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Calculation Method about Brittleness Index in Qijia Oil Field Tight Sandstone Reservoir Daqing China

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Abstract: The range of rock's brittleness index and distribution law are the important evidences of making reservoir fracturing scheme and increasing production of tight reservoir. However, the main way to get brittleness index is core test method or rock mechanics parameters metho, and for the oil fields, which lack data of core and rock mechanics parameters, how to calculate brittleness index, and then to determine the distribution law are the key for mining tight sandstone reservoir effectively. First we use the core from core hole to calculate brittleness index, and then makes a correlation analysis with well logs, after that we pick out the gamma log as the highest correlation to the brittleness index curve, then established the logging interpretation model of brittleness index of this area, at last by using gamma log we have calculated the brittleness index of all wells and layers in the hole area. We also analyze the relationship between brittleness index and the type, content, granularity of the rock, then we discover that brittleness index with quartz, carbonate minerals are positively correlated relationship, negative correlation with shale content, and uncorrelated with feldspar content. Higher rock grain size, quartz and calcareous cement, with better property make higher brittleness index. Picking well layers of high brittleness index carry out field investigation, and obtain a favourable effect.

Key words: *brittleness index; Young's modulus; Poisson's ratio; gamma-ray; tight reservoir*

I. INTRODUCTION

Qijia Oilfield tectonic position is on the northwest slope of Qijia-Gulong depression, Songliao basin, a dome anticline structure on a regional nose structure anticline. The porosity below 10% is accounted for 80%, and the permeability below 0.1×10-3μm^2 is accounted for 56% in Gaotaizi reservoir, Qijia Oilfield. It is a tight reservoir of low productivity. The calculation and distribution law of brittleness index are important to make seam fracturing scheme. Now we want to find well layers to carry out seam fracturing scheme to improve productivity in research area.

The tight reservoir has complex lithology, at present research results that fracture is the important way to improve [1-3], so the evaluation of fracture's possibility is important to pick out the well layers. By indoor rock brittleness experiments, foreign scholars found that the difficulty of the rock fracturing can be explained by brittleness index, the higher brittleness index, rigid formation properties, the more easy to form cracks, the more sensitive to fracturing operation, then make advantage to the fluid reservoir and migration in reservoirs. So this parameter is the important evidence in choosing fracture's well layers[4], to open up a way to evaluate fracture's possibility of tight reservoir.

Brittleness is when the rock stress reaches a certain limit and sudden rupture(before the rupture has a small plastic deformation), and a nature released by the form of elastic energy. Brittleness index is a measurement of the speed and ease before the moment rocks change. there are two ways to get the traditional brittleness index evaluation model, one is through the test method [5-8] , this method is high precision, but the rock core work is difficult and of high cost, so this method is of low cost performance. The other is based on the geophysical well logging data, using the mathematical formula to calculate the rock mechanics parameters. This method is economical, efficient, accurate data and strong continuity[9-10]. Longitudinal continuity of well log data is strong, high-resolution, abundant geologic information, intuitively reflect the characteristics of the formation and side borehole structure etc., so using the logging data to get brittleness index is reliability and accuracy. At present most popular way of using well logging data to study brittleness index is rock mechanics parameters method[11] and brittle mineral expression method[12]. The result of using rock mechanics parameters method to calculate brittleness index is uncertainty.
And affected by the formation environment factors, brittle mineral expression method also can't fully explain the brittleness index.

Given this, first the author pick the continuous sampling core hole, and testing samples indoor, after determined each samples' Young's modulus and Poisson's ratio, then calculate each samples' brittleness index. We extract corresponding value of the sample points from well logging curve, making correlation analysis between brittleness index and well logging curve, and pick out the most relevent well logging curve to build brittleness index interpretation model, at last using he model to explain the rest wells, which lack core, also we test the result's reasonableness.

