Application of continuous lithologic models in the identification of pyroclastic rocks

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Abstract. The lithologic profile of pyroclastic rock is based on the sedimentary environment of multiple sources, which has the characteristics of lithologic grain variation of continental clastic rock and the characteristics of rock composition from different sources. Based on the physical characteristics of the logging project, the curve value contains two aspects of rock particle size and composition information, so it is necessary to judge the transition lithology with thin thickness and complex composition according to the change relationship between upper and lower lithology. According to the variation characteristics of pyroclastic rock in the logging response of Hailaer Basin, a continuous lithologic profile variation model is established, which effectively improves the identification accuracy of transitional lithology in the lithologic profile.

Keywords: Pyroclastic rock; Lithology profile; Continuous mode; Logging response; Transition lithology.

1. Introduction:
Volcanic clastic rocks are widely developed in the Nantun Formation and the strata below in Hailaer Basin. The lithology includes pyroclastic rock, common sedimentary rock, volcanic lava and transitional rock. Accurate identification of these complex lithologies directly affects the effect of reservoir evaluation in Hailaer Basin. In recent years, great progress has been made in lithology identification of igneous rocks by using new techniques such as acoustoelectric imaging and ECS. At present, most of the lithology identification work focuses on the logging response data of the lithology analysis samples, and establishes the lithology identification standard by means of cross-plot and cluster analysis, without considering the internal correspondence between the continuous variation trend of the logging response and the sedimentary law of the lithology profile. The research results of this kind of property are suitable for the identification of the non-existent (or less existent) transitional lithology in the object, and the sedimentary thickness of the same lithology reservoir is larger. In literature [4], the corresponding relationship between the continuous variation trend of logging response and the lithology change of reservoir was fully considered, and a practical identification technology was established for the continuous section of sand and mudstone, which well solved the problems of the weak resolution ability of logging response and the weak lithology reflection ability of thin interlayer (less than 0.4
Therefore, it is necessary to establish a continuous change model between logging response and lithologic profile in order to realize reasonable identification of complex lithologic profile in Hailaer Basin.

2. Basic tendency of log response with lithologic change

Resistivity, volume density, acoustic time difference, photoelectric cross section index, natural gamma ray and its energy spectrum are all response functions of some physical properties of rock strata. Among them, the mineral composition, arrangement structure and particle size are the important factors leading to the change of logging curve.

Resistivity logging project. Under the condition of the same fluid properties, the resistivity amplitude will change from low to high as the rock particles change from fine to coarse and the arrangement structure changes from soft to tight. If in the process of reservoir deposition, there are certain volcanic debris and other components that are not conductive, then the reservoir resistivity value will also show an increasing trend.

The density log (DEN) curve is mainly affected by the arrangement structure of rock particles or the mineral composition of particles in the reservoir. The denser the arrangement of rock particles, the higher the volume density. The density tends to increase when the stratum contains pyroclastic material subjected to high temperature and pressure.

The acoustic time log (AC) curve is mainly affected by the mineral composition, rock density and rock structure. In normal sedimentary rocks, the finer the rock particles are, the greater the acoustic time difference is. In volcanic rocks, the acoustic time difference of altered pyroclastic rocks is higher than that of lava. The photoelectric cross-section index logging (PEF) curve is a gamma - gamma logging method which mainly uses the photoelectric effect to measure. The PEF value mainly depends on the composition and content of rock minerals. For the rocks containing CaCO$_3$ (5.05 target n/electron), BaSO$_4$ (266 target n/electron), FeCO$_3$ (14.69 target n/electron), ZrSiO$_4$ (zircon, 69.1 target n/electron) and other heavy minerals, the PEF value often presents high values. The PEF value of SiO$_2$ in sandstone is 1.81 target n/electron. Therefore, mudstones and volcanic rocks tend to be rich in various minerals, presenting slightly higher values than sedimentary sandstones.

Natural gamma ray and energy spectrum logging curve. Volcanic rocks gradually increase in content of radioactive minerals from basic to acidic. Therefore, among the common igneous lava strata, basalt has the lowest radioactivity, andesite is in the middle, and rhyolite is the highest. In the same type of rock, the structure of the rock also has an effect on radioactivity, and the transition from lava to pyroclastic rock increases radioactivity. The content of uranium in magmatic rocks decreases gradually from acid, neutral, basic to ultrabasic rocks.

According to the above analysis, for a geological sedimentary unit, the change of logging curve often reflects the evolution of geological sedimentary environment. Therefore, based on the analysis of a large number of actual data, a continuous model of logging response for lithology gradual change in geological sedimentary units can be established, which can greatly reduce the multiple solutions of logging lithology identification.

