Open Journal of Earthquake Research, 2020, 9, 417-426
https://www.scirp.org/journal/ojer
ISSN Online: 2169-9631
ISSN Print: 2169-9623

Study on the Igneous Rock Seismic Facies in Yingmai 32 Blocks

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How to cite this paper: Yan, L.L., Liu, Q.W. and Liu, X.F. (2020) Study on the Igneous Rock Seismic Facies in Yingmai 32 Blocks. *Open Journal of Earthquake Research*, **9**, 417-426.
https://doi.org/10.4236/ojer.2020.95024

Received: September 23, 2020
Accepted: November 27, 2020
Published: November 30, 2020

Abstract

The western part of north Tarim Uplift underwent multi-stage tectonic movement and multiple stages of magmatism. Igneous rocks are associated with carbonate and buried deep. The seismic response characteristics of igneous rocks are similar in many respects to the seismic response characteristics of karst, making the identification and prediction of igneous rocks more difficult. This study compares the seismic reflection characteristics of igneous rocks. Set up three types of igneous rock seismic facies model penetration type, fracture type and central type. And it concluded that a time-slice, coherence analysis, analysis of the seismic properties of the layers and the method of three-dimensional engraving to identify the igneous rocks. This method has been applied to the identification and prediction of carbonate rock buried and hill igneous rocks in the north Tarim basin YingMaiLi region and has achieved good results.

Keywords

Igneous Rock, Seismic Facies, Time Slice, Coherent Data Volume, Amplitude Tuning

1. Regional Geological Overview

Yingmai 32 well block is a long-term paleo uplift, which has experienced multi-stage tectonic movement, suffered serious denudation, and serious lack of stratigraphic development, forming a composite buried hill. The main formation period is from the late Early Paleozoic to the early Late Paleozoic, and from the late Late Paleozoic to the Late Triassic, which is the fault formation period. The faults are very complex and igneous rocks are relatively developed [1]. Basic extrusive rock, acid extrusive rock and pyroclastic rock are the main types. At the end of Carboniferous, magmatic activities began in this area, and the two main periods were the late Early Permian and the early Late Permian. The igneous rock distribution is very uneven and the regional comparability is poor. Before the Permian, the area experienced many large-scale tectonic movements, forming a series of major faults and network fractures connecting the basement. In the early Permian, the intermediate acid igneous rocks intruded along the network fractures, with poor mobility, and the magma continuously dissolved the thin overlying strata, forming a large irregular crater of nearly one thousand square kilometers, forming thousands of meters thick eruption rock and a large number of intrusive rocks, and the contact stratum has been modified to a certain extent [2]. However, due to the complexity of igneous rock lithology, deep burial, extremely uneven distribution, poor regional comparability, low signal-to-noise ratio of seismic data, and symbiosis with carbonate rock, the velocity of the two types of strata is very close, which is difficult to distinguish.

In this paper, the method of seismic facies analysis is used to distinguish igneous rocks. Firstly, the time slice and coherence body are used to identify igneous rocks, then the seismic attributes along the layer are analyzed, and finally the distribution of igneous rocks is three-dimensional carved.

2. Recognition of Igneous Rock Seismic Facies

Igneous rock is a kind of special rock body which is obviously different from conventional sedimentary rock. Its seismic facies reflects the physical characteristics of igneous rock, including the shape of igneous rock seismic emission on seismic section and slice, the contact relationship between wave group and surrounding rock, etc. Generally, igneous rocks have geophysical characteristics of high density, high magnetism, high wave velocity and high resistivity. In the seismic section, igneous rocks usually have the characteristics of plate, arc, mushroom, mound and other seismic facies [3] [4] [5]. Combining with the information of geology, drilling, well logging and logging, this paper analyzes the characteristics of igneous rock, makes fine demarcation on on the seismic section, summarizes the characteristics of igneous rock seismic facies, and then through analogy, identifies the igneous rock on the seismic attribute plan and seismic section, delimits its distribution range, and finally infers its genesis according to the characteristics.