II. PETROLOGY BASIC CHARACTERISTICS OF QIJIA AREA

1.1 Lithology and mineral composition

According to core observation and thin sections identification results etx., determine the rock types are debris-arkosic sandstone and feldspar lithic sandstone in GaoIII and GaoIV reservoirs this area. Through thin sections identification results, major ingredient of clasolite is quartz, feldspar and lithic. Quartz content is between 16～37% in commonly, average content is 26.97%. Average content of feldspar is 32.34%, among it the orthoclase content is between 16～39%, average content is 26.79%, plagioclase content is between 0～20%, average content is 5.54%. Lithic content is between 12～40%, average content is 27.64%, it is mainly the acidic extrusive clastic rock. Judging from three component contents, the contents of quartz, feldspar and lithic are almost the same. Average content of interstitial material is 13.05%, among that matrix is mainly composed of clay minerals content, about 5.01%, and illite content is 66% among clay minerals, chlorite is about 21%, illite-montmorillonite mixed-layer about 12%, the illite is the main ingredient. Cement is mainly maked up by carbonatite, average content is 8.07%, partly appear phenomenon of high muddy and calcium or fossil concentration. The scale of two kinds interstitial materials is different from different samples, generally sandstone layers are mainly maked up by calcium, the upper parts are mainly maked up by argillaceous.

1.2 Characteristics of rock structure

The result of grain statistics shows that the study area most sandstone grain size mainly distributed in 0.01 ~ 0.15mm, all in within the scope of powder - fine sand, in order to fine-grained sandstone and siltstone dominated(Figure 1). Different microfacies sand body with different particle size distribution, the most coarse granularity of distributary channel, mouth bar, with the highest proportion of fine sand, sorting is relatively good; The second is the inner edge of the dam and sheet sand, by very fine sand and thin silt primarily, sorting becomes worse ; The distributary thin sand for the proportion by the thin silt to be highest, sorting of the worst . particle contact relationship is given priority to with point - line contact, a small amount of point contact, psephicity is mainly subangular.

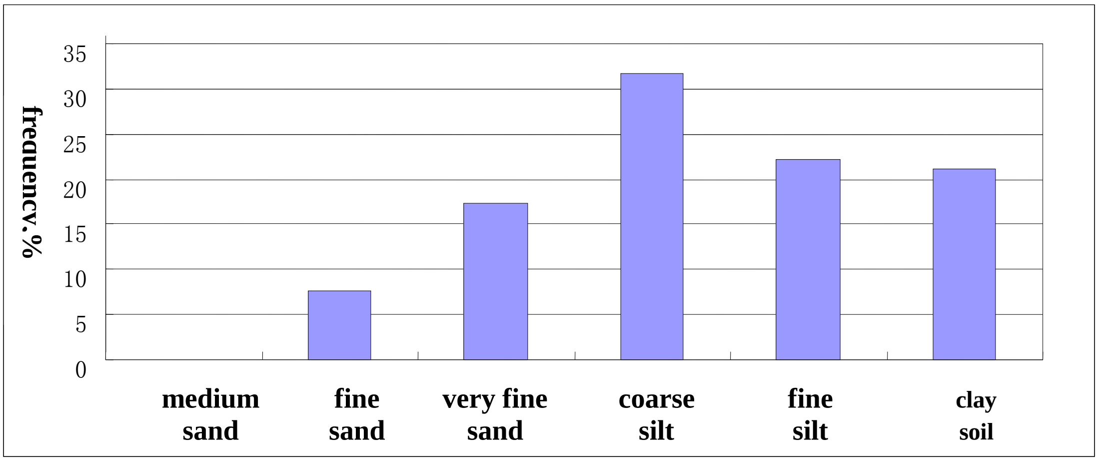


Figure 1 GaoIII、GaoIV oil layer group grain fineness frequency bar chart

III. BRITTLENESS INDEX EVALUATION BY LOGGING METHOD

2.1 Concept of using logging method to evaluate Brittleness

(1) Interval transit time curve

According to elastic wave mechanics theory, interval transit time has a great instruction to rock's mechanical properties, the most important logging data in Calculation of rock mechanics parameters is interval transit time data. Horizontal-vertical interval transit time can reflect the formation pressure and shear character etc., and they can provide important basic data for elasticity modulus, Shear modulus and Poisson's ratio etc., and then they can guide the formation pressure, ground stress and formation pressure evaluation[13-14].