3. A representation of a continuous pattern

3.1. Continuous model of pyroclastic sedimentary rocks

The typical lithologic change model is: Tuffaceous mudstone → Gray (silty) sandstone → Tuffaceous (sandy) conglomerate. The variation of logging response of such lithology is basically the same as that of common sedimentary rocks. In other words, with the change of lithology granularity from coarser to finer, the logging curve also changes in a series: The resistivity gradually increases, the neutron value gradually decreases, the photoelectric absorption cross section gradually increases (Figure 1), and the thorium value gradually decreases. However, due to the fact that the composition of conglomerate in the study area is often rhyolite and granite, etc., the radiation curve value rises, that is, the Gamma and
Thorium values show different variation trends from those in Figure 1 (Figure 2), while the variation trends of other curves are consistent with those in Figure 1.

![Diagram](https://example.com/diagram.png)

**Figure 1.** Variation law of response value of continuous model logging for pyroclastic sedimentary rocks (I)

![Diagram](https://example.com/diagram2.png)

**Figure 2.** Variation law of response value of continuous model logging for pyroclastic sedimentary rocks (II)

Figure 3 is an example of the comprehensive curve and lithologic profile of the model shown in Figure 1. The lithology from bottom to top of 1442.5m ~ 1448.5m in the figure is a continuous pattern of tuffaceous mudstone → tuffaceous siltstone → tuffaceous sandstone, and the curve variation trend is similar to that shown in Figure 1.

![Core Map](https://example.com/core_map.png)

**Figure 3.** Tuffaceous mudstone, tuffaceous siltstone, tuffaceous sandstone continuous model case well
(The units of SP, CAL and GR are mV, in and API. MSFL, LLS, LLD and ZLLD are Ω·m; The units of PEF, CNL, DEN and DT are B/E, %, PU, g/cm3, μs/ft. The units of THOR, UR and POTA are PPM, PPM and %. The curve shown in the following figure is consistent with this.)

3.2. General sedimentary rock to pyroclastic sedimentary rock

It is difficult to find such lithologic continuum patterns on well logs. The reason is that either the presence of tuffaceous rocks in the general sedimentary environment or the presence of volcanic-clastic sedimentary rocks in the general sedimentary environment is often associated with a specific sedimentary environment, such as the occurrence of geological activities such as volcanic eruptions nearby during the deposition process. But the logging curve resolution ability is limited, it is difficult to reflect these information. The purpose of this model is to show a relative variation trend of the logging curve if the same reservoir group is classified as common sedimentary rock or pyroclastic sedimentary rock.

Figure 4 shows the relative variation trend of logging curves from ordinary sedimentary rocks to pyroclastic sedimentary rocks (Take siltstone and volcanic rock as an example).

3.3. Pyroclastic sedimentary rock → submerged pyroclastic rock → pyroclastic rock

This model is given for the case that the volcanic material contained is fine and coarse. In application, the relative size of some lithologic particles of sedimentary rocks and volcanic rocks should be taken into full consideration, and it should be noted that the coarse-grained lithology in the study area often contains radioactive substances to a certain extent. The basic principle is that when the coarse-grained sedimentary rock is mixed with its fine-grained volcanic ash, the resistivity curve will decrease, the radioactivity curve will increase, and the density curve will decrease slightly. For fine-grained sedimentary rocks mixed with coarse-grained volcanic material relative to them, the resistivity curve increases, the radioactivity curve increases (acidic volcanic rock) or decreases (intermediate-basic volcanic rock), and the density curve increases. Figure 5 shows an example of the log change from tuff to pebbled tuff to tuffaceous conglomerate.
3.4. Pyroclastic rock to volcanic lava

This pattern usually appears at the bottom of Tongbomiao and Budate oil formation. Two types of lithology are often associated. Embodied in lava tend to present the resistivity logging response characteristics of high, low porosity, and lava alteration after fracture, and then mixed with a certain amount of fine particles of volcanic debris, often present resistivity drop, higher porosity (that is, the higher neutron curve, density decreased, acoustic time rise), radioactive curve slightly higher trend. Figure 6 shows the variation trend of logging responses among andesitic tuff, altered andesite, and andesite in a well.
4. Conclusion
In view of the actual characteristics of the volcanic-bearing strata in Hailaer basin, a continuous sedimentary change model of lithology response is established, which can overcome the multi-solution of logging lithology interpretation effectively and improve the identification accuracy of transitional lithology. It should be pointed out that, in this paper, we give four consecutive sedimentary pattern changes mainly involve lithology granularity and volcanic rock composition changes in the two cases, therefore, in order to adapt to the variability of stratum lithology, can be on the basis of these patterns, is set in a particular lithology value, according to the variation of amplitude logging curve the evolution of the other continuous mode.

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