2.1. Reflection Characteristics of Igneous Rock on Seismic Section

In this block, Yingmai encountered igneous rock 102 meters in Ordovician system, and its lithology is shown as acid igneous rock intrusion; 344M granite in Yingmai A well; 1010 m igneous rock in Yingmai B well, with eruption rock in the upper part and intrusion rock in the lower part; 7 m igneous rock in Yingmai C well. (See **Table 1**)

Table 1. Comparison of igneous rock wells drilled.

Well name	Drilling depth (m)	lithology	Seismic facies	remarks
A	344	Granite	Acidic igneous intrusions	
B	1010	Mainly rhyolite, andesite, tuff, etc.	The centrally erupted eruptive rocks flow down from the top of the volcanic crater, forming volcanic deposits with thin tops and thick wings. They have multiple stages, with obvious lithological interfaces and large-scale flaky distribution.	The shape is distributed in a larger scale (The distribution range of volcanic deposits is closely related to ancient landforms)
C	7	Igneous rock	Messy reflection, weak amplitude, poor stratification.	There are upward diverging magma channels, which are associated with faults.

Well B encountered a huge reddish-brown, gray-yellow igneous rock with slight changes in lithology, but all have the properties of eruptive rocks. On the seismic profile, there is a layered reflection, which is extremely incompatible with the occurrence of the surrounding rock.

Well C drilled into 7 m igneous rock; by calibrating the fine synthetic records of multiple wells, and marking the igneous rock development section on the seismic section, it is clear that the igneous rock in this block exhibits chaotic reflections on the seismic section, with weak amplitude and stratified the poor reflection characteristics (**Figure 1**) are clearly different from the layered reflection characteristics of carbonate rocks. In addition, because they generally have upward diverging magma channels, or associated with faults [6].

2.2. Characteristics of Eruptive Facies of Igneous Rocks

According to the analysis of the volcanic passage and the igneous rock wells encountered, combined with the regional geology, it is believed that the igneous rock development in this block mainly has three modes: penetration type, fracture type and center type.

2.2.1. Penetration Type

The main features are large vents, irregular shapes, mixed distribution of igneous rocks and sedimentary rocks, mainly acid rocks. As this area has experienced multiple periods of tectonic movement, a large number of networked faults can be seen. Analysis shows that during the Early Permian, the Silurian, Devonian, and Carboniferous strata in the Yingmaili area had different degrees of denudation, and the magma had relatively low fluidity. Hot magma continues to dissolve, and intrudes into the thinner overlying stratum along the reticular fissures, forming larger and irregular large-scale volcanic vent [7].

Wells B and C encountered intermediate-acid superficial and super superficial intrusive rocks, mainly reddish brown syenite and granite. This intrusive rock forms a mushroom shape with a small bottom and a large top, which invades upward along the fracture or weak plane of the formation, and its diameter ranges from tens of meters to tens of kilometers. It is in abrupt contact with the surrounding rock, its internal reflection is chaotic, the outline is clear, and On the plane, it appears as a circle of different sizes [8] [9] [10].

The penetration-type eruption area appears as the weak amplitude on the amplitude plane; it appears as a contiguous low coherence value on the coherent data volume. Mainly distributed around Yingmai B well, east to Yingmai C-Yingmai A well.

2.2.2. Fracture Type

The grout invades along structural cracks or faults, and the deep and large faults that pass through the basement can be clearly seen on the seismic section. The reflections are disorderly within a certain range, and the upward smoke spreads or the messy pull-down phenomenon, which is a reflection of the igneous neck of the crack-like eruption. The early east-west strike-slip faults in the study area and the compression faults in the north are the main channels for the migration of igneous rocks. As shown in **Figure 1** and **Figure 2**.