(2) Resistivity curve

We can recognize rock mineral composition and its structure through the difference of resistivity curve, as already mentioned, rock mineral content, internal structure and hardness of rock have close connection with hardness of rock, degree of deformation and compressive shear strength, and they are important factors to brittleness index.

(3) Natural gamma curve

Natural gamma curve is used in calculating shale content of layers, and implement lithologic division and stratigraphic correlation etc. Rock shale content has intimate connection with particle contact relationship and cementation etc., generally speaking, rock of high shale content has s low compressive strength[15] and brittleness index.

2.2 Log model to brittleness index explaination in tight reservoir Qijia Oil Field

At present, most studies about brittleness index are based on core experiment measurement, but this method cannot completely really reflect the rock under formation factor influence brittle index, and poor continuity, therefore, must establish the relationship between rock brittleness index and logging data, in order to realize the calculation and judgment of rock strength parameters of continuous profile [16]. Well logging data continuity and high resolution characteristics, bring about use logging data evaluation index of brittleness is one of the most economical and effective way, and be able to accurately locate the fracturing of the destination (well, layer).

2.2.1 Rickman brittleness index calculation

Young's modulus refers to rock burst, the rock maintains the crack ability which it forms, the value is higher then easier to form the complex crack; Poisson's ratio, refers to when the rock by force, it is the ability to resist destruction, the higher the value the greater is not easy to form cracks. Using the Richman summary of shale gas formation brittleness index calculation method used in dense sandstone formation, Based on young's modulus and Poisson's ratio of brittleness index models:

$$B_R = \frac{(\Delta E + \Delta \mu)}{2} \times 100\% \qquad (1)$$

within formulae: $\triangle E$——The young's modulus after normalization,non-dimensional;

$\triangle \mu$——The poisson ratio after normalization,non-dimensional;

B_R——Brittleness index,%。

In order to apply the formula 1 to calculate the rock brittleness index, the young's modulus and Poisson's ratio of elastic parameters is the key to obtain. To get high accuracy Young's modulus and the Poisson Ratio, etc. rock resiliency parameters, logging acquisition series should be equipped with high precision density logging and array sonic logging(or sound wave scanning well logging), at the same time, by rock mechanics experiment observed value scale division well logging predicted value [17]. Determinations of elastic parameters of rock are divided into static method and dynamic method. The static elastic parameter is obtained directly by rock mechanics experiment of rock properties, including the Poisson's ratio, Young's modulus, compressive strength, tensile strength, shear strength and friction angle etc; The dynamic elastic parameters are obtained through the determination of rock P-wave and S-wave velocity and volume density after conversion, the formula is as follows:

$$\Delta E = \rho\left(\frac{3}{\Delta t_p^2} - \frac{4}{\Delta t_s^2}\right) \Bigg/ \Delta t_s^2 \left(\frac{1}{\Delta t_p^2} - \frac{1}{\Delta t_s^2}\right) \qquad (2)$$

$$\Delta \mu = \left(\frac{1}{\Delta t_p^2} - \frac{2}{\Delta t_s^2}\right) \Bigg/ 2\left(\frac{1}{\Delta t_p^2} - \frac{1}{\Delta t_s^2}\right) \qquad (3)$$

within formulae: Δt_p—— P-wave interval transit time, μs/m;

Δt_s—— S-wave interval transit time, μs/m;

ρ —— The volume density , g/cm^3.

