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Study on Logging Response and Identification Method of Deep Coal Body Structure

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Abstract

Aiming at the problem of coal structure identification of 8 # coal seam in Benxi Formation in Ordos Basin, this study is based on the core observation data to clarify the logging response characteristics of different coal structures; the multi-parameter intersection pattern is constructed based on the conventional logging curve to quantitatively divide the coal structure types. the results show that, The highlight image of homogeneous block native structure, The large time difference of the acoustic wave (>420μs/m), Neutron value (>54%); Cucut native structure electroimaging image highlight, Distribution of irregular dark short lines, spots, The large time difference of the acoustic wave (>420μs/m), Neutron value (<54%); Strianding native structure images highlighting containing dark color bands, The large time difference of the acoustic wave (<420μs/m), Wide neutron distribution range; The image of the broken coal is a "cow yoke", The irregular aggregation of dark spots shows the granular and even molecular structure, The three generally exist together, Increwith the fragmentation, The lower the resistivity, The wave-neutron map mainly judge the coal structure, This method effectively improves the identification accuracy of the coal body structure, Provide technical support for the efficient development of coal and rock gas.

Keywords

Benxi Group 8#Coal; Coal Structure Identification; Electrical Imaging Logging; Acoustic-Neutron Map; Coal Rock Gas Development.

1. Introduction

As an unconventional resource, deep coal and rock gas has a wide distribution area and a large amount of resources, which is an important replacement target for the scale increase of natural gas storage. Ordos Basin is the core area of onshore coal and rock gas exploration and development in China, among which the No.8 coal seam of Benxi Formation is the key target layer [1] with its broad thick reservoir (average thickness of 6-16m) and high gas content (12.6-36.4m^3/t). However, under the control of multi-stage tectonic activities and sedimentary environment evolution, the internal structure of coal seam is not homogeneous, and a variety of coal types, such as primary structure coal, crushed coal and crushed coal, are developed, which restricts the fracturing transformation effect of coal rock gas well and the capacity release of [2]. At present, the coal structure identification mainly depends on core observation and empirical interpretation of single logging curve, but the core core cost is high and the spatial coverage is low, and the response sensitivity of conventional logging to crack development is insufficient, so it is difficult to realize the continuous fine characterization of coal structure in the whole well section. Therefore, this study is based on the high precision description of the core, calibrated the spatial spread characteristics of coal structure by electric imaging logging (FMI), integrated the acoustic wave time difference (AC) and neutron porosity (CNL), and constructed a multi-parameter quantitative identification map, aiming to break through the technical bottleneck of coal structure identification and provide geological basis for the efficient development of coal rock gas in Ordos Basin.

2. Regional Geological Overview

Ordos Basin is located in the west of North China Claton, spanning the five provinces of Shaanxi, Gansu, Ningxia, Mongolia and Shanxi, covering an area of about 370,000 square kilometers, and is the second largest sedimentary basin in China. The tectonic pattern of the basin is "steep slope in the east, north and south division", which can be divided into six tectonic units [3], namely, Yimeng uplift, northern Weihe uplift, western Shanxi flexfold belt, Tianhuan depression, northern Shaanxi slope and the western thrust zone (Figure 1).