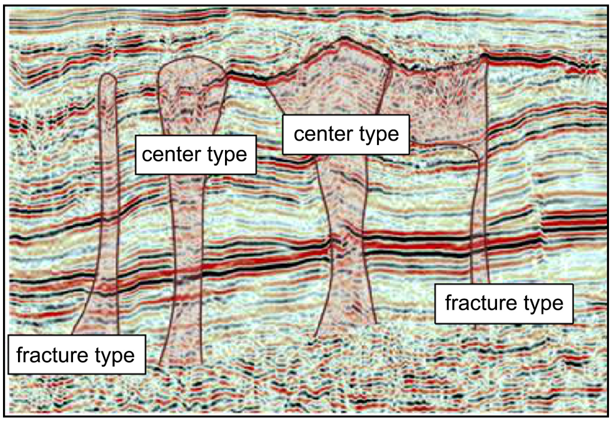

Figure 1. Fracture seismic reflection section.

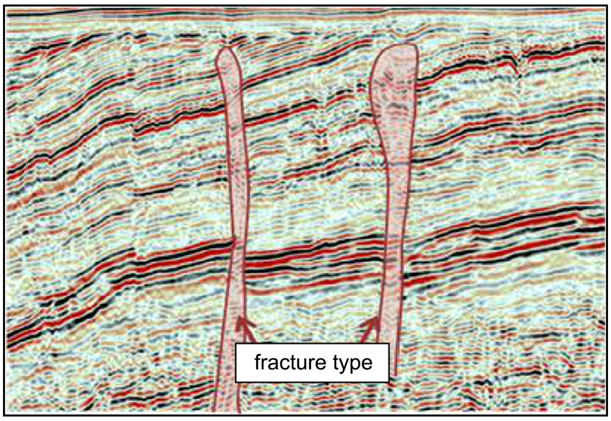

Figure 2. Fracture and central seismic reflection section.

Seismic facies are small in scale and pierce the overlying strata at a large angle along small faults or along weak zones of rock strata. Its contours are clear, internal reflections are rather messy, and most of them still vaguely retain the layered features of the original strata. The main seismic facies are Distributed in the east and north of the study area [11] [12] [13] [14].

2.2.3. Central Type

The main feature is that the channel through which the magma erupts out of the surface is tubular, with strong eruptions, a large number of pyroclastic materials are accumulated near the crater, and volcanic cones are formed on the outer edge of the crater. The performance on the plane is similar to the crack type.

The igneous rock invaded upward along the fracture plane on the seismic profile, and the strata were in abrupt contact with the strata. The internal reflections were messy and the contours were clear. They were distributed along the extension direction of the fault on the plane, often in the form of strips or beads.

2.3. Time Slice and Coherence Volume to Identify Igneous Rocks

Use seismic time slices to study the distribution characteristics of igneous rocks. Based on the reflection characteristics of each time slice in this block, the pink area in the figure is the area where igneous rocks are developed. The reflections of igneous rocks are very special, showing messy spots, weak or medium amplitude, with relatively smooth boundaries, which are easy to distinguish from the surrounding reflections. As shown in **Figure 3**.