2.2.2 Brittleness index evaluation model of gamma ray logging

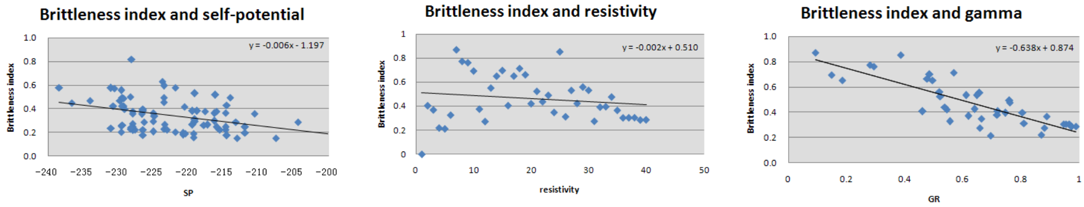
We usually have to locate well layers in order to pick out the accurate fracture place, but the conventional method to calculate the index of brittleness index cannot meet the demand. The conventional logging data to the mechanical properties of rock reaction in a certain extent use QiPingYi well logging data to calculate the relevant parameters. In Figure 2 a, b, c respectively show the use of formula (1) calculation of brittleness and natural potential, resistivity, the relationship between natural gamma ray logging, you know the relationship between the natural potentiometer and resistivity logging and brittle index less relevant, But the natural gamma logging and brittle index clearly Negative Linear High-related, the correlation coefficient was 0.82. The gamma curve is used in calculating shale content of layers, Rock shale content has intimate connection with particle contact relationship and cementation etc., generally speaking, rock of high shale content has s low compressive strength, fit with the above negative altitude correlation result. Then according to the gamma curve fitting index of brittleness, obtains the brittleness index logging interpretation model:

$$B_{GR} = -0.6384 \times SH + 0.8742 \qquad (4)$$

$$SH = \frac{GR - GR_{min}}{GR_{max} - GR_{min}} \qquad (5)$$

within formulae : B_{GR}——Logging fitting brittleness index, %;

SH —— GR relative value;
GR —— Object layer natural gamma log value;
GR_{min} ——Natural gamma's value at pure sandstone formation;
GR_{max} ——Natural gamma's value at pure mudstone formation.



a Brittleness index and self-potential b Brittleness index and resistivity c Brittleness index and gamma