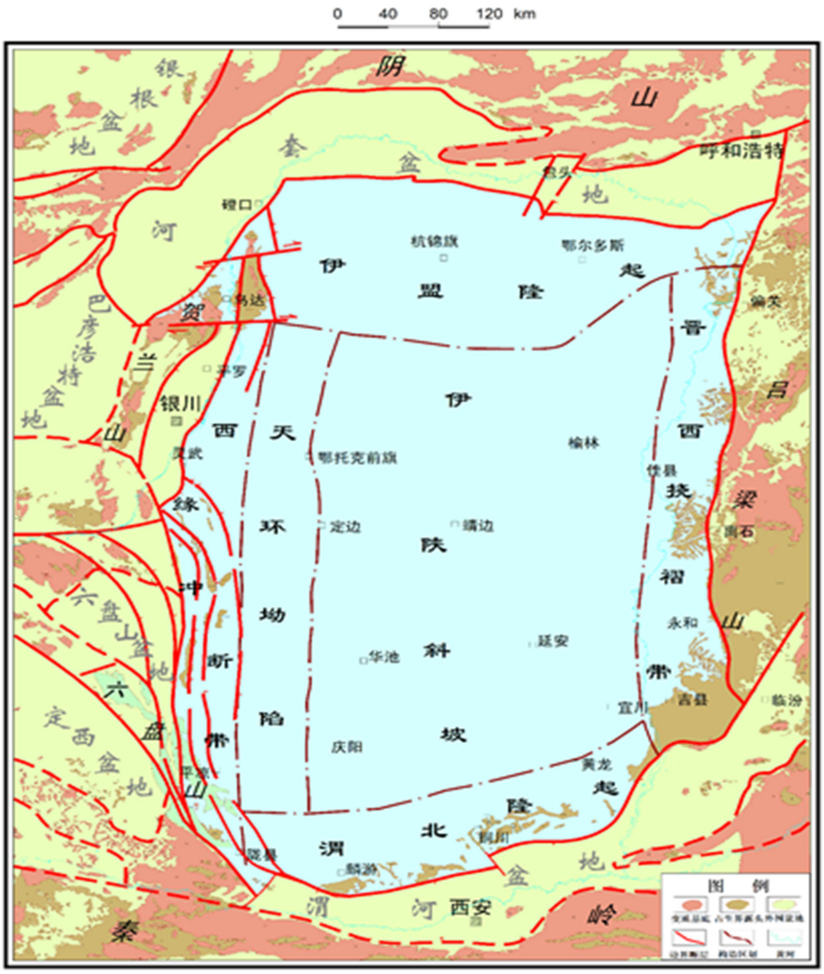

Fig 1. Tectonic zoning of Ordos Basin and its relationship with surrounding tectonic units

The upper paleozoic developed the coal-bearing strata of the Benxi Formation, the lower Permian Taiyuan Formation and the Shanxi Formation of the basin, and the sedimentary environment changed from sea and land to continental [4]. Coal seam distribution is stable with a total thickness of 35m. The coal from the top to the bottom is 1-10 is the main target of the basin. The production of the 8 # coal seam is flat, and the distribution is continuous and stable.

3. Classification of Coal Body Structure

Coal structure refers to the structural characteristics of the coal seam after the experience of various geological effects in the geological historical period. The coal structure is divided according to the characteristics of joint development degree, coal integrity and strength.

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According to the Rules for prevention and Control of Coal and Gas Proburst, the destruction types of coal are divided into: primary structure coal (class I), fragmented structure coal or transition structure coal (class), strong destruction (sheet coal, class), strong destruction (granular coal, class) and strong destruction (crushed coal, class V) [6]. According to the morphological characteristics of logging curve, drilling centering description, coal rock crushing degree, multi-stage structural movement, physical properties and other parameters, different coal structure types engineering geophysics are classified [7]. That is, coal structure mainly includes primary structure and primary-fragmentation structure Block structure, fragmentation structure, fragmentation-fragment structure, fragment structure, fragment-chyli structure and chyli structure. According to the national standard GB / T30050-2013 coal seam structure classification, it is mainly divided into four categories of [9]. See Table 1.