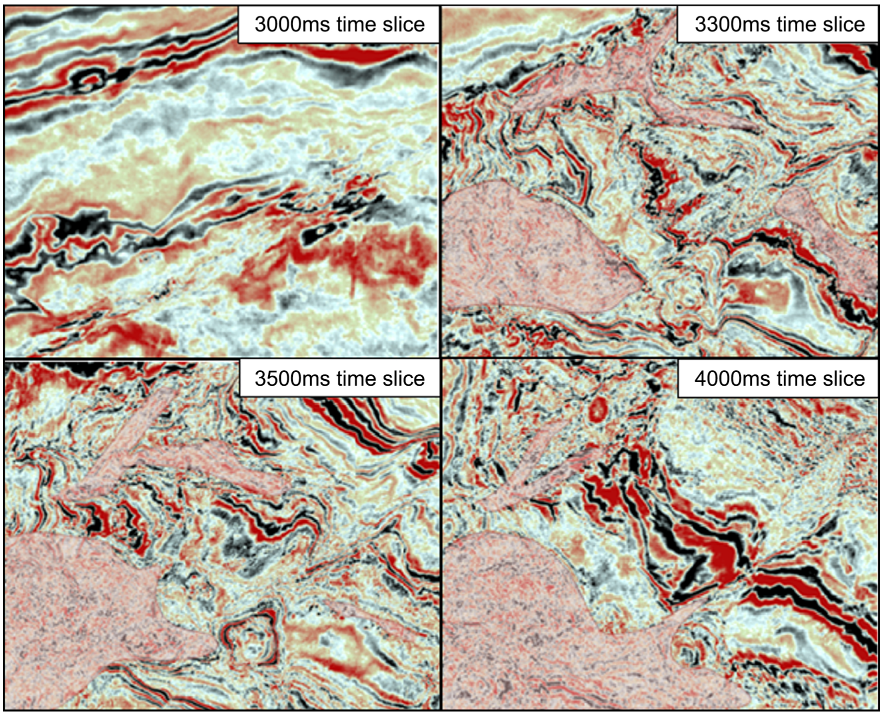

Figure 3. Time section of the study area.

2.4. Analysis of Seismic Attributes along the Layer

After careful interpretation of horizon calibration, multiple time windows and multiple attributes are extracted, and through comparative research, the appropriate time window is selected to accurately describe the distribution range of igneous rocks near the target layer. There are three main attributes: along-layer waveform clustering, amplitude attributes and frequency-divided amplitude characteristics.

2.4.1. Clustering Features

The phase changes of carbonate strata follow certain laws, while the changes inside igneous rocks are very messy, and the edges are in abrupt contact with the strata. Therefore, the distribution of igneous rocks can also be judged according to the instantaneous phase. The waveform clustering attributes are extracted along the top surface of limestone and the bottom surface of Lower Cambrian respectively in 100 ms, combined with seismic calibration and reflection characteristics of igneous rock, the regional igneous rock plane is divided. On the waveform clustering plan, the igneous rock interior is generally manifested as areas with chaotic reflections, weak amplitude, poor stratification, chaotic color code changes, and different heights, mostly igneous rock development areas. The color code changes gently and more uniformly for the carbonate strata, which is obviously different from the adjacent normal sedimentary strata with relatively good stratification, as shown in Figure 4.

2.4.2. Along the Layer Amplitude Information

Due to the influence of igneous rock lithology and minerals, the inner reflection of the igneous rock on the seismic profile has the weak amplitude. The root mean square amplitude is extracted along the reflection layer of the limestone top surface (0 - 30) ms, in which red is weak amplitude and blue is strong amplitude, as shown in Figure 5. It can be seen from the figure that the root-mean-square amplitude of the igneous rock developed near the buried hill appears to be weak amplitude. Near the strip-distributed fault, there are a series of weak amplitude areas distributed in points. The analysis shows that this is the intrusion of igneous rock along the fault. Some rock ridges or walls are reflected.

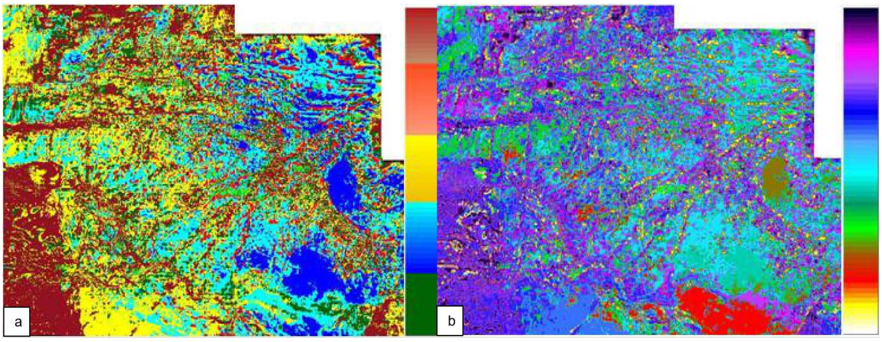

Figure 4. Waveform cluster diagram of limestone top surface and Lower Cambrian.

