Quantitative Characterization of Brittle Minerals in Shale Gas Reservoir, Jiaoshiba Area, China*

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Abstract

Jiaoshiba area is the first industrialized area of shale gas in China. The Wufeng Formation and the lower Longmaxi Formation belonging to the Ordovician and the Silurian respectively are the primary exploration interval. The methods and technology of exploration and development in Jiaoshiba area will be a good example for shale gas development in China. The prediction of the brittle minerals distribution in the shale based on the geological and geophysical data is an important technique in the shale gas development because the brittle minerals have important effect on fracture generation in the shale gas development. Laboratory test data of 421 samples were collected and analyzed. The results show that the mineral composition of the shale gas reservoir in the lower of Longmaxi Formation is composed of quartz, feldspar, pyrite, clays, and carbonate minerals. The brittle minerals and clays are about 45-55% and 40-50% respectively. The content of brittle minerals in the Jiaoshiba area is higher than that in the Barnett Shale. Based on the laboratory test data and geophysical data, the statistics shows that Young's modulus and Poisson ratio in the interesting interval is negatively correlated with the content of quartz, so the high Young's modulus and low Poisson's ratio indicate the high brittle zone. The pre-stack inversion of 3D seismic data was carried out to calculate Young's modulus and Poisson ratio. The distribution maps of Young's modulus and Poisson ratio indicate a high brittle zone, which has a good agreement with the fact indicated by the drilled wells.

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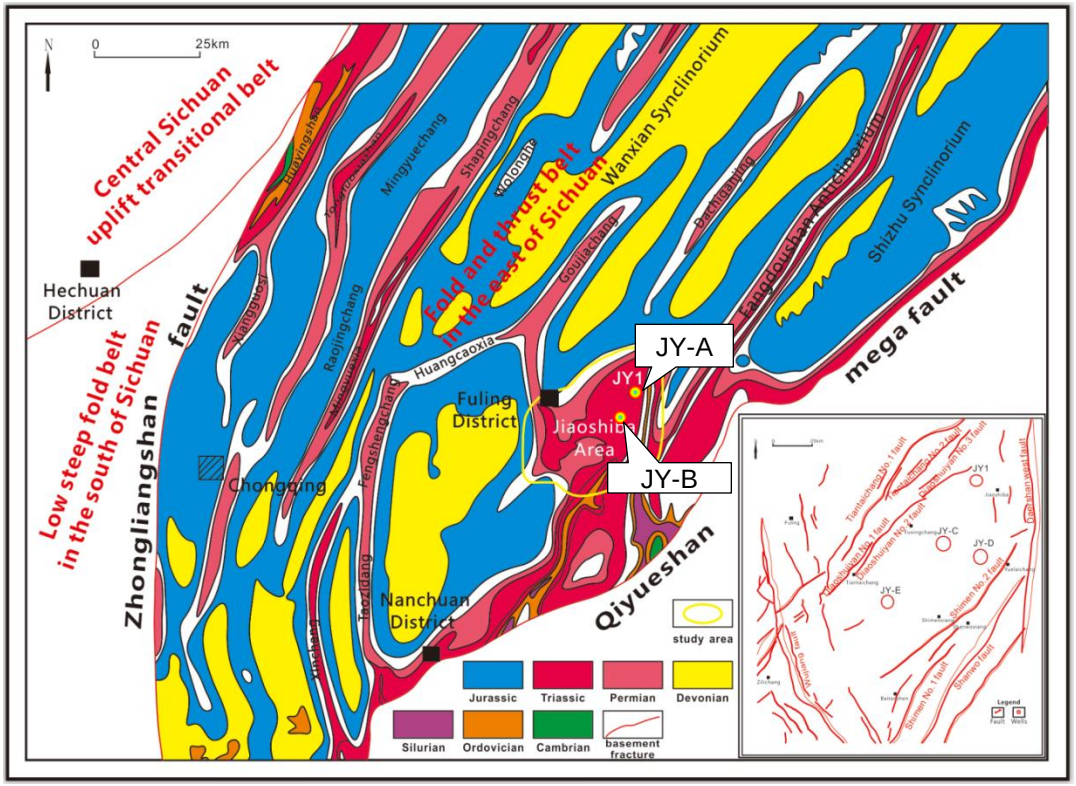
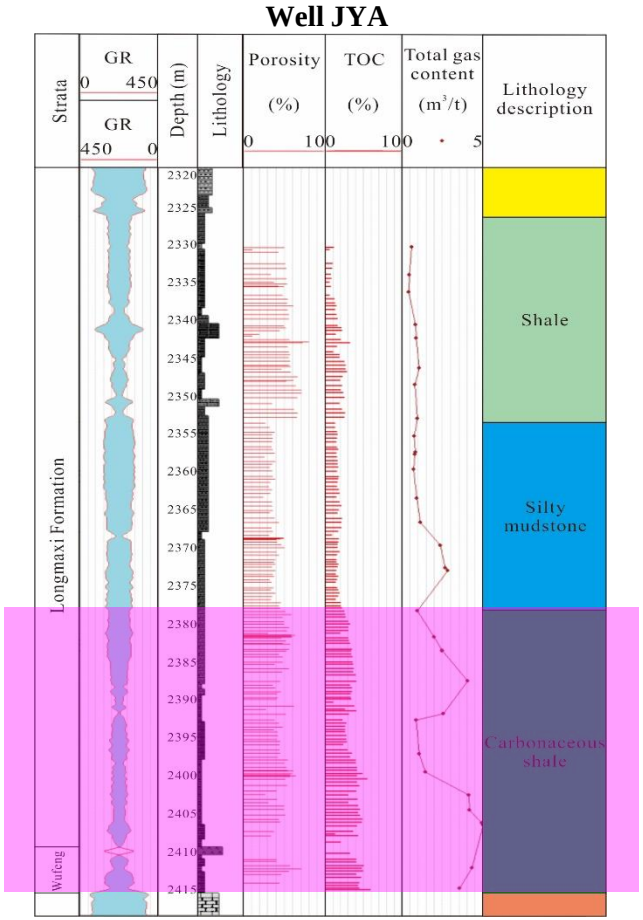
Outline

