometer Specord M40 in a region of 400…4000 cm^{-1} with a resolution of 0.01 cm^{-1} and a Shimadzu spectrophotometer IRPrestige-21 with Fourier Transform (FTIR-8400S) in a region of 300…4000 cm^{-1} with a resolution of 0.001 cm^{-1} (FT-IR), using the software IRsolution [5]. Study samples were taken from training collections and Mineralogical Museum collections of the Tomsk Polytechnic University and Tomsk region oil and gas fields. A sample was finely ground in an agate mortar to the powder with a particle size of 2 μm and less. Then it was mixed with KBr powder of Very Pure and Analytical Reagent (AR) grades, and then the powder mixture was put in a press mould and pressed at a high pressure to form translucent thin disks. When measuring IR spectra by a spectrophotometer FTIR – 8400S, a sample weight varied in the range of 0.1 – 0.5 mg.

3. Experimental results and discussion

The clay mineral samples shown in fig.1 can be attributed to kaolinite by IR absorption spectra. Their IR spectra demonstrate fully-represented and well-resolved Si-O-Si and Al-O-Si bands of the mineral lattice around 1102, 1033, 1014, 938, 755, 693, 541, 462 and 432 cm^{-1} and also clearly-seen absorption bands of OH stretching. The main distinctions of kaolinite-group minerals is observed in OH stretching absorption; particularly, there are two narrow and intensive absorption peaks around 3695 and 3630 cm^{-1} and weak band peaks around 3650 and 3666 cm^{-1} which are characteristic of an ordered variety of kaolinite [6, 7].

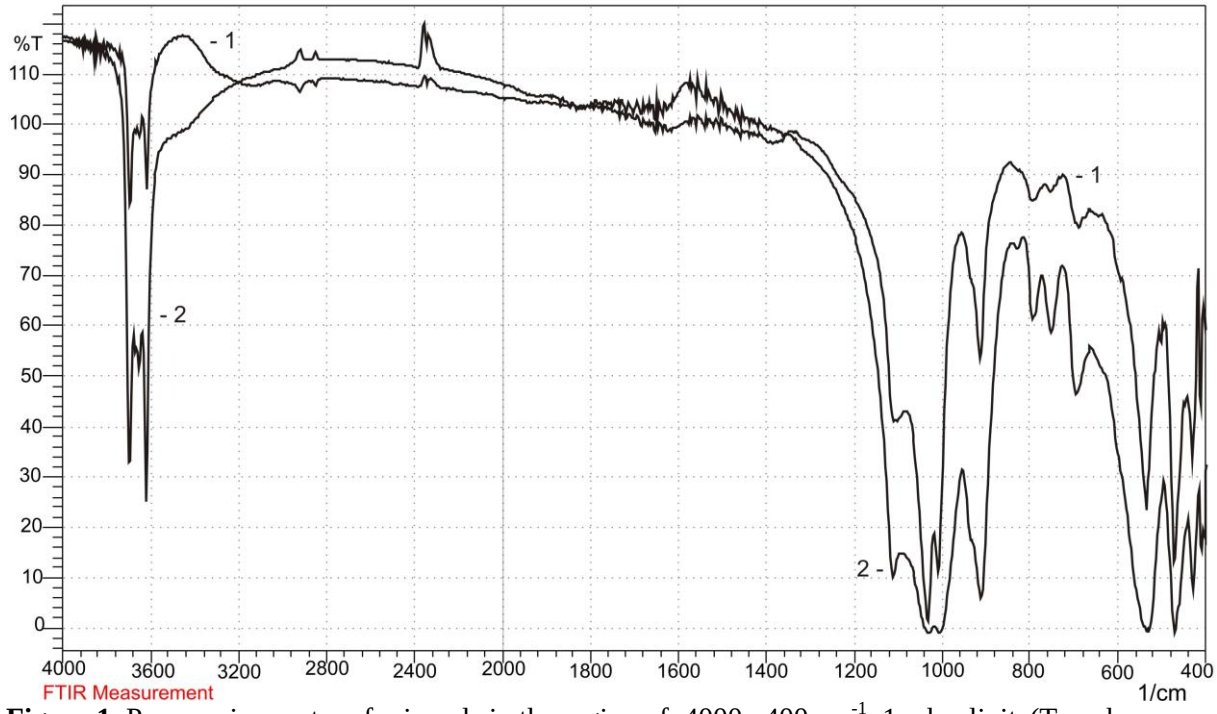

Figure 1. Panoramic spectra of minerals in the region of 4000...400 cm^{-1}: 1 – kaolinite(Tomsk Polytechnic University's training collection), 2 – kaolinite (Russia, Krasnoyarsk region, Field Verkhoturovskoye)

IR absorption spectra of montmorillonite-group minerals illustrated in fig. 2 are characterized by a double absorption peak around 3620 and 3400 cm^{-1}, an intensive peak around 1032 cm^{-1} and weak peaks around 920 and 842 cm^{-1} [6, 8]. Spectra of montmorillonite and bentonite, being a clay mineral whose main constituent is montmorillonite, are rather the same. The bentonite quality depends on the content and ionic

form of montmorillonite. The difference is that there appear intermediate absorption bands in the region of 1679…1600 cm^{-1} and that a weak splitting of the peak around 1032 cm^{-1} is and, at the same time, a weak peak is not observed around 1105 cm^{-1}.

