Study on automatic recognition method of Continental Shale Sandy laminae based on electrical imaging image

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Abstract. Aimed at the characteristics of complex continental shale lithology, the development of sandy striae, and the difficulty of artificial recognition. In this paper, the sandy texture of the Chang 7 shale gas reservoir in the Mesozoic of the Yanchang Oilfield is taken as the research object. First, the core fine observation description and X-ray diffraction analysis of the whole rock minerals were carried out to determine the development characteristics of sandy striae of continental shale. Then the research focuses on methods such as full-wellbore wall restoration, automatic identification of the striae boundary, and construction of the striae development index model for the electric imaging log images. Finally, comprehensive evaluation is made on the sandy stratum of the extended continental shale gas reservoir. The results show that the mineral types of Changqi shale in the study area are mainly clay minerals, quartz and feldspar, and the average thickness of sandy lamina is 1.93cm, with a layer density of 26 layers / m. After verification and analysis with core description, the method based on image recognition can accurately identify the striae layer, which lays a foundation for shale gas layer selection in the study area.

1. Introduction

At present, the research on the characterization and identification of the sand lamination of continental shale gas is mainly carried out from the perspective of geology through core observation statistics and thin-film identification. The crossplot recognition and neural network prediction are carried out in logging [5-6]. However, since the resolution of conventional logging is difficult to reach the stratified level, the focus needs to be identified by means of imaging logging. At present, it is mainly through human-computer interactive recognition through electro-imaging, but it is limited by the experience of interpreters and tedious and numerous manual picking operations, which restricts the fine characterization and evaluation of layer selection of shale gas sandy texture layers. For this reason, it is very necessary to carry out fine processing on the electric imaging logging images, automatically identify the shale sandy striae and fractures, accurately extract the striae and fracture parameters, and achieve the fine quantitative characterization of shale sands striae and selection.

This article takes the Mesozoic Chang 7 shale gas reservoir sandy texture layer in Yanchang Oilfield as the research object. First, it carries out fine core observation and description and X-ray diffraction analysis of whole rock minerals to clarify the development characteristics of continental...
shale sandy texture layer. Then, it focuses on methods such as full-wellbore wall restoration, automatic identification of striation boundaries, and construction of a stratum development index model. Finally, it conducts a comprehensive evaluation of the extended shale gas reservoir sandy striae.

2. Experimental Analysis of Sandy Lamina of Shale

2.1. X-ray diffraction experiment and shale mineral composition

Through the study of 355 rock samples from 30 wells, the mineral types in the study area are mainly clay minerals, quartz and feldspar, and the clay content of Mesozoic chang7 and chang9 shale is 20.0-77.0%, with an average of 48.6%, and the average content of quartz is about 29.8%; (Figure 1). The main types of clay minerals are Yimeng mixed layer, smectite, chlorite and kaolinite. The content of Yimeng mixed layer of Mesozoic chang7 and chang9 shale is 29.0-88.0%, with an average content of 57.0% (Figure 2).

![Fig. 1 Mineral composition of Chang7 and Chang9 rocks in the study area](image-url)
2.2. Core fine observation description
The continental shale sandy texture layer mainly refers to the texture layer of thin sandstone, argillaceous siltstone, silty mudstone shale in the form of thin stratum, thin strip and thin interlayer. The color of the sandy texture layer is mainly white and off-white, and it is interbedded or interlayered with dark homogeneous shale. The thickness ranges from tens of centimeters to tens of millimeters to tens of micrometers. The shape is mostly developed into straight and corrugated types. The straight type consists of a single layer or a group of approximately parallel grain layers or interlayers, which extend far laterally and have small thickness changes. The corrugated shape is lenticular or continuous wave-shaped, with poor lateral continuity, large thickness changes, and frequent sharpening and staggered lamination [8].

According to the detailed observation and analysis of the chang 7 sandy lamination core of Yanye 1 well (Figure 3a) A total of 125 layers of silty interlayer / textured layer with a thickness of 0.05 cm or more were developed in the study section, and the thickness of the single layer showed a power exponential distribution (Figure 3b). The cumulative thickness is about 241.6cm, the average thickness of a single layer is 1.93cm, most of them are distributed between 0.05 and 0.1cm, and the average layer density is 26 layers / m (Figure 3c).

3. Image recognition method of Shale Sandy laminae
The method of identifying shale sandy strata based on electrical imaging logs is mainly divided into four steps(Fig. 4), namely: (1) 360-degree filling of electrical imaging logs; (2) watershed algorithm to identify striation boundaries; (3) target geology Objects are automatically classified; (4) Shale sandy striae development index model is constructed.
Fig. 3 Comprehensive analysis chart of core observation of Chang 7 sand Lamina in Yanye 1 well
3.1. 360-degree filling of electro-imaging logs
Imaging logging can obtain two-dimensional images of the well circumference, which can more intuitively and clearly reflect the structure and characteristics of the well wall. The visibility and intuitiveness of well logging images can solve geological problems that are difficult to solve with conventional well logging. However, due to the structure of the wellbore and the structure of the electrical imaging logging instrument, the instrument was in an open state during the measurement, which caused part of the borehole wall to fail to be measured while scanning along the borehole wall. White bands are generated on the log images, which affects the image quality and is not conducive to subsequent image processing and identification of geological phenomena. The filling of blank bands in electric logging images belongs to the category of image restoration. The predecessors discussed the inverse distance weighted interpolation method, the multi-point geostatistical Filtersim simulation method [9]. In this paper, Filtersim simulation method is used for 360-filling of electro-imaging logging images (Figure 5).

