Application of rock brittleness evaluation in tight oil exploration—— Taking Lijiaweizi Fault Depression in Qijia Area as an Example

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Abstract. Brittle rock is one of the key factors in the use of unconventional oil and gas exploration technology to be considered. The stronger the brittleness of rock is, the easier to produce fractures to form fracture network in the over flushing of fracturing, the stock of oil and gas storage layer will be increased, and the production of single well will be increased. At present mainly based on rock elastic parameters, we use Young's modulus and Poisson's ratio of two ways to analyze brittle rock in earthquake prediction evaluation. However, since these two methods in the process, both the need for elastic parameters of rock normalized, leading to large errors, adaptability reduce. Based on this, we propose a Young's modulus and Poisson's ratio coefficient of utilization compared to the brittle rock evaluation method to effectively improve the accuracy of prediction and evaluation of brittle rock and anti-jamming capability, while the brittle evaluation method based on the use of pre-stack seismic inversion of elastic parameters to Qijia area of Songliao basin compact oil brittle rock predict deployment guidance wells to obtain stable high level of industrial oil flow.

1. Introduction
As one of the essential energy materials in the industrialized society, oil is the key to promote the development of the whole industrial society and economy. In recent years, with the declining production of conventional oil and gas exploitation and the rising price of oil and gas, the development and progress of unconventional oil and gas resource exploration technology have been promoted. The shale gas revolution, which was first put forward and started in the United States, was a sign, and successfully led to the exploration and development of unconventional oil and gas resources in the world.

In recent years, unconventional oil and gas exploration technology has also become the focus of research in the field of oil exploration technology in China, and a series of strategic achievements have been made in recent years. As an important unconventional oil and gas resource, tight oil is mainly stored in sandstone and tight carbonate reservoirs. In the process of mining, a single well usually has no natural production capacity, but it can obtain industrial production and meet the industrial production standard by adopting certain technical means and economic costs. From the current tight oil production, it mainly involves two core technologies: horizontal well drilling and horizontal well multi-stage volume fracturing. At the same time, it is necessary to focus on rock brittleness in the exploration process. Generally, it is necessary to analyze the strength and sensitivity of rock to fracturing reaction and the complexity of fracture network formed by rock brittleness, and effectively...
transform the entire storage according to these characteristics. To improve the oil and gas production of single well. At present, in the study of rock brittleness, it is mainly described by young's modulus and Poisson's ratio. However, both methods need to normalize the elastic coefficient of rock in the description process, which makes its anti-interference and adaptability extremely low, prediction accuracy difficult to grasp, and poor universality.

In view of this background, this paper proposes a method to evaluate the rock brittleness by using the ratio of Young's modulus and Poisson's ratio, which can effectively improve the adaptability of traditional methods using a single young's modulus and Poisson's ratio, improve its universality and accuracy of prediction results.

2. Evaluation method of rock brittleness based on the ratio of Young's modulus and Poisson's ratio

In the implementation of the rock brittleness evaluation method based on the ratio of Young's modulus and Poisson's ratio, it is necessary to establish brittleness evaluation standards through experiments, then calculate the young's modulus and Poisson's ratio of rock on this basis, and finally calculate the brittleness index. In this section, the principle of the whole rock brittleness evaluation method based on the young's modulus and Poisson's ratio will be introduced in detail from these three aspects.

2.1. Establishment of brittleness evaluation standard

The establishment of brittleness evaluation standard is mainly to define the brittleness of rock by the stress-strain curve mentality of a large number of rock samples and the failure state of rock samples. It can be divided into three grades: good brittleness, general brittleness and poor brittleness. The specific definitions of these three grades are as follows:

A. The brittleness is good, and the distribution of axial stress-strain data obtained from the experiment is linear.

B. The brittleness is medium, the distribution of the axial stress-strain data obtained from the experiment presents a S-shaped curve.

C. The brittleness is poor, and the distribution of axial stress-strain data from the experiment shows a concave curve.

2.2. Calculation of Young's modulus and Poisson's ratio of rock

Based on the experimental data, the young's modulus and Poisson's ratio of rock are calculated according to the following mathematical model:

\[ E = \frac{\Delta \sigma}{\Delta \varepsilon_1} \]

\[ V = \frac{\Delta \varepsilon_2}{\Delta \varepsilon_1} \]

In the formula, \( E \) is young's modulus, \( V \) is Poisson's ratio, \( \Delta \sigma \) is axial stress increment, \( \Delta \varepsilon_1 \) is axial strain increment, \( \Delta \varepsilon_2 \) is radial strain increment.