1. Geological background

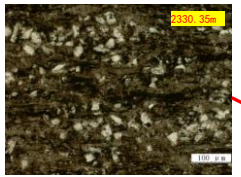


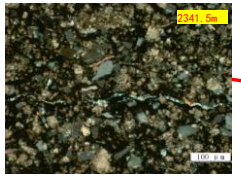
Geological map of Jiaoshiba area and the sampling locations of wells

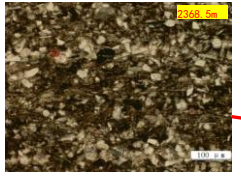


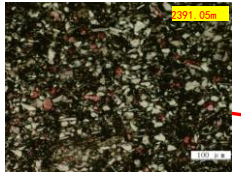
High gas-bearing shale interval

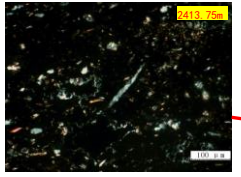
1. Geological background

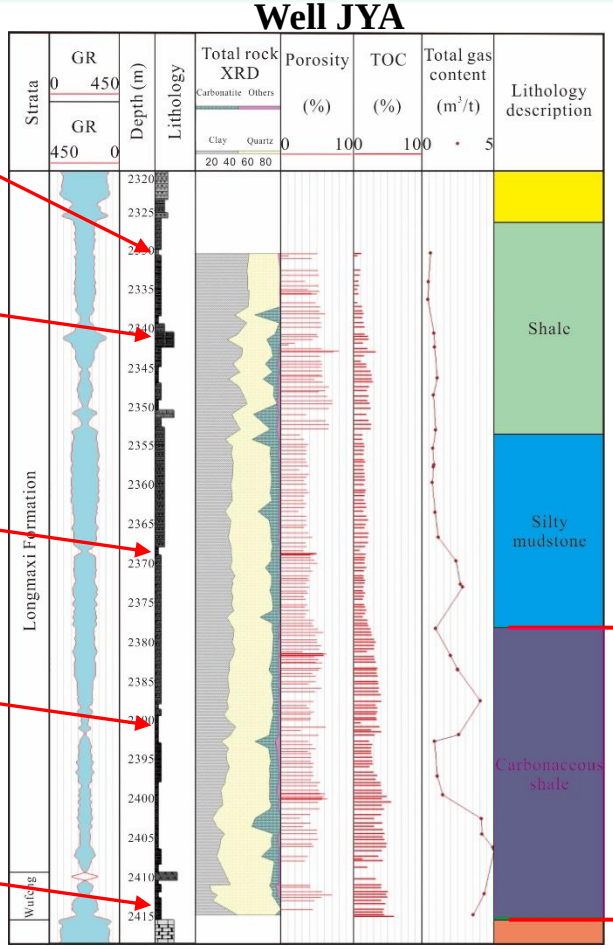












TOC:

0.55% ~ 5.89%, averaging 2.54%.

Types:

Type I kerogen.

R_o :

2.2% ~ 3.13%, averaging 2.65%.

Porosity:

1.17% ~ 7.98%, averaging 4.61%.

Permeability:

0.0011×10^{-3}~$335.20\times10^{-3}\mu m^2$, averaging $22.50\times10^{-3}\mu m^2$.

Net thickness:

From 80m to 120m.

Buried depth:

From 2250 to 3700m.

Outline

2、Geophysical response

Evaluation methods of Brittleness in shale reservoir

1、Accurate measurement and evaluation of the brittle mineral content In laboratory

Brittle Degree: $B_{rit}=X/W_{Tot}$ (1)

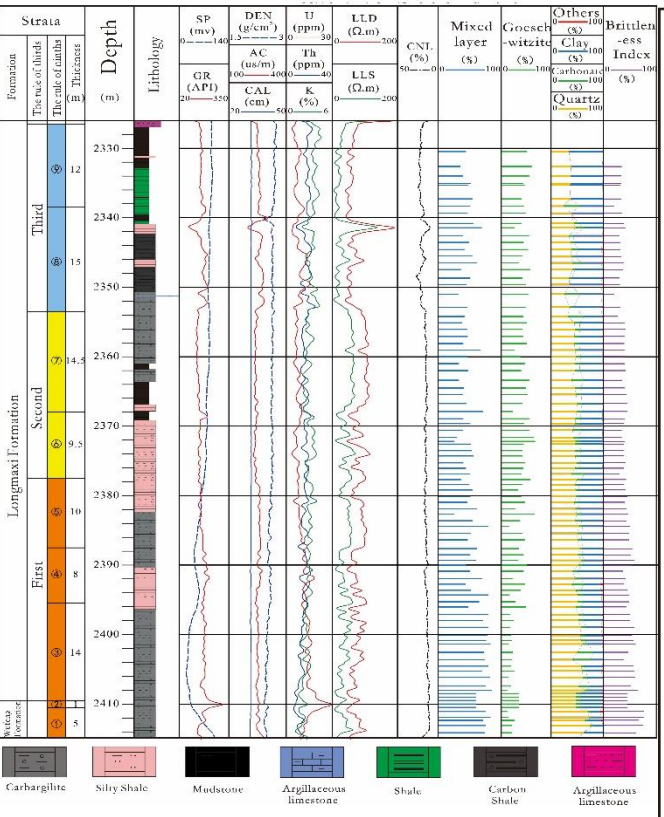
X is brittle minerals content(such as quartz, mica and carbonate) . W_{Tot} is total mineral content.

