Indexed in
Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 05

October 2016, P.P.2268-2272

Lithological Identification of Conglomerate Using Resistivity Imaging Logging: A Case of Baikouquan Formation in Mahu Depression, Junggar Basin, Northwest China

YUAN RUI[1, 2], ZHANG CHANGMIN[2], QU JIANHUA[3], WU TAO[3], SUN YUQIU[1] AND ZHU RUI[2]

[1]School of Information and Mathematics, Yangtze University, Jingzhou, Hubei, 434023, China
[2]School of Geoscience, Yangtze University, Wuhan, Hubei, 430100, China
[3]Research Institute of Exploration and Development, Xinjiang Oilfield Company, PetroChina, Karamay, Xinjiang, 834000, China
***Email:** yuanrui87@163.com; zcm@yangtzeu.edu.cn*

Abstract: Mahu Depression, in the northwestern margin of Junggar Basin, is one of the most oil and gas bearing depression in the basin. On gentle slope region, a serial of large scale typical conglomerate fan-delta deposits were developed in Triassic Baikouquan Formation. Because of the complication of lithology, lithological identification of the formation is difficult and need to be solved for petroleum important exploration wells. Combining with cores and resistivity imaging logging, a typical lithological chart from resistivity imaging is formed for ten kinds of lithology of Baikouquan Formation in Mabei slope zone. According to the chart, lithology of twenty-one wells is recognized qualitatively. Moreover, result of qualitative identification is compared to that of observation and description of cores. Result of lithological qualitative identification of conglomerates based on resistivity imaging logging makes known the proposed method is feasible and effective.

***Keywords:** Mahu Depression, fan-delta, resistivity imaging logging, lithological identification*

1. Introduction

The exploration of Mahu Depression, one of the most hydrocarbon depressions in Junggar Basin, northwestern of China, has moved from the northwestern margin fault zone of basin to slope area of depression. In March 2012, the commercial oil flows from M13X well of Triassic Baikouquan Formation meant a breakthrough of hydrocarbon exploration in the slope area of Mahu Depression [1]. Baikouquan Formation in Mahu Depression was deposited as a series of fan-deltas [2-3], which is characterized by various types of complicated lithology and closely relates to distribution of the favorable reservoirs. Therefore, it's necessary to accurately identify the lithology of fan-deltas, which are nearly impossible using conventional logging methods. Benefit from ultrahigh vertical resolution, as high as 5 mm, and imaging function, resistivity imaging logging technology is promising to be used for identifying lithology finely [4-10]. On the base of calibration and comparison resistivity imaging with core, a typical lithological chart from resistivity imaging is formed. The lithological chart includes 10 kinds lithology of fan-delta sedimentary, such as mudstone, pebbly mudstone, siltstone, fine-sandstone, medium-sandstone, gritstone, pebbled sandstone, fine-conglomerate, pebble-conglomerate and cobble-conglomerate. According to the chart, lithology of twenty-one wells with resistivity imaging logging data is recognized qualitatively. What's more, the identification results are compared with the observation results of cores from coring wells.

2. Geological Setting

The study area is located in slope area of northern Mahu Depression, called Mabei slope area, northwestern margin of Junggar Basin, northwest China (Figure 1). The strong intensely syn-sedimentary faulting and thrust-nappe structures resulted in the northwestern margin of Junggar Basin belongs to the large-scale landlocked depression basin in Late Permian -Triassic Period, within multistage slope-break belt, which controlled the development of fan body in Mabei region. Triassic Formation, in ascending order, consists of Baikouquan (T1b), Karamay (T2k) and Baijiantan (T3b) Formation. As target formation in this paper, the thickness of Baikouquan is 120-250 m. The depositional system is typical large-scale, coarse-grain fan-delta on gentle slope, such as Xiazijie and Huangyangquan fan-delta [11-13]. The stratum mainly contains gray, grayish green and brown sandy conglomerate, conglomeratic sandstones and brown sandy conglomerate, and with grayish brown, brown mudstones and sandy mudstone [2-3]. Conglomerate is primary reservoir of hydrocarbon, whose character of lithology is complicated. So, resistivity imaging logging technique is used to identify the lithology of Baikouquan Formation in this paper.