2.3. Calculation of brittleness index

On the basis of the calculation model of Young's modulus and Poisson's ratio given above, the parameters of Young's modulus and Poisson's ratio of calibration logging obtained by experiments are calculated according to the model, and then the ratio is calculated as the brittleness index. The calculation mathematical model is as follows:

\[ BI = \frac{E}{V} = \frac{\Delta \sigma}{\Delta \varepsilon_2} \]

The above is the rock brittleness evaluation method based on Young's modulus and Poisson's ratio adopted by the author. Through this method, it can effectively avoid the error effect caused by the normalized value of rock elastic coefficient used in the calculation process of Young's modulus and Poisson's ratio, effectively improve its adaptability and accuracy, and can effectively evaluate the
brittleness of the whole well point in the earthquake prediction. It can get more accurate analysis results when it is applied to the brittle distribution of tight oil layer, which provides the basis for more accurate and reliable exploration and development plan.

3. Evaluation of rock brittleness in Qijia area of Songliao Basin

In order to study the rock brittleness in Qijia area of Songliao Basin, aiming at the target stratum of Songliao Basin, that is, the fault stratum in lijiawizi fault depression area, continuously takes the stratum of 1872 well in lijiawizi fault depression area as the research sample, and takes 85 rock samples for analysis, and carries out triaxial rock mechanics experiment on them. At the same time, the rock is analyzed by the stress-strain relationship of rock brittleness is evaluated and analyzed. The confining pressure is 10MPa and the loading speed is 50N/s in the whole process. Britleness is evaluated according to the brittleness evaluation standard and method proposed above.

First of all, the stress-strain characteristics of three kinds of rocks with good brittleness, general brittleness and poor brittleness are statistically analyzed. The statistical characteristics of three kinds of brittleness evaluation are as follows:

A. Good brittleness: the stress-strain curve of the experimental rock sample shows excellent elasticity, the whole curve is in a straight line, and the slope of the curve is large. At the same time, when the maximum compressive strength is reached, the whole rock begins to break, and the rock breaking time axis is generally less than 0.8%, as shown in Figure 1.

![Fig. 1 Stress-strain curve of rock with good brittleness](image)

B. Medium brittleness: the stress-strain curve of the rock is mainly S-shaped. When the stress reaches the maximum compressive strength of the rock, the rock can be damaged. At the same time, when the rock is damaged, the axial stress is greater than 0.8%, less than 1.5%. The curve characteristics are shown in Figure 2.

![Fig. 2 Stress-strain curve of medium brittle rock](image)

C. Poor brittleness: the stress-strain curve of the rock in this state shows a concave shape, and the stress keeps elastic deformation until it reaches the maximum compressive strength, and can not be destroyed until it is greater than 1.5%. The characteristic curve is shown in Figure 3.
Secondly, according to the above experimental results, the data are processed to establish brittleness evaluation parameters, as shown in Table 1.

| Brittleness grade | Young's modulus (GPa) | Poisson's ratio | Britleness evaluation index(GPa) |
|------------------|-----------------------|----------------|---------------------------------|
| A                | >=15                  | <=0.2          | >75                             |
| B                | 10~15                 | 0.2~0.23       | 43.5~75                         |
| C                | <10                   | >0.23          | <43.5                           |

Through statistical processing, it is found that the overall brittleness of lithic dolomite, dolomitic sandstone and microcrystalline dolomite in the sample is in a good state, while the brittleness of argillaceous dolomite and microcrystalline dolomite is medium, and the brittleness of carbonaceous mudstone and mudstone is poor. The brittleness distribution of various rocks is shown in Figure 4.

### 4. Conclusion
Finally, based on the above experimental analysis principles and results, the brittleness of the rocks in lijiaoweizi fault depression in Qijia area can be predicted. The young's modulus and Poisson's ratio can be calculated by using the P-S wave data, and then the brittleness in the sampling well can be continuously characterized, and the brittleness evaluation of lijiaoweizi fault depression in Qijia area can be obtained. This method can effectively improve the accuracy and anti-interference ability of rock brittleness prediction and evaluation. At the same time, based on this brittleness evaluation method, the seismic prestack elastic parameter inversion is used to predict the tight oil rock brittleness of lijiaoweizi fault depression in Qijia area of Songliao Basin, and guide oil well deployment to obtain stable high-level industrial oil flow.

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