Table 1. National standard coal body structure classification table

type	code	Classification factors					key
		Macro coal rock type The degree of resolution	Layer integrity	The coal body broken level	Rift and scrunch The degree of development	Hand try intensity	
protogenesis structure	MJ-I	The macro coal rock type boundary is clear, and the macro coal rock composition can be distinguished	The native structure is intact and the layers are continuous	The coal body is complete	The crack is not staggered layer, no kneading and structural slip surface	Hard, hard	
splintering structure	MJ-II	The boundary of macroscopic coal rock type is clear, the composition of macroscopic coal rock can be distinguished, and the local slight dislocation	The native structure is slightly damaged, and the layer is easy to distinguish	Coal body is relatively complete or the coal body is broken, and the broken block particle size is generally larger than 5mm	Exogenous fissure development, cracks will slightly stagger the layer, kneading does not develop, occasionally see structural scratches	Hard	
particle structure	MJ-III	The type boundary of macro coal rock is not ishable, and the composition of macro coal rock in small fresh sections can be distinguished	The native structure is severely damaged, the layer is difficult to distinguish, and the layer structure is occasionally visible inside the local small block	Coal body is broken, and the particle size is mostly 1mm-5 mm	Coal body is cut into blocks, common kneading, slippery surface development	Loose	
Chili edge structure	MJ-IV	The macroscopic coal rock type cannot be distinguished, and the composition of coal rock cannot be distinguished	The native structure suffered severe damage and the layers disappeared	Coal body is mostly scaly and crumpled	The fissure can not be observed, kneading and slide pole development	loose	

4. Structural Characteristics of Deep Coal and Coal Body

As observed by the core, The study area mainly developed primary structural coal, Accounted for 80%, Fragfragmented structures were 15%, The crushed structure is only 5%, A single Myrim structure is barely developed, Through core observation and characterization of electrical imaging data, The deep coal structure is subdivided into four categories: massive primary structure, cut primary structure, strip native structure, fragmentation-fragmentation structure, Block native structure coal is mainly layered, Even in the color distribution of the smooth layer, No obvious exogenous fissure, Irirregular linear residual cut is locally visible, Electrical imaging appears as a homogeneous block; To cut the primary structure is to cut the more developed primary structure coal, Electrical imaging image highlight, The distribution of irregular dark color short lines, spots; The banded native structures are banded on electrical imaging, Usually represented as highlighted images containing dark color bands, Thin interlayer, The interlayer is generally 10-30cm thick; The image of the broken coal is a "cow yoke", Two high-angle fractures with similar production show coal fragmentation, The irregular aggregation of dark spots shows the granular and even molecular structure, Generally, the three structures coexist. In addition, gangue is obvious in electrical imaging. Different from coal rock, gangue is shown as dark layer on electrical imaging, with clear and complete dark strip, and the resistance is lower than that of coal.

