The Study on Brittleness Evaluation of Chang 7 Reservoir in Longdong Area in Ordos Basin

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Abstract. Brittleness is very important in the fracability evaluation and exploration of unconventional oil and gas. In this paper, the rock mechanics parameter method and the mineral composition method are used in order to calculate the brittleness index in Chang 7 reservoir in Longdong area in Ordos basin. The results show that the brittleness index calculated by rock mechanics parameters is 44.9%-62.23% and by mineral composition method is 52.5%. The brittleness indexes calculated by the two different methods are not greatly different, and the overall brittleness index is high, which indicate Chang 7 reservoir in Longdong area has high brittleness and good fracability.

1. Introduction
With the fast growth of oil and gas demands in the world and the gradual depletion of conventional resources, the exploration and development of unconventional oil and gas resources attracted more and more attention [1]. In oil and gas geology, Brittleness is generally defined as the difficulty of transient change before rock rupture, it can be quantitatively represented by the brittleness index [2,3]. The greater the rock brittleness, the stronger the crack-forming ability, and the easier it is to form a complex network of cracks. Domestic and foreign scholars have done a lot of work on the unconventional oil and gas reservoir brittleness, and proposed many different calculation methods which are applied very well in different regions [4,5]. But there are still some problems in the study of rock brittleness, especially in the precise definition and quantitative calculation. Different definitions of brittleness and different calculation methods often cause inaccuracy or even errors in the results. Therefore, choosing the appropriate calculation method has become the key to brittleness evaluation.

2. The basic situation of the study area
Longdong area is located in the southwestern part of the Ordos Basin, mainly spanning two primary structural units of the Tianhuan Depression and the Northern Shaanxi Slope (Fig. 1), with an area of about $5 \times 10^4\text{km}^2$. The rapid expansion of the lake basin and the continuously stable deep-water sedimentary are necessary for the formation of the Chang 7 reservoir. Due to the characteristics of low porosity and ultra-low permeability, the study of the fracability based on brittleness evaluation is particularly important.
Figure 1. The study area in Ordos Basin

3. Brittleness index calculation

3.1. Brittleness index of Chang 7 calculated through the rock mechanics parameter method

Since rock brittleness is a comprehensive reflection of Young’s modulus and Poisson’s ratio, Rickman [6] proposed a brittleness index calculation formula based on rock mechanics parameters (Equation 3):

\[
\Delta E = \frac{E - E_{\text{min}}}{E_{\text{max}} - E_{\text{min}}} \times 100\% \\
\Delta \mu = \frac{\mu_{\text{max}} - \mu}{\mu_{\text{max}} - \mu_{\text{min}}} \times 100\% \\
B = \frac{\Delta E + \Delta \mu}{2} \times 100\%
\]

In the above equations, \(\Delta E\) is the normalized Young’s modulus, \%; \(E\) is the Young’s modulus of the rock, GPa; \(\Delta \mu\) is the normalized Poisson’s ratio, \%; \(\mu\) is the Poisson’s ratio of the rock, no dimension; \(B\) is the brittleness index, \%; subscripts min and max represent the maximum and minimum values of the parameter in a certain stratum.

We collected 39 rock samples which are from X-1, X-2, Y-1 and Y-2 well in Chang 7 reservoir in Longdong area. The size of those samples is \(\Phi 38.1 \text{ mm} \times \text{h76.2 mm}\). Young’s modulus and Poisson’s ratio are obtained through Triaxial compression test(The test results of Chang 7 in Longdong area are shown in Table 1). After obtaining the rock mechanical parameters, the normalized Young’s modulus and Poisson’s ratio can be calculated by equations (1) and (2), and then the brittleness index will be calculated by equation (3).

The maximum and minimum values of Young’s modulus in X-1 well are 4.195 and 3.336 GPa, the maximum and minimum values of Poisson’s ratio are 0.232 and 0.181, and the brittleness index calculated is 38.8%; The maximum and minimum values of Young’s modulus in Well X-2 are 2.443 and 1.291 GPa, the maximum and minimum values of Poisson’s ratio are 0.2167 and 0.191, and the
brittleness index is 47.8%. The maximum and minimum Young’s modulus measured in Y-1 well are 2.556 and 1.529 GPa, the maximum and minimum Poisson’s ratio are 0.289 and 0.175, and the brittleness index calculated is 62.23%. The maximum and minimum values of Young’s modulus in Y-2 well are 2.553 and 2.213 GPa, the maximum and minimum Poisson’s ratio are 0.237 and 0.181, and the brittleness index is 44.9%.

Table 1. Static Young’s modulus and Poisson ratio determined by triaxial compression test