2、 Evaluated by the physical parameters and mechanical parameters at the regional scale

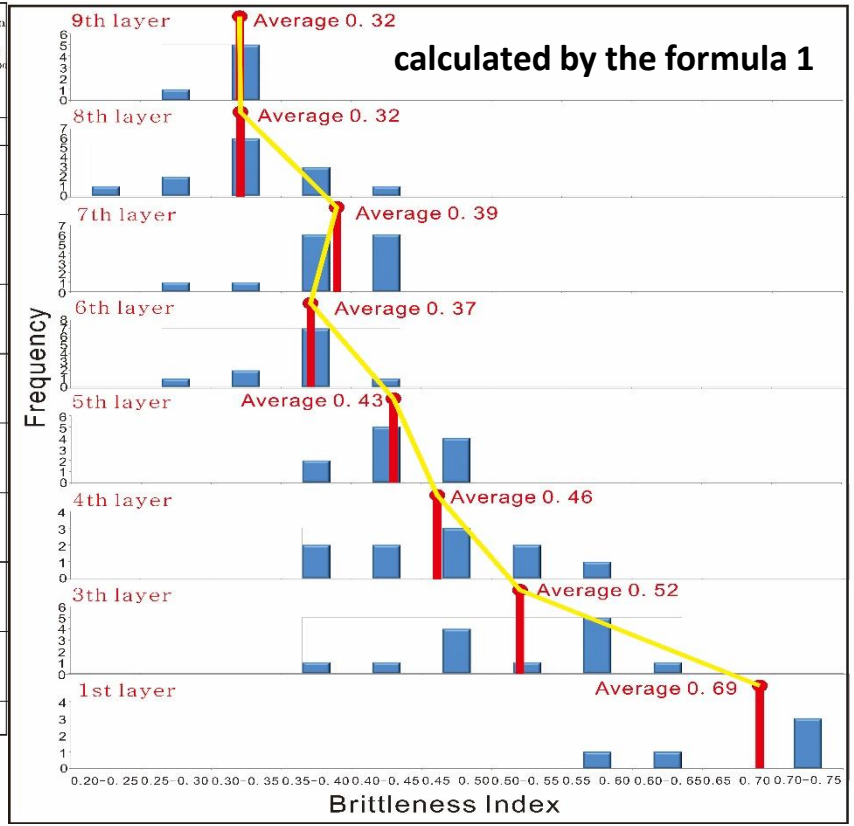
According to the mechanics properties of the rock to evaluate of the brittle degree. In this study, we use the young's modulus and Poisson's ratio parameters.

2、Geophysical response

Brittle degree of JYA well calculated by the formula 1



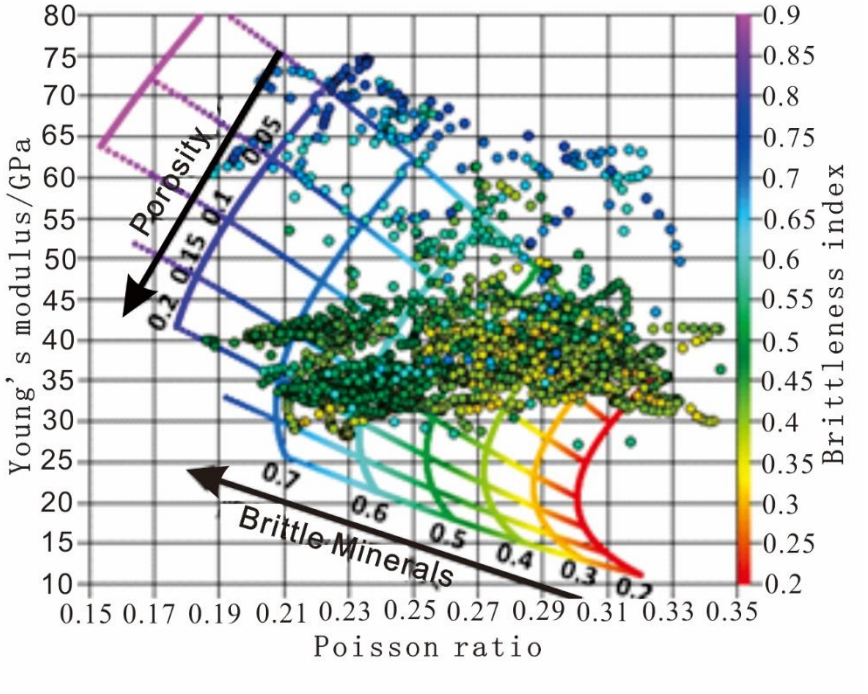
Integrated histogram of JYA well



Average brittleness index of the lower layer 1-5 is between 0.4 ~ 0.7, it is easy to fracture;
The upper layer 5 to 9 less than 0.45, fracturing is less favorable.