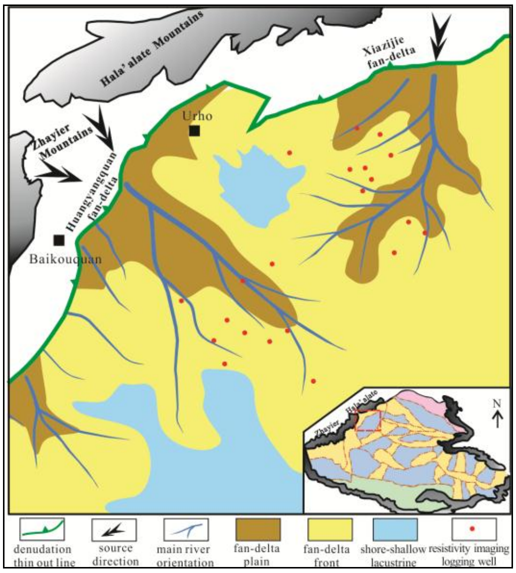


Figure 1: *Tectonic location of Mabei slope area in Mahu Depression and its sedimentary facies plans of Baikouquan Formation*

3. Database

There are more than 150 exploitation wells in the study area. Almost all of wells are measured by conventional logging suite, such as borehole diameter (CALI, in), gamma ray (GR, API), self-potential (SP, mV), deep investigation resistivity (RT, Ω·m), middle investigation resistivity (RI, Ω·m), shallow investigation resistivity (RXO, Ω·m), acoustictime(AC, μs/ft), compensated neutron(CNL, %) and compensated density(DEN, g/cm^3). Some wells have been bored with coring and major cores are color scanned for images in 360 degree.

Resistivity imaging logging raw data, acquired by FMI(Fullbore Formation MicroImager, Schlumberger) or XRMI(Extended-Range MicroImager, Halliburton), has obtained in twenty-one wells of Baikouquan Formation, eleven wells in Xiazijie fan-delta and ten wells in Huangyangquan fan-delta. The tools are designed to acquire data at a vertical resolution of 5 mm[14-15], which can measure a large quantity of micro-resistivity data from periphery of well. Disposal software offers two patterns of imaging: static image for lithological correlation throughout the full well; and dynamic image for fine lithological correlation of the local intervals [14-15]. The images use different color gradations from 0 to 255 representatives of different lithological characteristics. For example, dark color correspond to low resistivity, yellow to median resistivity, and light to high resistivity values, respectively. Depth discrepancy between conventional and resistivity imaging logging has been removes by GR form both logging. Calibration and comparison resistivity imaging with core, is a basic work of the resistivity imaging logging technology, which was processed in a depth scale of 1:5 in this paper.

4. Resistivity imaging logging characteristic of lithology

4.1 Grain size classification

Grain size of conglomerate is important index of hydrodynamic force and depositional environment. According to the grain size of criterion of for Baikouquan Formation in Mahu Depression, ten kinds lithology of fan-delta sedimentary would be identified, such as mudstone, pebbly mudstone, siltstone, fine-sandstone, medium-sandstone, gritstone, pebbled sandstone, fine-conglomerate, pebble-conglomerate and cobble-conglomerate (Table 1, Figure 2).

4.2 Resistivity Imaging Logging Characteristic

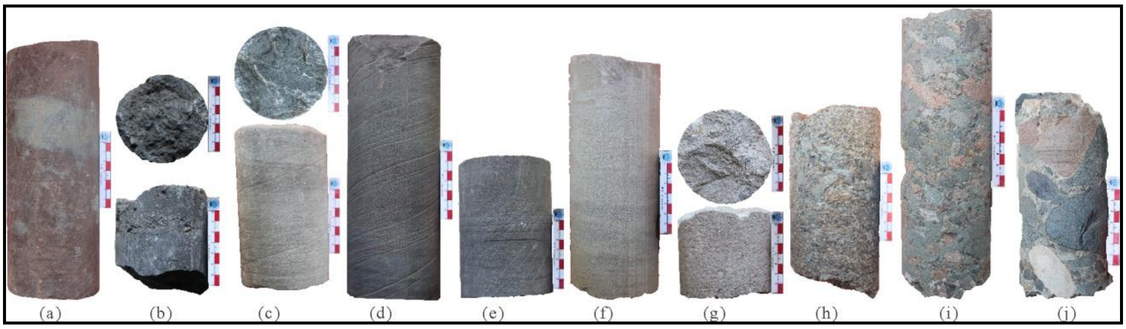
On the base of calibration and comparison resistivity imaging with core in the scale of 1:5, typical lithological chart (Figure 3) from resistivity imaging has been formed. Lithological identification of conglomerate using resistivity imaging logging is just based on the chart.