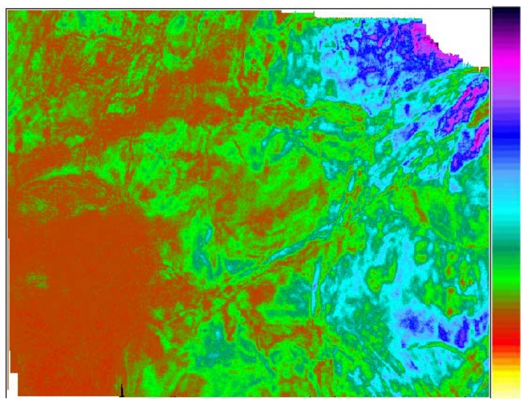

Figure 5. (0 - 30) ms root mean square amplitude attribute map of limestone top surface.

2.4.3. Frequency Division Amplitude Characteristics

Spectrum decomposition is to achieve time-frequency conversion through mathematical transformation. The seismic data volume is processed by frequency division, so that the resolution of seismic data is higher than the time resolution of 1/4 wavelength that can be achieved by conventional seismic main frequency, and the resolution effect is significantly improved. The igneous rock burial depth and the poor quality of seismic data in this area have obvious advantages.

The 15 - 35 Hz amplitude spectrum in the study area has a clearer description of igneous rocks. The upper Cambrian bottom to the top of the limestone and the lower Cambrian 30 Hz amplitude spectrum slices are extracted. The amplitude changes frequently and irregularly in the figure. The areas with scattered star points are mostly igneous rocks.

2.5. Three-Dimensional Sculpture of Igneous Rock Space

In order to show the development area and characteristics of igneous rocks more intuitively, we adopted spatial three-dimensional carving technology to sculpt the distribution range and characteristics of igneous rocks in this area. Through amplitude attribute three-dimensional carving, the igneous rock distribution was caved respectively from the Upper Cambrian to the buried hill and the Lower Cambrian. As shown in **Figure 6** and **Figure 7**. The pink three-dimensional display in the figure indicates the range of igneous rocks, and the unequal height indicates different intrusive heights of igneous rocks.

The distribution of igneous rocks was identified and predicted through seismic profile characteristics and various seismic attributes. Each seismic attribute has multiple solutions. In order to increase seismic attributes to accurately identify igneous rocks, especially in carbonate areas where igneous rocks are developed, since carbonate rocks are similar to igneous rocks, we adopted time slices and correlations. Based on the analysis of seismic attributes of the body and the stratum, and the spatial three-dimensional carving, they are carefully compared and analyzed. According to the calibration results of the drilling, each seismic attribute is analyzed carefully to distinguish the igneous rock and carbonate rock

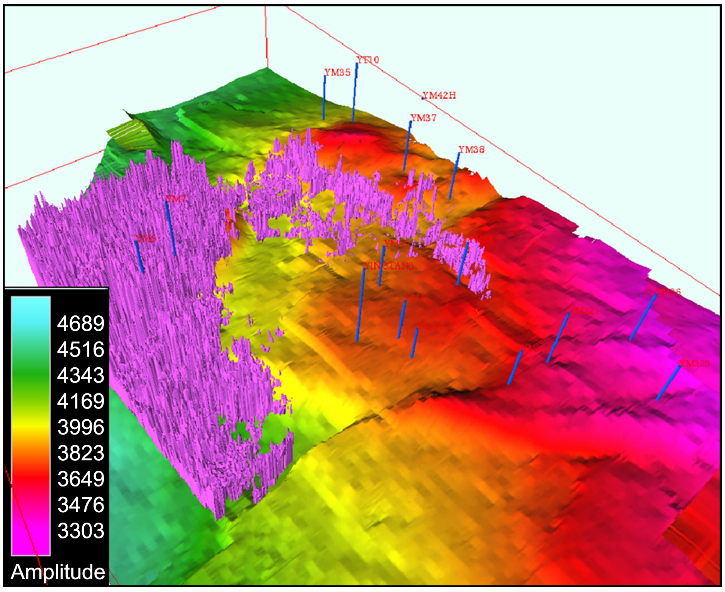

Figure 6. Three-dimensional sculpture of Lower Cambrian igneous rock.