2、Geophysical response

Brittle and geophysical response characteristics parameters



The template of Young's modulus 、Poisson's ratio and the brittleness index

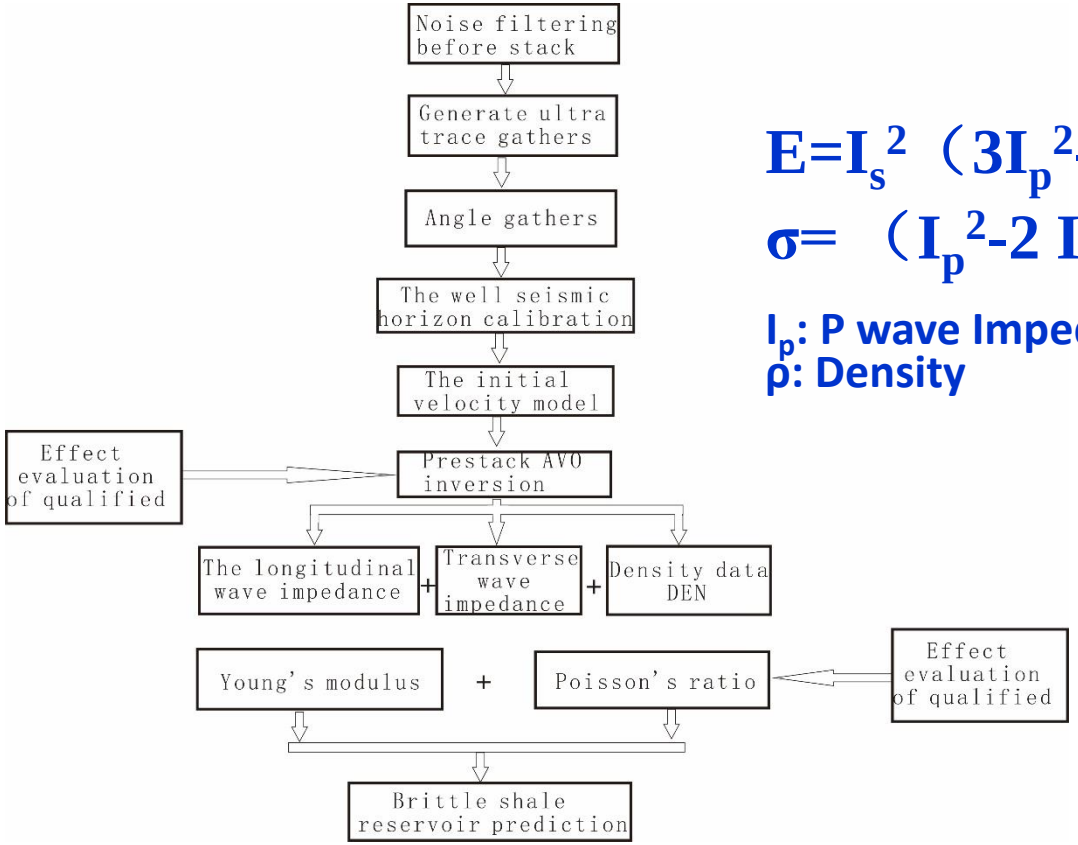
Based on measured data of JYA well and brittle mineral content to establish the young's modulus, Poisson's ratio - brittleness index template.