(1) Mudstone and siltstone

Mudstone (M) formation has low resistivity signatures, which correspond to dark massive (thick bed) or band (thin bed) of resistivity imaging. Because of floating gravel particles in mudstone, called pebbly mudstone (PM), resistivity imaging is dark massive or band with light scattered sports, which is often found in the core of Baikouquan Formation. Siltstone (S) corresponds to as slight light as yellow-dark massive or band imaging signatures.

Table 1: *Grain size classification and code for Baikouquan Formation in Mahu Depression*

	Mud	**Pebbly mud**	**Siltstone**	**Fine-sand**	**Median-sand**	**gritstone**	**Pebbled sand**	**Fine-cong.**	**Pebble-cong.**	**Cobble-cong.**
Grain size (mm)	<0.03		0.06-0.03	0.25-0.06	0.5-0.25	2-0.5		8-2	32-8	128-32
Letter code	M	PM	S	FS	MS	GS	PS	FC	PC	CC
Number code	1	2	3	4	5	6	7	8	9	10



(a) mudstone, MZ1 well, 4296.74 m; (b) pebbly mudstone, M604 well, 3869.98 m; siltstone, M601 well, 3844.99 m; (d) fine-sandstone, FN401 well, 2557.17 m; (e) median-sandstone, M136 well, 3252.68m; (f) gritstone, M603 well, 3803.1 m; (g) pebbled sandstone, FN10 well, 2743.7 m; (h) fine-conglomerate, AH13 well, 3148.28 m; (i) pebble-conglomerate, X723 well, 2714.2 m; (j) cobble-conglomerate, X75 well, 2413.63 m.

***Figure 2:** Typical coring photos of Baikouquan Formation*

Lith-ology	Code	Imaging Characteristic	Typical Image (DEP, Static Image, Dynamic Image, Core Iamge 0–10cm)
M	1	dark, massive or band	M15X well
PM	2	dark with light scattered sports, massive or band	AH1 well
S	3	dark-yellow, massive or band	FN1X well
FS	4	yellow, massive or band	M13X well
MS	5	light-yellow, massive or band	M15X well
GS	6	light, massive or band	M15X well
PS	7	yellow-light with sports, massive or band	AH1 well
FC	8	yellow-light, blurred particle	AH1 well
PC	9	yellow-light, blurred-clear particle	FN1X well
CC	10	yellow-light, clear particle	M15X well

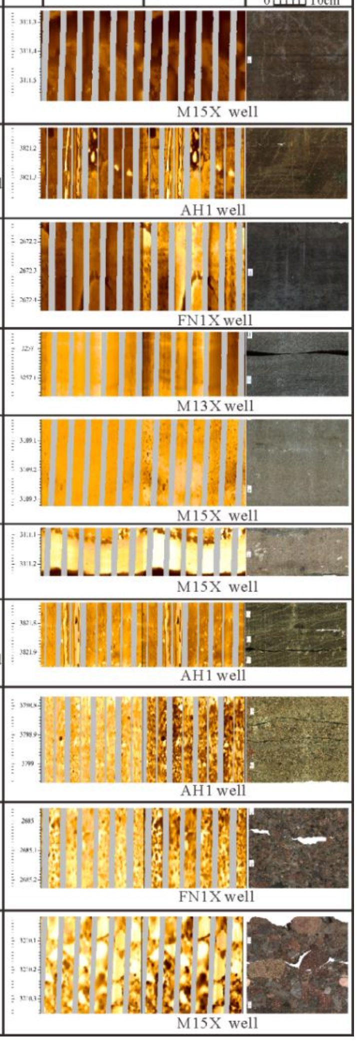


***Figure 3:** Typical lithology chart of resistivity imaging*

(2) Sandstone

Sandstone formation generally has median-resistivity characteristic. According to core observation, few sandstone in the Baikouquan Formation was deposited and almost in thin bed. Fine-sandstone (FS) is resistivity imaged to yellow massive or band signatures; median-sandstone (MS), as slight lighter as light-yellow massive or band; gritstone (GS) correspond to bright massive or band owing to high resistivity values. Be similar with pebbly mudstone, sandstone often mingling with gravel grains too, called pebbled sandstone (PS), in yellow massive with scattered light spots in resistivity imaging.