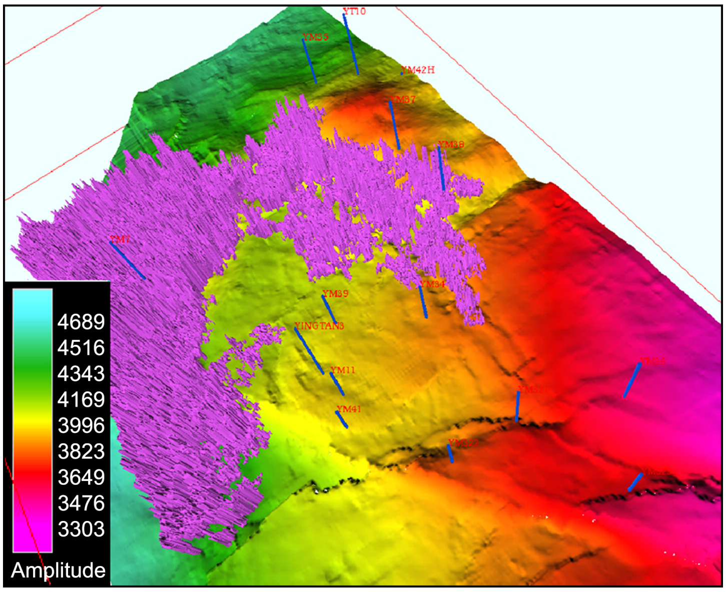

Figure 7. Three-dimensional sculpture of Upper Cambrian igneous rock to the top of buried hill.

strata [15] [16]. Comprehensive application of seismic profile features, multiple seismic attribute features and spatial three-dimensional carving techniques of igneous rocks, to finely identify igneous rocks in the Yingmaili area, divide the carbonate karst distribution areas, and avoid the nearby complex the igneous rock mass to obtain high-yield commercial oil and gas flow, which provides a basis for further exploration in this area.

3. Conclusions

1) Analyze the reflection characteristics of igneous rocks on seismic profiles,

and classify and describe the seismic facies types of igneous rocks encountered in the study area.

2) The study believes that igneous rocks are mixed with carbonate rocks and have similar seismic velocities. Through the comprehensive application of seismic facies, amplitude attributes, coherent data volume processing and frequency division processing, combined with 3D carving technology, the distribution range of igneous rocks in the area and The features are carved, and the igneous rock distribution is depicted through the 3D carving of the amplitude attribute, and the igneous rock distribution maps from the Upper Cambrian to the top of the buried hill and the Lower Cambrian are respectively carved, which can make a more accurate prediction of the spatial distribution of the igneous rock and form a set of technology series.

3) Analyze the similarities and differences of the seismic reflection characteristics of igneous rock and carbonate rock. So far this method has been applied to the exploration and development in the sixth, eighth and ninth areas of Karamay oil field and has achieved good results.

Acknowledgements

In the process of writing this article, I received great help from Hengtai Aipu Company and Guangdong Institute of Petrochemical Technology. I would like to thank you.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Chen, G.P., Pan, W.Q., Zheng, D.M., *et al.* (2007) Seismic Identification and Prediction of Igneous Rock Bodies in Carbonate Buried Hills. *Petroleum Geophysical Prospecting*, **42**, 87-93.

[2] Wang, W. (2017) Analysis of Genetic Model of Igneous Rock Reservoir in Pai 66 Block of Chunfeng Oilfield. *Journal of Southwest Petroleum University* (*Natural Science Edition*), **39**, 25-33.