- **Young's modulus and Poisson's ratio is the main mechanics parameters of brittle shale.**
- **High-brittleness shale usually has a high young's modulus and low Poisson's ratio.**

Outline

3、Inversion and analysis of Poisson's ratio and Young's modulus

Pre-stack elastic parameter inversion



The flow chart of prestack inversion

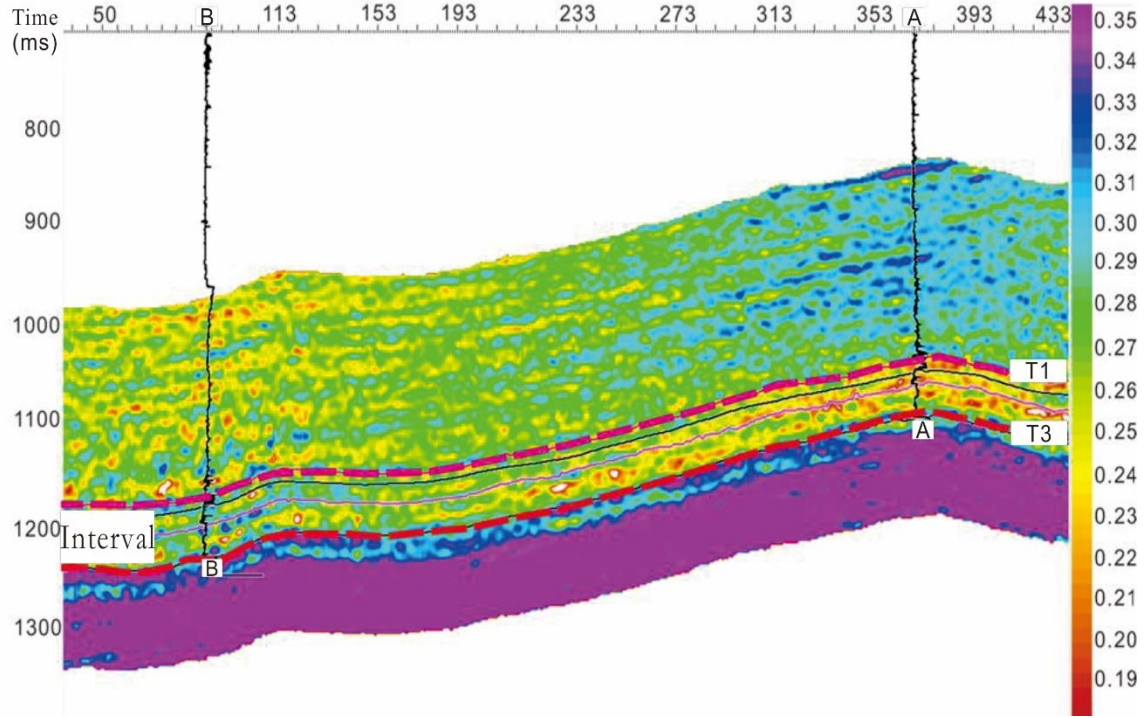
$$E=I_s^2\ (3I_p^2-4\ I_s^2)\ /\rho\ (I_p^2-\ I_s^2)$$