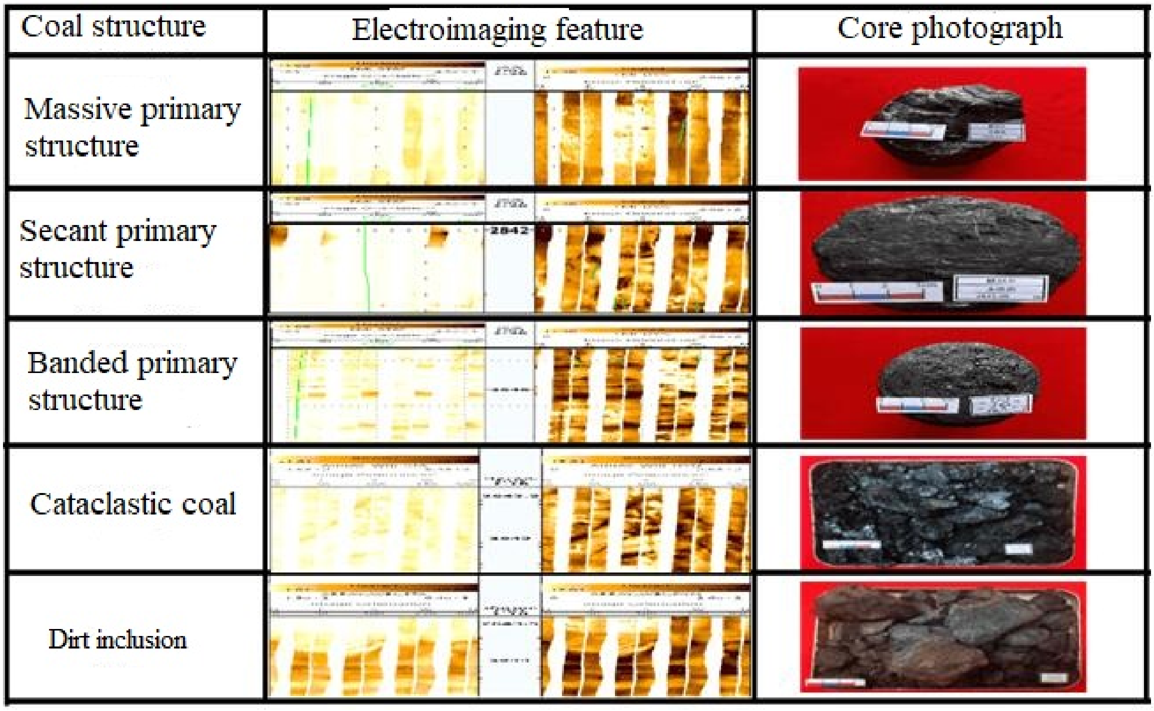

Fig 2. Log response characteristics of coal structure by electrical imaging

5. Identification Method for Conventional Logging

At present, the coal structure logging identification method includes two qualitative and quantitative methods [10]. Among them, the qualitative method is based on the morphological characteristics of the conventional logging curve, which is related to the low mineral content in coal and the relatively small coal seam density, which can be identified by density logging combined with coal quality (ash) parameters [11]. In general, the coal seam has poor compaction, large porosity, high water and humic acid, so the resistivity is low for [12]. The quantitative method is based on the data of logging parameters, and combined with empirical formulas, models and software to formulate, modularize and intelligently identify [13].

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5.1. Log Response Characteristics of Coal Body Structure

There are some differences in the response changes of different coal structures in the geophysical logging data, but in the coal reservoir, the crack structure and its distribution characteristics, mineral content, water content and coal and rock gas content will have an influence on the logging response [14][15]. According to the theory combined with the actual logging data response, with the value of CAL, AC and CNL of the fragmentation of coal, the DEN value decreases and tends to stabilize, the RLLD value mostly decreases, and the GR value changes different [16] due to the influence of coal impurities or radioactive elements in the formation water.

Based on the conventional logging and logging response mechanism analysis of electrical imaging scale, Form the coal body structure conventional logging response characteristic table, See Table Table 2, all in all, Block native structure coal exhibited low radioactivity, low density, High jet difference, Compensation for high neutron values, Characteristics of the high resistance values, Bbanded native structures have a larger range of natural gamma higher values, It is strongly influenced by radioactive substances, As some inorganic mineral effects, High upper density limit, Lower lower limit of resistivity, It also shows that the influence of minerals; Cut primary structure coal compared with massive native, The PE values were even lower, Close to the empirical value of the pure coal rock, Even lower compensating neutron values, Higher acoustic values, The side reflect the positive correlation between the development of the cut ision, Of the fragmented structures are more acoustic compared to the three native structures, A lower lower resistance limit; The response of the gangue clip in electrical imaging and conventional logging curve is obvious, Natural gamma, PE, density values are higher than the coal rock, Above the 100API, respectively, The PE is greater than 1b / e, DEN>1.7g/cm^3; The time difference and resistivity of acoustic wave are obviously lower than that of coal rock.