(3) Conglomerate

Conglomerate has high-resistivity characteristic, which are well-developed in the Baikouquan Formation in thick bed. Because of the vertical resolution with 5 mm, the resistivity imaging logging unit can effectively reflect the gravel grains in diameter more than 5 mm in yellow-light spot. Fine-conglomerate (FC), 2-8 mm in diameter, is imaged as blurred particles in yellow-light; pebble-conglomerate (PC), 8-32 mm in diameter, blurred-clear grains; and cobble-conglomerate (CC), 32-128 mm in diameter, clear particles.

5. Lithology Identifies

According to the typical lithology chart of resistivity imaging, lithology of 21 exploratory wells in Mabei slope area with resistivity imaging logging data, were qualitatively identified at a high depth scale. Figure 4 shows the lithological identification result, XRMI_Lith, of the Triassic Baikouquan Formation (3238-3407 m) in M13X well. Numbers for 1 to 10 are representative different lithology in Figure 3. As shown in the Figure 4, the Baikouquan Formation consists of coarse-grain sedimentary in the lower part stratum, coarse and fine-grain interbeddings in the middle stratum, and fine-grain deposits in the upper part stratum mainly. It is a type of regressive fan-delta.

The statistics of the lithological identification result for a 169 m interval of the Baikouquan Formation in this well indicates that this formation consists of pebble-conglomerate, 52 m in thickness, as dominant, accounting for 30.77% of the total formation (Figure

5). Cobble-conglomerate, 31.38 m in thickness, aggregates 18.57% of the total interval as secondary, while fine-conglomerate, 18.88 m in 11.17%.

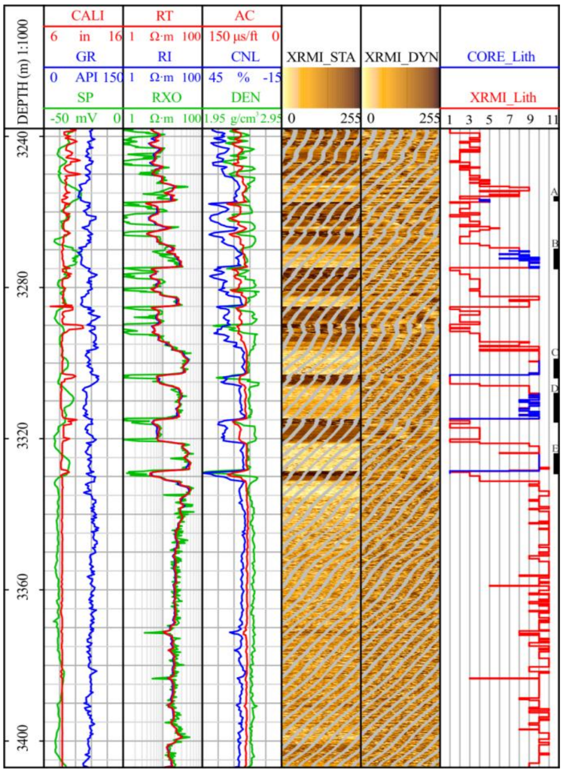


Figure 4: *Lithological qualitative identification result of Baikouquan Formation of M13X well*

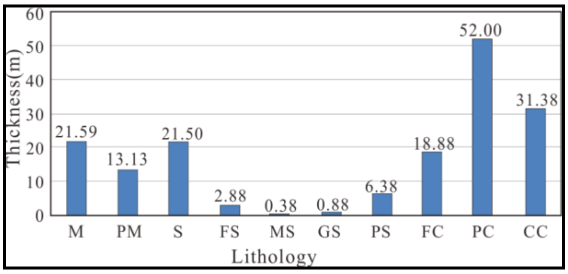


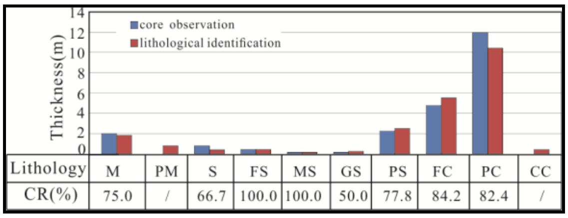
Figure 5: *Lithological qualitative identification statistical graph of Baikouquan Formation of M13X well*

Sandstone, including fine-sandstone, median-sandstone, gritstone and pebbled-sandstone, poorly developed as accounting totally for only 6.25% of the formation. Thickness and percentage of mudstone, pebbly mudstone, and siltstone are all little more than sandstone, 21.59%, 7.76% and 12.72% in respectively. So conglomerate is the main lithology, while mudstone and siltstone is secondly and sandstone is not development. These lithological content characteristics coincide with the proximal source, rapid accumulate of the fan-deltas in study area.