3.2. Watershed algorithm identifies lamina boundary
The watershed segmentation method is a mathematical morphology segmentation method based on topological theory. The basic idea is to treat the image as a topographical topography in geodesy. The gray value of each pixel in the image represents the altitude of that point. Each local minimum and its area of influence is called a catchment basin, and the boundaries of the catchment basin form a watershed. The concept and formation of a watershed can be illustrated by simulating the immersion process. On each surface of the local minima, pierce a small hole, and then slowly immerse the entire model in water. As the immersion deepens, the area of influence of each local minima slowly expands outward, and in two catchments A dam is constructed at the confluence of basins, forming a watershed [10].

Fig. 4 Flow chart of image recognition method for Shale Sandy laminae
The watershed calculation process is an iterative labeling process. The more classic calculation method of watershed was proposed by L Vincent. In this algorithm, the watershed calculation is divided into two steps, one is the sorting process, and the other is the flooding process. First, the gray level of each pixel is sorted from low to high, and then in the process of submerging from low to high, the first in first out (FIFO) structure is used to judge and label the influence domain of each local minimum in h-order height.

The watershed transform is the watershed image of the input image. The boundary point between the watersheds is the watershed \[1_{1-12}\]. Obviously, the watershed represents the maximum point of the input image. Therefore, in order to obtain the edge information of the image, the gradient image is usually used as the input image, that is:

\[
g(x,y) = \nabla(f(x,y)) = \left\{ \sqrt{[f(x,y) - f(x-1,y)]^2 + [f(x,y) - f(x,y-1)]^2} \right\}^{0.5} \tag{1}\]

In the formula, \(f(x, y)\) represents the original image, \(\nabla\{\cdot\}\) means gradient operation.

The watershed algorithm has a good response to faint edges. Noise in the image and subtle gray changes on the surface of the object will cause excessive segmentation. But at the same time, it should be seen that the watershed algorithm has a good response to weak edges and is guaranteed by closed continuous edges. In addition, the closed catchment basin obtained by the watershed algorithm provides the possibility to analyze the regional characteristics of the image.

In order to eliminate the excessive segmentation generated by the watershed algorithm, two processing methods can usually be adopted. One is to remove the irrelevant edge information by using

| Depth (m) | Electrical imaging statics | Electrical imaging statics | Electrical imaging statics | Electrical imaging statics |
|----------|---------------------------|---------------------------|---------------------------|---------------------------|
| Depth    | Electrical imaging        | Electrical imaging        | Electrical imaging        | Electrical imaging        |

**Fig. 5** Image of blank band filling in electrical imaging
prior knowledge. The second is to modify the gradient function so that the catchment basin only responds to the target that it wants to detect.

To reduce the over-segmentation generated by the watershed algorithm, the gradient function is usually modified. A simple method is to perform threshold processing on the gradient image to eliminate the over-segmentation caused by small changes in gray scale. That is [13]:

\[ g(x,y) = \max(\text{grad}(f(x,y)), g_\theta) \]  

In the formula, \( g_\theta \) represents the threshold. As shown in figure 6 below, Fig. 6a is the image of the electrical imaging logging data after the preliminary data, and then the Filtersim algorithm is used to fill the blank 360°. Figure 6b shows the boundary obtained by the watershed algorithm, and then smoothed by removing the "burr" according to the relevant technology principle of computer vision (green line). Figure 6c shows the image of seam hole captured by target tracking or algorithm according to the seam hole boundary. Figure 6d is the filling image of the target geological object obtained by grasping the target geological object and filling with the mean value.

**Fig. 6** Electrical imaging image segmentation to pick up seam and hole boundaries and geological objects

3.3. **Automatic classification of geological objects**

The target geological object still has multiple solutions, and the sand striations, sand striations and block sandstones all present bright color stripes or striations on the images. Through image segmentation and boundary extraction, countless closed area graphs can be obtained. It is very important to identify these closed area graphs as the sand striations.

3.4. **The model of laminar development index was constructed**

Approximate a polygon as a rectangle, and find its equivalent length and width; The length and width of striations are relatively large, while the ratio of length and width of block sandstone is relatively small. Because the coordinates of this polygon are known, first choose any point \( x_0 \), find the distance between this point \( x_0 \) and all the other points, and form the set \( D_n \); Then, when \( D_n \) is maximized, the corresponding two points \((x_1, y_1)\) and \((x_2, y_2)\) rotate in the same direction with fixed step size, and the distance set \( D_n \) of the two points is solved. The maximum value of the two-point distance set \( D_n \) is
determined as the equivalent length $L$ of the polygon. Then, according to the principle of integration, the area $S$ of the polygon is obtained, and the equivalent width $H$ of the polygon is obtained by using $S/L$. Finally, the ratio $K$ of $L/H$ was calculated, and $K>5$ was defined as the lamina (figure 7).

Fig. 7 flow chart of laminae classification and recognition

Fig. 8 Identification Result of gas-sand Lamination in continental shale compared with core observation
4. Examples are applied and analyzed
A treatment analysis of the sandy striations of the Shengli Oil Field Shale oil reservoir was carried out and verified against the core description results, as shown in figure 8. As can be seen from the drawing, the method of this paper has identified the sand laminations described by 13 cores, and identified 9 thin sand laminations and 5 massive sand laminations, which are 1 layer more than that described by the core. The statistical coincidence rate is 92%, the error is 8%.

5. Conclusion
(1) For continental shale gas reservoirs, detailed core description and X-ray diffraction experiments were carried out, and it was clear that the mineral types of shale in changqi in the study area were mainly clay minerals, quartz and feldspar. The sandy striation was very developed, with an average thickness of 1.93 cm and a density of 26 layers/m.

(2) After verification and analysis of core description, the striation can be accurately identified based on the image recognition method.

(3) With yanpag-1 and yanpag-2 Wells as the research objects, lithology identification and fine evaluation of reservoir selection were initially carried out, and certain application effects were obtained.

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