[3] Luo, S.L., Shao, H.M. and Zhang, C.C. (2003) Overview of Volcanic Rock Oil and Gas Reservoir Research Methods and Exploration Techniques. *Acta Petrolum Sinica*, **24**, 31-38.

[4] Ren, K.X., Pan, W.Q., Gao, H.L., Han, L.J. and Zheng, D.M. (2007) Characteristics and Exploration Directions of Igneous Reservoirs in the Western Part of the Tabei Uplift. *Geological Prospecting*, **30**, Article No. 2.

[5] Cui, H.F., Zheng, D.M., *et al.* (2016) Distribution and Significance of Composite Buried Hill Strata in Yingmaili Area. *Progress in Geophysics*, **23**, 1514-1519.

[6] Wang, Y.J., Wang, G.Z., Wang, J.Z., *et al.* (2007) Application of Seismic Attributes in the Description of Igneous Rocks in Yingmaili Area. *Geophysical Prospecting for Petroleum*, **46**, 48-52.

[7] Zhong, W.W., Lu, S.F., Zhang, S.G., Huang, W.B., Shao, M.L. and Wang, L.W.

(2010) Physical Characteristics of Igneous Rock Reservoirs and Their Influencing Factors—Taking Longshen 1 Well Area of Yingtai Fault Depression in Southern Songliao Basin as an Example. *Acta Sedimentologica Sinica*, **28**, 563-571.

[8] Wang, W.F., Gao, B., Wei, P.S., *et al.* (2012) Research on Volcanic Reservoir Characteristics and Hydrocarbon Accumulation model. *Advances in Geophysics*, **27**, 2478-2491.

[9] Xiong, Y.X., Xi, A.H., Ran, Q.Q., *et al.* (2012) The Origin of Volcanic Primary Reservoir Space and Its Four-Stage Evolution—Taking the Carboniferous in Dixi Area of Junggar Basin as an Example. *Chinese Geology*, **39**, 146-155.

[10] Liu, S.Q., Zhang, S.C., Dai, L., *et al.* (204) Characteristics and Main Controlling Factors of High-Quality Carboniferous Volcanic Reservoirs in Junggar Basin. *Journal of Lanzhou University* (*Natural Science Edition*), **50**, 786-794.

[11] Xie, Q.B., Gao, X., Xia, Q.J., *et al.* (2012) Reservoir Characteristics and Controlling Factors of Igneous Gas Reservoirs in Yingcheng Formation, Changde Area, Songliao Basin. *Acta Geologica*, **86**, 1217-1225.

[12] Guo, Y.F., Luo, J.L., Liu, H.Q., *et al.* (2012) Mesozoic and Cenozoic Igneous Rock Reservoir Characteristics in Qikou Sag, Bohai Bay Basin. *Special Oil* & *Gas Reservoirs*, **19**, 33-36.

[13] Wang, J.H., Zou, C.N., Jin J.Q. and Zhu, R.K. (2011) Fracture Characteristics and Control Factors of Fracture Formation in Igneous Rock Reservoirs. *Petroleum Exploration and Development*, **38**, 708-715. https://doi.org/10.1016/S1876-3804(12)60005-6

[14] Zhou, D.L., Wang, Y., Zhang, X.B., *et al.* (2010) Favorable Igneous Rock Reservoirs and Oil and Gas Accumulation Analysis. *Petroleum Geology and Recovery Factor*. **17**, Article No. 5.

[15] Chen, G.P., Pan, W.Q., Sa, L.M., Han, J.F. and Guan, W.S. (2005) Application of Prediction Techniques in Carbonate Karst Reservoir in Tarim Basin. *Applied Geophysics*, **2**, 111-118. https://doi.org/10.1007/s11770-005-0042-4

[16] Sruoga, P., Rubinstein, N. and Hinterwimmer, G. (2004) Porosity and Permeability in Volcanic Rocks: A Case Study on the Sorie Tobifera, South Patagonia, Argentina. *Journal of Volcanology and Geothermal Research*, **132**, 31-43. https://doi.org/10.1016/S0377-0273(03)00419-0