Figure 2 Different logging and brittleness index crossplot

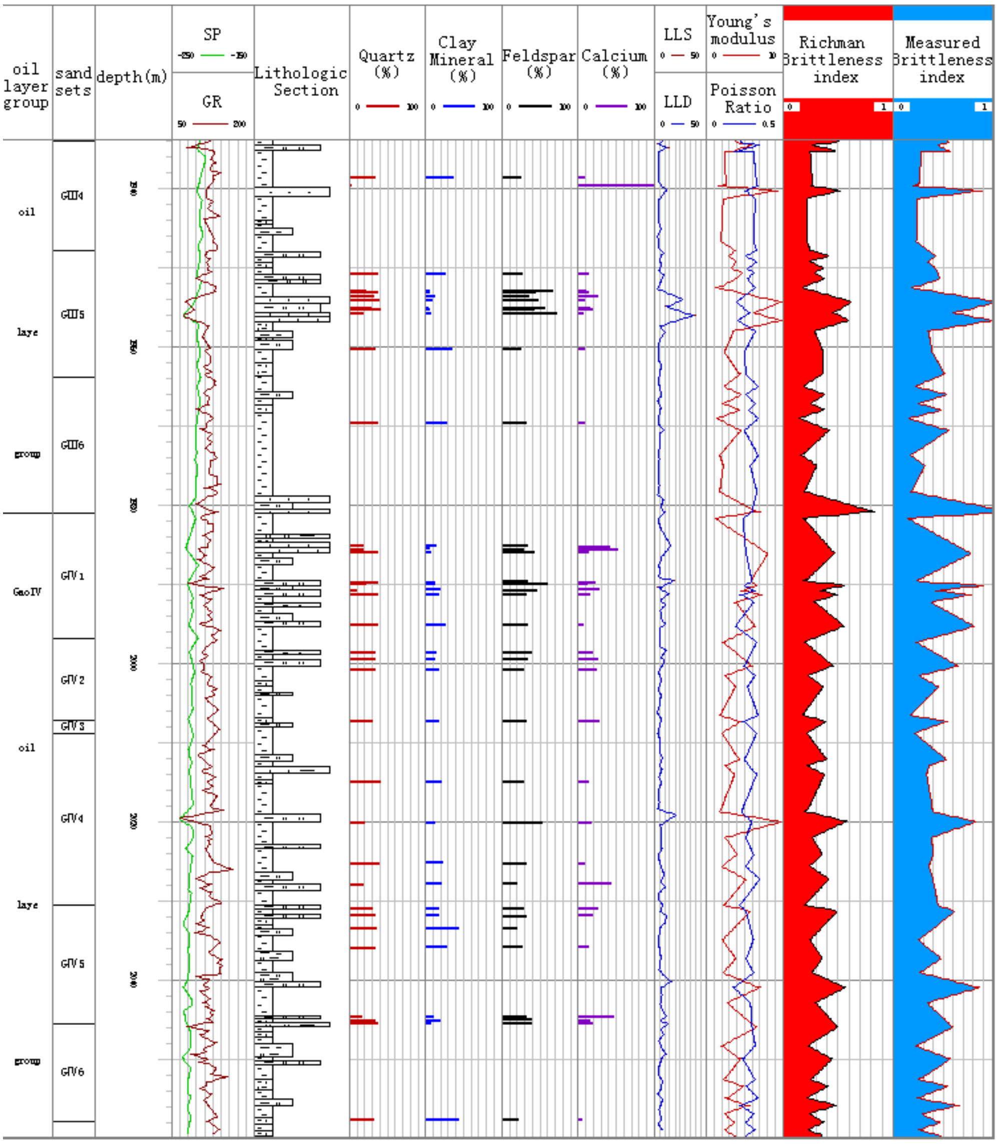


Figure 3 Measured and derived brittleness index comparison diagram of Qipingyi well

IV. THE RATIONALITY ANALYSIS OF CALCULATION METHOD

3.1 Analysis of brittleness index error logging interpretation

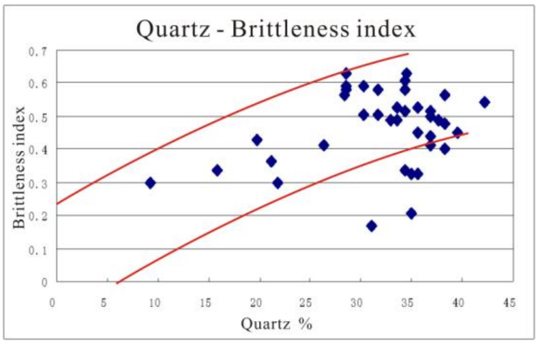
By gamma ray log realized the fragility index strike. Natural gamma QiPingYi well were normalized according to the formulae (4), well fitted QiPingYi brittleness index, and measured brittleness index were compared. Contrast figure as shown in figure 3 - histogram QiPingYi well, the last two columns for Richman brittleness index and measured brittleness index trend line.

You can see from Figure 3, the measured brittleness index curve and the theoretical curve of brittleness index of the same trend, anastomosis quite good, the standard error is only 0.002. This shows that if there are logging data in the study area, in the coring data is missing or inadequate test costs in the case, can be obtained by logging data brittleness index.