$$\sigma=\ (I_p^2-2\ I_s^2)\ /\ (2I_p^2-\ I_s^2)$$

I_p: P wave Impedance； I_s: S wave Impedance ；
ρ: Density

3、Inversion and analysis of Poisson's ratio and Young's modulus

Inversion results of Poisson's ratio

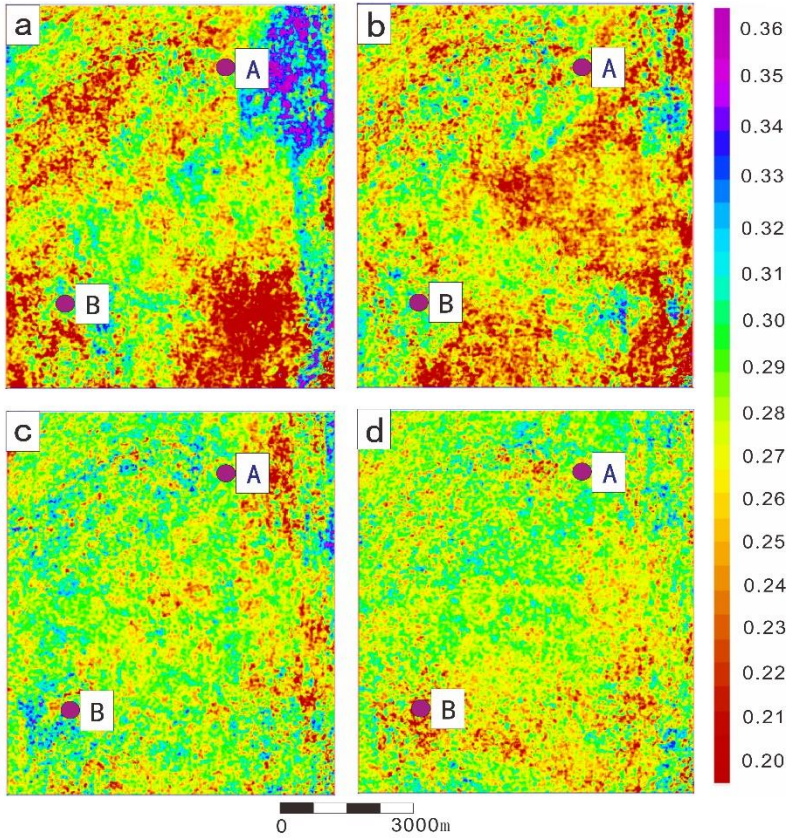


Poisson's ratio inversion profile

- **Poisson’s ratio of objective interval in A well area (<0.26) , the upper and lower interval (> 0.30);**
- **Poisson’s ratio of objective interval in B well have little difference with the overlying strata , ranged from 0.23 to 0.27;**
- **Poisson’s ratio of objective interval in A well interval is lower than B well area. In the perspective of Poisson’s ratio values, fracturing conditions of A well area is better than B well area.**

3、Inversion and analysis of Poisson's ratio and Young's modulus

Inversion results of Poisson's ratio

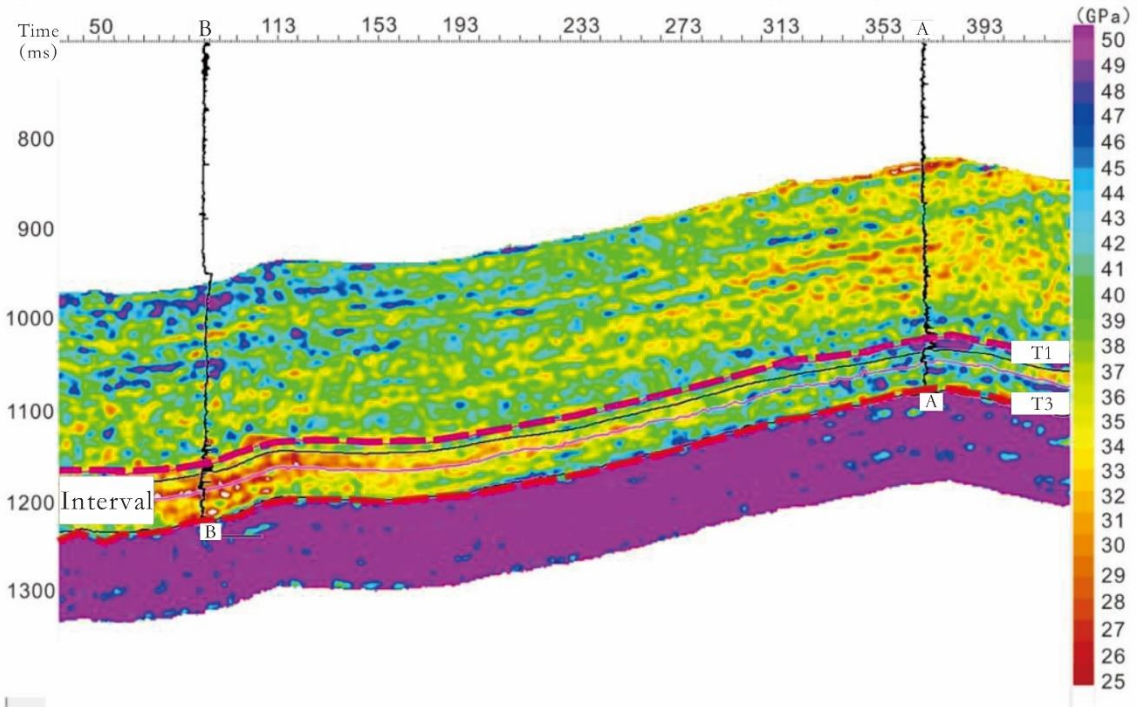


Poisson's ratio inversion of horizon attributes Horizon Attribute values of 10 ms(a), 20ms(b), 60ms(c), 80ms(d) above T3 ;