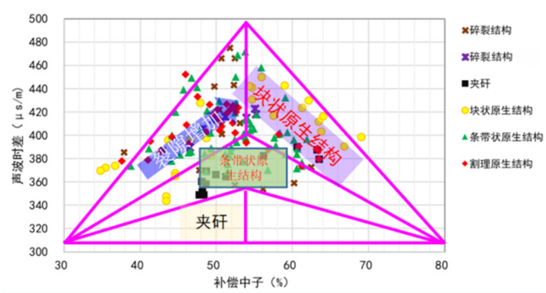
Table 2. Routine logging response characteristics of coal body structure

Coal structure	The Natural Gamma API	PEb/e	interval transit time μs/m	Compensation neutron%	Density /g/cm^3	resistivity Ω˙m
Block native structure	15-40	<1.3	340-410	40-70	<1.45	>5000
Bbanded native structure	25-100	0.9-1.2	370-420	40-65	1.4-1.55	1000-10000
Ccutting the native structure	20-100	<1.1	390-410	40-55	<1.45	1000-10000
cataclastic texture	20-80	<1.1	>410	45-65	<1.55	500-10000
parting	>100	>1	<330	<55	>1.70	<2000

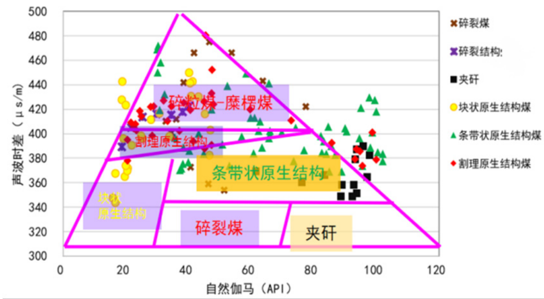
5.2. Identification Method of Coal Structure Diagram

Through the sorting and summary of the conventional logging response characteristics of coal structure, four sets of coal structure identification maps are formed, respectively, acoustic wave jet difference-compensated neutron, acoustic wave time difference-natural gamma, density-compensated neutron, acoustic wave jet difference-resistivity. Among them, the acoustic jet difference-compensation neutron differentiation effect is good, and the discrimination standard is as follows:

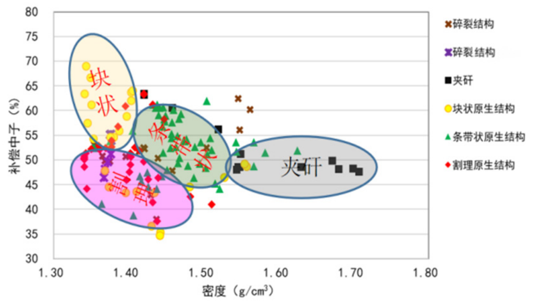
Standard of acoustic jet lag-compensation neutron discrimination coal structure: RST>Δt> BR 1, With a simultaneous CNL> 54 and a GR <45, Judging to be a massive native structure; When the log curve LST>Δt> BL1, Also, Δt <420 and GR <45, Judging to cut off the native structure; When the logging curve CNL> 54, Meanwhile, BL1>Δt> BL2, As a banded native structure; When the log curve LST>Δt> 420, Meanwhile, CNL <54, Judgment as a broken grain structure; When the logging curve Δt <BL2, While CNL <54 and GR> 70, It is judged to be a gangue clip (Figure 3).



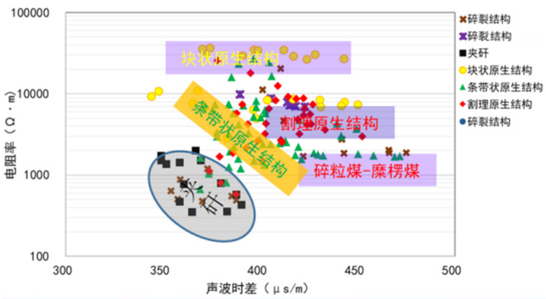
Acoustic jet difference-compensation neutron coal structure identification map



Acoustic jet difference-natural gamma coal structure recognition map



Density-compensated neutron coal body structure identification version



Sound wave jet difference-resistivity coal structure identification plate

Fig 3. Identification version of acoustic jet difference-compensated neutron coal structure

5.3. Application of Coal Structure Discrimination Method

The electric imaging + acoustic wave-neutron map was made in Ordos basin, and the calibration and the vertical recognition resolution of coal structure increased from 2-3m to 0.5m, and the agreement with core description was 89%, especially the differentiation accuracy of crushed coal and crushed coal was increased by more than 30%.