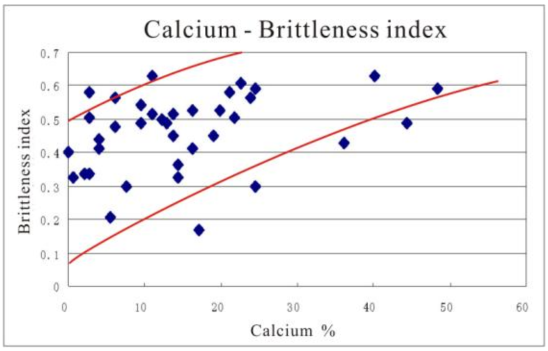
3.2The relationship between mineral composition and brittleness index

Minerals are the main constitute part of the rock, the mineral composition and content of rock has an important influence on the mechanical properties of rock. According to the analysis results of previous rock mechanics experiment, appraises the rock brittle index using the rock mineral ingredient to have the good effect, for this purpose, the use of mineral content of formula (4) to verify the calculation of brittleness index.

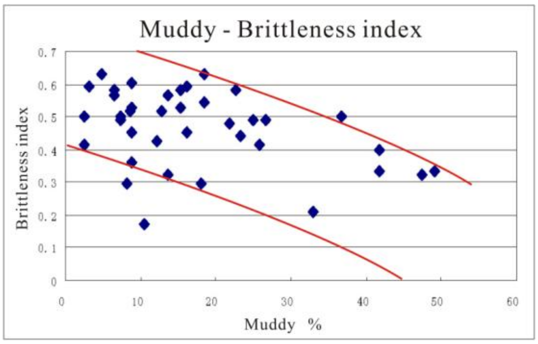
Select QiPingYi well research the relationship between the mineral content and brittleness index. In Figure 4 respectively for the formula (4) calculation of brittleness and quartz, calcareous, argillaceous, correlation analysis of feldspar content cross plot. Obviously the quartz, the carbonic acid salt content, the shale content have certain influence to the brittle index, that is brittle index and the quartz and carbonate minerals has a positive correlation, the inverse correlation with the shale content, with feldspar content non-correlated.



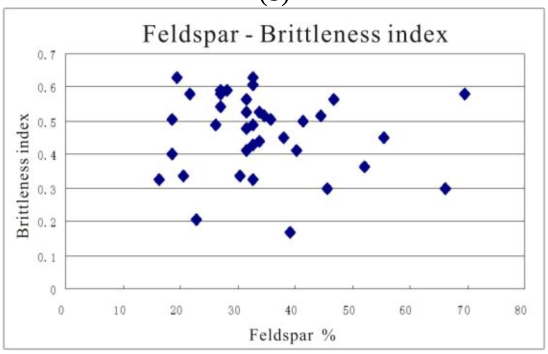
(a)



(b)



(c)



(d)

Figure 4 Different components and brittleness index Crossplots

Using the formula (4) to carry on the comprehensive interpretation of brittleness index, and compared with the mineral composition, particle size distribution. The results showed that the brittleness index of high value region corresponding to the high content of quartz, low content of cuttings, high permeability area.

3.3 The grain size of rock and brittleness

Brittleness index of high value corresponding to the coarse granularity region area, namely the high value area of brittleness index of fine sand size and high content of brittleness index low value area of clay content is relatively high.

The verification results, Qijia area using logging data to evaluate the brittleness index model is reasonable, brittleness index distribution by mineral composition and size distribution influence is bigger, with Qijia area mineral composition distribution and better applicable condition. Therefore, the evaluation model has practical value.

V. CONCLUSION

We build a new way, which can calculate all wells' brittleness index throughing Gamma curve with the help of calculating one well's brittleness index throughing Young's modulus and Poisson's ratio, in the study area; through the actual mineral composition, content and plane distribution rule, and verify the calculation result about brittleness index. Brittleness index distribution is influenced by mineral composition and grain fineness; provide the parameters basis for well layers' fracture. Among that, high brittleness index mostly at the west of study area in Gao IV oil layer group, and brittleness index becomes higher bottom-up, Gao III oil layer group has a higher brittleness index than Gao IV oil layer group's, the brittleness index is higher in west and east part of study area, and it is the key area for fracture.

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