- **Fig.a - b reflecting Poisson's ratio of lower longmaxi formation ;**
- **Fig.c reflecting the Poisson's ratio of the top of the study interval;**
- **Fig.d reflecting the Poisson's ratio above the study interval.**

3、Inversion and analysis of Poisson's ratio and Young's modulus

Inversion results of Young's modulus

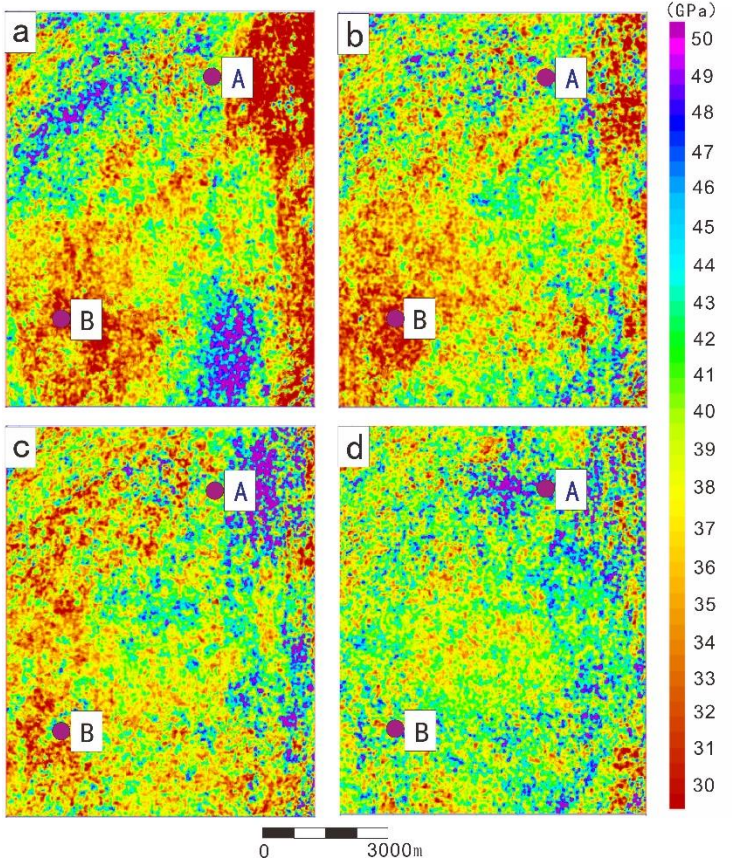


Young's modulus inversion profile

- **Young's modulus of objective interval in A well area is higher than 40 Gpa overall , higher than that of overlying layer;**
- **Young's modulus of objective interval in B well area is below 35 Gpa.**

3、Inversion and analysis of Poisson's ratio and Young's modulus

Inversion results of Young's modulus



Young's modulus inversion of horizon attributes Horizon Attribute values of 10ms(a),20ms(b), 60ms(c), 80ms(d) above T3 ;

- **Fig.a-b reflecting Young's modulus of lower longmaxi formation ;**
- **Fig.c reflecting the Young's modulus of the top of the study interval;**
- **Fig.d reflecting the Young's modulus above the study interval.**

4、Summary

1. Brittle mineral content of the Longmaxi and Wufeng formation in A well of the research area is high overall, showing positive correlation with depth.

2. Lateral inversion results show that A well area with higher brittleness interval has high Young's modulus and low Poisson's ratio; B well area of mechanical parameters is general, and fracturing condition is slightly worse than A well area in the process of mining.

3. The inversion results have good consistency with measured results on depth, which can be take into account to predict the condition of fracturing in study area.

The end

Thank you!

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