6. Result analyses

In order to examine the effectiveness of the chart and lithological identification result, five coring intervals (A, B, C, D and E in Figure 4) in M13X well were finely observed and described, observation results of the cores signed as CORE_Lith in Figure 4. Lithological statistics and correlation of the both result are shown in Figure 6. Coincidence rate of lithological identification is defined as ratio of thickness where XRMI_Lith is same with CORE_Lith to thickness of corresponding core observation result. No pebbly mudstone and cobble-conglomerate observed in the cores, no coincidence rate of them. Fine-sandstone, median-sandstone and gritstone almost appear as thin band, with thicknesses as limited as to about 0.15 m, which cause a significant influence on low coincidence rate. Mudstone, pebbled sandstone, fine-conglomerate and pebble-conglomerate are well-developed in coring intervals, with coincidence rate of 75.0%, 77.8%, 84.2% and 75.0% respectively. Therefore, by the typical lithology chart of resistivity imaging, lithological identification of conglomerate could be effective and reliable. It would be introduced to other fan-deltas in Mahu Depression of Junggar Basin.

For the coring intervals, resistivity imaging and its lithological identification result, core photos and its observation result are shown in Figure 7. Compare with coring, resistivity imaging logging has unique advantage in lithological identification. The coring of conglomerate would be break when well drilling. It is unfavorable in observed and described. For example, there is an erosion surface at 3274.8 m, pebble-conglomerate is overlying and mudstone underlay. But in core house, coring of 3274.8-3275.0 m had been gone and was absent. The erosion surface would not be described from coring, while is very clear on the image of resistivity imaging logging.



CR: coincidence rate

Figure 6: *Coincidence rate of lithological qualitative identification in M13X well*

7. Conclusion

A typical lithology chart of fan-delta sedimentary from resistivity imaging, including mudstone, pebbly mudstone, siltstone, fine-sandstone, medium-sandstone, gritstone, pebbled sandstone, fine-conglomerate, pebble-conglomerate and cobble-conglomerate, has been developed for Baikouquan Formation of Mabei slope area in Mahu Depression, northwestern margin of Junggar Basin. According to the chart, lithology of 21 wells with resistivity imaging data has been qualitatively identified detailed. What's more, the lithological identification result has been compared with the core observation result at the coring intervals, which makes known the proposed method is feasible and effective. Baikouquan Formation consists of the conglomerate as dominant, especially pebble-conglomerate; mudstone, pebbled sandstone, and siltstone as secondary. Sandstones are poorly developed in band and always mingling conglomerate.

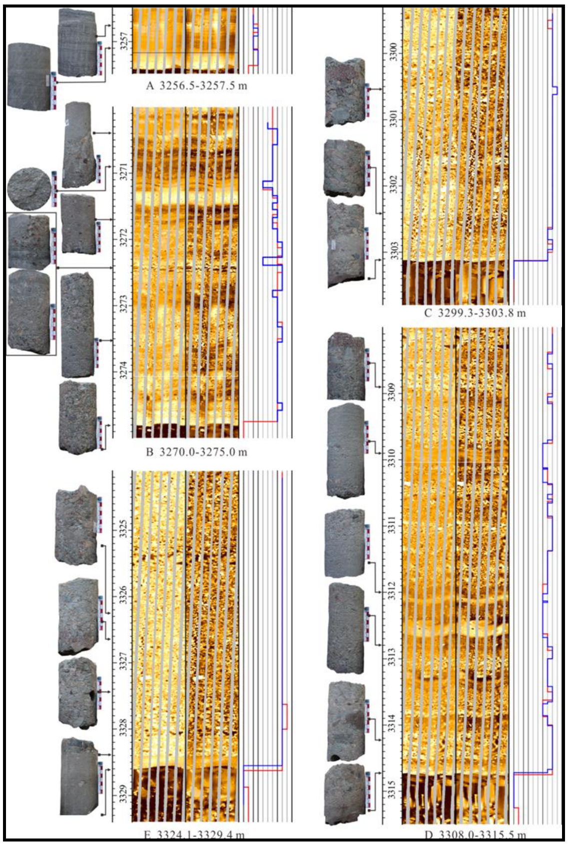


Figure 7: *Resistivity imaging, lithological qualitative identification result, core observation result and its photos*