This method reduces the demand of core core, and can realize the coal structure of the whole well section through logging data, so as to provide efficient technical support for large-scale industrial development. Well Y1: Four layers of crushed coal (cumulative thickness of 3.0m) accurately identified the 2.2m native structure coal target (Figure 4); the horizontal section of well Y1 was 1550m, and the coal structure of the whole well section (Figure 5), the 51 clusters were optimized, and the daily gas volume reached $10.9*10^4$ m^3 / d after modification, which set a new high in the block. This method realizes a breakthrough in the whole chain of "qualitative description and quantitative characterization engineering application" of coal structure, significantly improves the development benefit of coal and rock gas in Ordos Basin, and has important promotion value for the exploration of similar complex coal reservoirs.

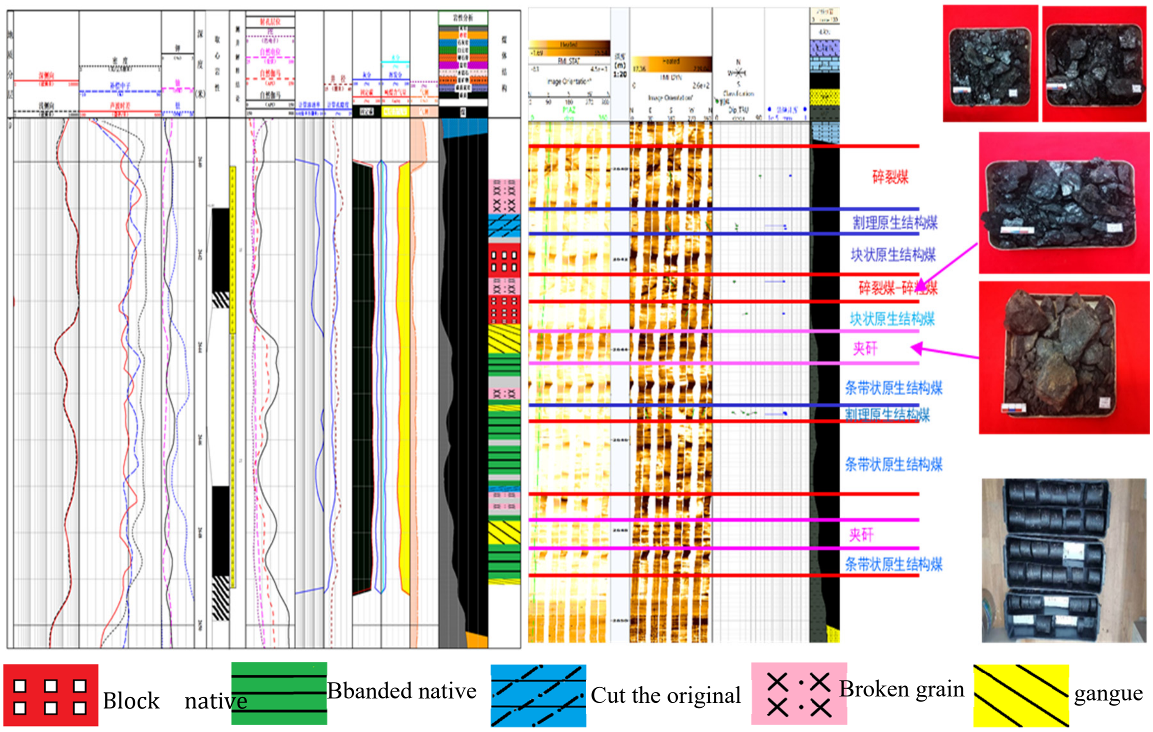


Fig 4. Coal Body Structure Identification Figure of Well Y 1

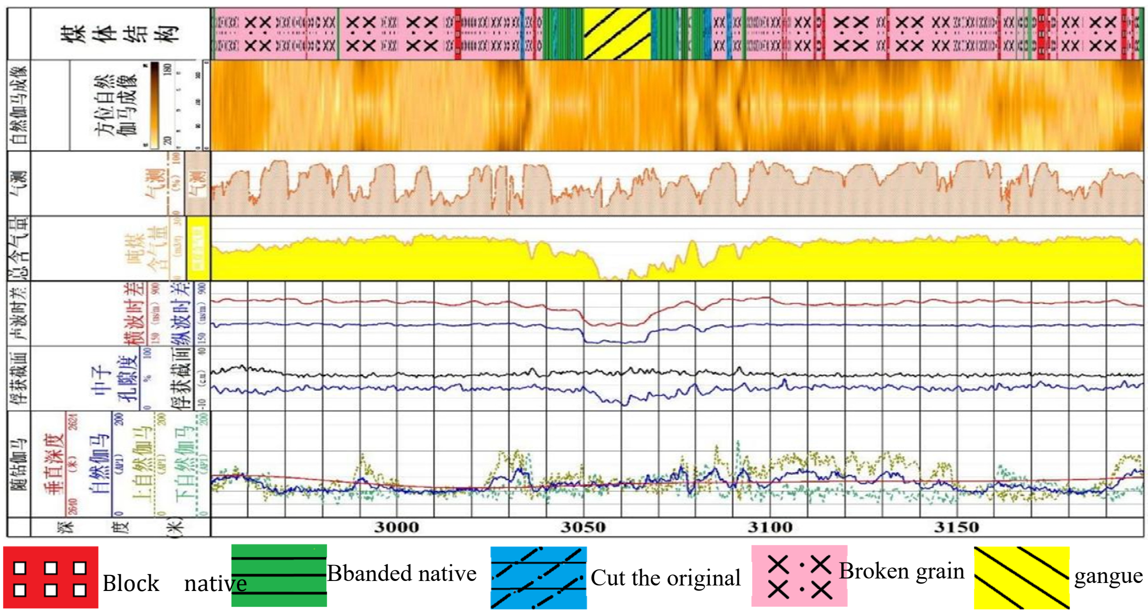


Fig 5. Identification figure of coal structure in horizontal section of well Y 1

6. Conclusion

In this study, in view of the identification problem of heterogeneity of no. 8 coal structure in Ordos Basin, a multi-parameter intersection map version was constructed by fine core calibration and conventional logging parameters such as acoustic time difference (AC) and neutron porosity (CNL), to realize the quantitative identification of coal structure. the results show that:

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1. The primary structure coal is homogeneous and massive on FMI image; the electrical imaging image of cut native structure is highlighted with irregular dark short lines and spots; the image of broken strip native structure is highlighted with dark strips; the image of broken coal is "oxbow", and the irregular aggregation of dark spots shows broken grains and even sharp structure.

2. Acoustic time difference (AC) and neutron porosity (CNL) are sensitive to coal structure specificity, massive primary structure coal AC> 420μs/m and CNL> 54%; strip primary structure coal AC <420μs/m and CNL wide range between 40 and 60%; fragmented structure coal AC> 420 μs/m, with fragmentation degree, resistivity is significantly different from primary structure coal.

3. The acoustic-neutron map version established based on the core-electric imaging calibration, the identification accuracy of the coal structure is more than 85%, which effectively overcomes the multi-solution of the traditional single logging parameters, and provides reliable technical support for the prediction of coal and gas dessert and fracturing section optimization in Ordos Basin.

The innovation of this method lies in the fusion of high-resolution electrical imaging and conventional logging parameters, which realizes the synergistic characterization of " macro form-microscopic physical property " of coal structure, and has the promotion value for the fine evaluation of similar strongly heterogeneous coal gas reservoirs.

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