| Well number | Lithology | Depth(meter) | Sample number | Confining pressure (MPa) | Elastic modulus $E \times 10^4$MPa | Poisson’s ratio $\mu$ |
|-------------|-----------|--------------|---------------|--------------------------|-----------------------------------|------------------------|
| L1-1        | sandstone | 1407-1412    | L1-1          | 3.668                    | 1.95                              |
| L1-2        | sandstone | 1407-1412    | L1-2          | 3.418                    | 1.81                              |
| L1-3        | sandstone | 1407-1412    | L1-3          | 3.336                    | 0.232                             |
| L1-4        | sandstone | 1407-1412    | L1-4          | 3.697                    | 0.188                             |
| L1-5        | sandstone | 1407-1412    | L1-5          | 3.818                    | 0.200                             |
| L1-6        | sandstone | 1407-1412    | L1-6          | 3.826                    | 0.210                             |
| L1-7        | sandstone | 1407-1412    | L1-7          | 3.886                    | 0.226                             |
| L1-8        | sandstone | 1407-1412    | L1-8          | 3.932                    | 0.229                             |
| L1-9        | sandstone | 1407-1412    | L1-9          | 3.899                    | 0.223                             |
| L1-10       | sandstone | 1407-1412    | L1-10         | 4.167                    | 0.232                             |
| L1-11       | sandstone | 1407-1412    | L1-11         | 3.999                    | 0.201                             |
| L1-12       | sandstone | 1407-1412    | L1-12         | 4.195                    | 0.223                             |
| L2-1        | sandstone | 1407-1412    | L2-1          | 1.350                    | 0.201                             |
| L2-2        | sandstone | 1407-1412    | L2-2          | 1.291                    | 0.243                             |
| L2-3        | sandstone | 1407-1412    | L2-3          | 1.647                    | 0.255                             |
| L2-4        | sandstone | 1407-1412    | L2-4          | 2.427                    | 0.191                             |
| L2-5        | sandstone | 1407-1412    | L2-5          | 2.415                    | 0.197                             |
| L2-6        | sandstone | 1407-1412    | L2-6          | 2.443                    | 0.214                             |
| L3-1        | sandstone | 1407-1412    | L3-1          | 2.013                    | 0.286                             |
| L3-2        | sandstone | 1407-1412    | L3-2          | 1.529                    | 0.289                             |
| L3-3        | sandstone | 1407-1412    | L3-3          | 2.323                    | 0.270                             |
| L3-4        | sandstone | 1407-1412    | L3-4          | 2.323                    | 0.213                             |
| L3-5        | sandstone | 1407-1412    | L3-5          | 2.475                    | 0.213                             |
| L3-6        | sandstone | 1407-1412    | L3-6          | 2.525                    | 0.177                             |
| L3-7        | sandstone | 1407-1412    | L3-7          | 2.556                    | 0.175                             |
| L3-8        | sandstone | 1407-1412    | L3-8          | 2.542                    | 0.218                             |
| L3-9        | sandstone | 1407-1412    | L3-9          | 2.379                    | 0.201                             |
| L4-1        | sandstone | 1407-1412    | L4-1          | 2.392                    | 0.212                             |
| L4-2        | sandstone | 1407-1412    | L4-2          | 2.219                    | 0.181                             |
| L4-3        | sandstone | 1407-1412    | L4-3          | 2.303                    | 0.181                             |
| L4-4        | sandstone | 1407-1412    | L4-4          | 2.451                    | 0.189                             |
| L4-5        | sandstone | 1407-1412    | L4-5          | 2.213                    | 0.195                             |
| L4-6        | sandstone | 1407-1412    | L4-6          | 2.385                    | 0.182                             |
| L4-7        | sandstone | 1407-1412    | L4-7          | 2.384                    | 0.239                             |
| L4-8        | sandstone | 1407-1412    | L4-8          | 2.519                    | 0.188                             |
| L4-9        | sandstone | 1407-1412    | L4-9          | 2.457                    | 0.213                             |
| L4-10       | sandstone | 1407-1412    | L4-10         | 2.553                    | 0.237                             |
3.2. Britteness index of Chang 7 calculated through the mineral composition method

The formula (4) proposed by Xiaoyan Qin et al. [7] is used to calculate the brittleness index of the study area.

\[ B = \sum_{i=1}^{n} a_i M_i, \quad a_i = \frac{E_i}{\mu_i} \]  

In the above formula, \( B \) is the rock brittleness index, \( i \) is the mineral type, \( a \) is the brittleness coefficient, \( M \) is the volume fraction of the mineral in the stratum, \%; \( E_i \) is the Young’s modulus of the \( i \)-th mineral, GPa; \( \mu_i \) is the Poisson’s ratio of the \( i \)-th mineral.

The sandstone and siltstone samples from X-1, X-2, Y-1 and Y-2 well in Chang 7 reservoir were selected for mineral composition identification. The samples are ground into powder with a diameter of about 0.07mm, their mineral composition was tested by the X/max-2500 X-ray diffractometer. The results are shown in Figure 2.

The Chang 7 reservoir is mainly composed of quartz, feldspar and clay minerals, in addition to a small amount of carbonate and pyrite. Quartz content ranges from 17% to 34%, with an average of 26%. Feldspar content ranges from 17% to 41%, with an average of 29%. Clay mineral content ranges from 23% to 49%, with an average of 35%. The carbonate and pyrite content are 4% to 14% and 1% to 4%, and their average contents are 8% and 2%, respectively.

The brittleness coefficients of pyrite, quartz, feldspar, carbonate minerals and clay are 3.2, 1.0, 0.44, 0.39, and 0.12, respectively. So the brittleness index of Chang 7 reservoir in Longdong area can be calculated as 52.5% by equation (4).

![Figure 2. Mineral composition of Chang 7 in Longdong area](image_url)

4. Conclusion

Brittleness is an important parameter for favorable block and favorable stratum selection. The better the brittleness of the stratum, the stronger the crack-forming ability, the easier it is to form a complex fracture network. The brittleness index of Chang 7 reservoir in Longdong area calculated rock mechanics parameter method is 44.9%–62.23%, by mineral composition method is 52.5%. The overall brittleness index is high, and the results calculated by various methods are not greatly different. The brittleness index ranges from 44.9% to 62.23%, indicating it has good fracability which is favorable for oil and gas exploration.
Acknowledgments
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