8. Acknowledgements

This research has been financially supported by National Science and Technology Major Project (NO. 2016ZX05027-002-007) and Natural Science Fund of Hubei Province, China (NO. 2013CFA053). The support is gratefully acknowledged.

References

[1] Kuang Lichun, Lv Huantong, Qi Xuefeng, et al. Exploration and targets for lithologic reservoirs in Junggar Basin, NW China [J]. Petroleum Exploration and Development 2005, 32(6): 32-37.

[2] Yu Xinghe, Qu Jianhua, Tan Chengpeng, et al. Conglomerate lithofacies and origin models of fan deltas of Baikouquan Formation in Mahu sag, Junggar Basin [J]. Xinjiang Petroleum Geology, 2014, 35(6): 619-627.

[3] Zhang Shuncun, Zou Niuniu, Shi Ji'an. Depositional model of the Triassic Baikouquan Formation in Mahu area Junggar Basin [J]. Oil & Gas Geology, 2015, 36(4): 640-650.

[4] Michael P. Ekstroml, Claude A. Dahanl, Min-Yi Chen, et al. Formation imaging with microelectrical scanning arrays[C]. SPWLA 27th Annual Logging Symposium, June 9-13, 1986.

[5] J. C. Trouilier, J. P. Delhomme, H. Anxionnaz.1989 Thin-Bed reservoir analysis from borehole electrical images[C]. 64th Annual Technical Conferenceand Exhibitionof the Society of Petroleum Engineers, San Antonio, USA, October 6-11, 1989.

[6] J. P. Sovich, B. Newberry. Quantitative applications of borehole imaging [C]. SPWLA 34th Annual Logging Symposium, June 13-16, 1993.

[7] Akira Mizobe, Pieter J. Pestman, Toshiaki Takimoto, et al. Borehole electrical images as a reservoir characterization tool: Guarico 13 field, astern Venezuela[C]. SPWLA 43rd Annual Logging Symposium, June 2-5, 2002.

[8] Zhang Longhai, Dai Dajing, ZhouMingshun, et al. Application of imaging logs in studying lake basin sedimentations [J].Petroleum Exploration and Development, 2006, 33(1): 67-71.

[9] Yan Jianping, Cai Jingong, Zhao Minghai, et al. Application of electrical image logging in the study of sedimentary characteristics of sandy conglomerates [J]. Petroleum Exploration and Development, 2011, 38(4): 444-451.

[10] Atle Folkestad, Zbynek Veselovsky, Paul Roberts. Utilising borehole image logs to interpret delta to estuarine system a case study of the subsurface Lower Jurassic Cook Formation in the Norwegian northern North Sea [J]. Marine and Petroleum Geology, 2012(29):255-275.

[11] Yang Hai-bo, Qian Yong-xin, Li Zhenhua, et al. Analysis on exploration potential of the western Mahu Slope in Jungger Basin [J]. Acta Petrolei Sinica, 2005, 26(5): 82-85.

[12] Gong Qingshun, Huang Geping, Ni Guohui, et al. Characteristics of alluvial fan in Baikouquan Formation of Wuerhe oil field in Junggar Basin and petroleum prospecting significance[J]. Acta Sedimentation Sinica, 2010, 28(6): 1135-1144.

[13] Tang Yong, Xu Yang, Qu Jianhua, et al. Fan-delta group characteristics and its distribution of the Triassic Baikouquan reservoirs in Mahu sag of Junggar Basin [J]. Xinjiang Petroleum Geology, 2014, 35(6): 628-635.

[14] Tao Honggen, Wang hongjian, Fu Yousheng. The imaging logging technology and its application in Daqing Oilfield [M]. Beijing: Petroleum Industry Press, 2008, 2-16.

[15] AAPG/Datapages. Atlas of borehole imagery [M]. Tulsa: AAPG/Datapages, 2009.