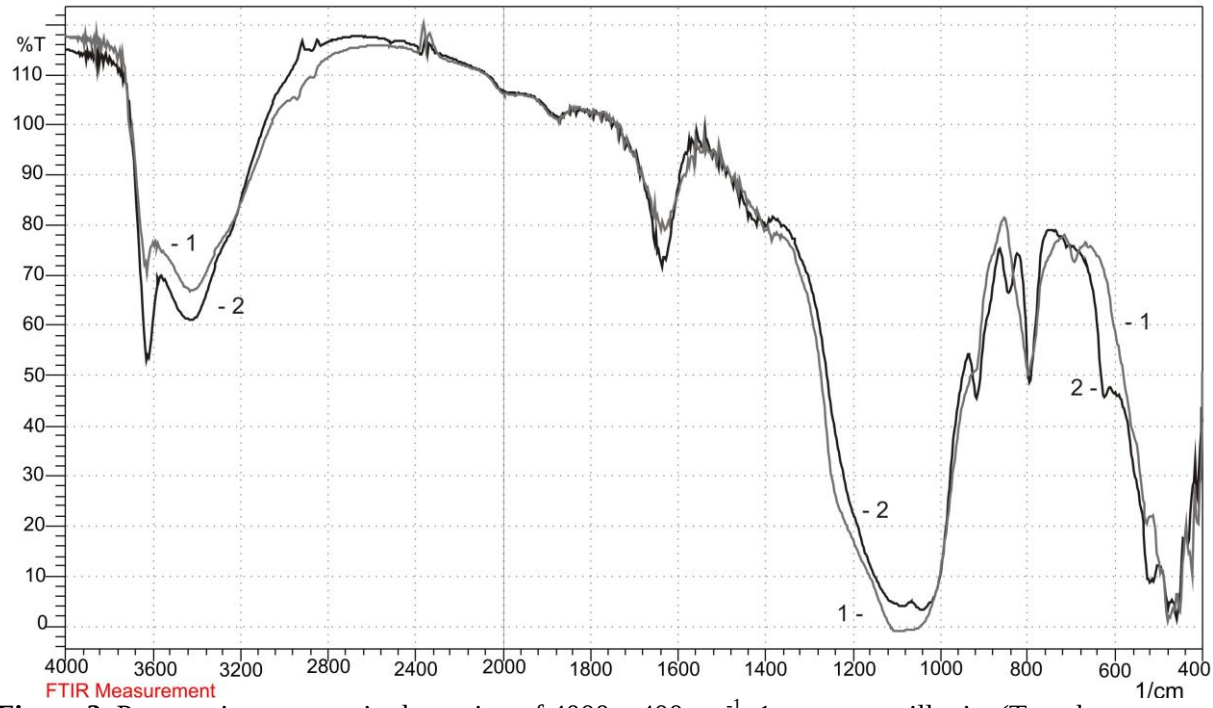

Figure 2. Panoramic spectrum in the region of 4000…400 cm^{-1}: 1 – montmorillonite (Tomsk Polytechnic University's training collection), 2 – bentonite (Republic of Tadjikistan)

4. Conclusion

Spectra of clay minerals are rather complicated; the intensity and position of IR absorption peaks are dependent on conditions of mineral formation and presence of various impurity ions and elements including Mg, Ca, Fe in a lattice of the mineral; the larger the ionic radius is, the more peaks shift to a longer-wave region. Comparison of IR spectra of various modifications of a clay mineral allows us to identify spectra of the mineral structure and to assess the impact of such mineral structure spectra on the structure itself. Bands around 3695, 3666, 3650 and 3630 cm^{-1} and bands around 3620 and 3400 cm^{-1} are the most diagnostically reliable for kaolinite and montmorillonite, respectively; also absorption bands in the region of 1200…955 cm^{-1} are equally diagnostic for the all examined clay minerals. Thus, an FTIR spectroscopy makes it possible to reliably identify unknown clay minerals. Currently, with the help of atlases and computer-assisted files of spectra, it is possible to identify any compounds, minerals and substances, provided that they and their vibration spectra have been already recorded and held in storage.

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