Particle Size Analysis about Tight Sandstone in He 8 Member of Sulige Gas Field

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***Abstract* — With the year-by-year decrease of conventional oil and gas reserves, unconventional reservoirs had become the target of exploitation in the world wide. Tight gas reservoir, as a kind of unconventional gas reservoir, was abundant in strata, but its exploitation was difficult. To improve the efficiency of exploitation, rock samples from He 8 member of Suglige, the typical gas field, were analyzed. Through casting thin sections and electron microscope scanning, typed of sandstone and pore, and particle size distribution of sandstone samples was obtained. For tight gas reservoir, general method of calculation was insufficient, so that standard deviation was employed to get more accurate sorting coefficient. Based on professional statistical analysis of the experiment data and analysis of particle size in different permeability, particle size distribution chart was obtained. Results, compaction, cementation and dissolution in stratigraphic formation influenced the porosity and permeability of sandstone, and made the reservoir tight. Results of this research on the Suglige gas reservoir provided theoretical basis for study of dense reservoir percolation mechanism and guided the actual mining.**

Keywords - Tight sandstone; Sandstone type; Particle size distribution; Sorting coefficient

I. INTRODUCTION

With the year-by-year decrease of conventional oil and gas reserves, unconventional reservoirs have become the target of exploitation in the world wide. Tight gas reservoir, as a kind of unconventional gas reservoir, is abundant in strata, but its exploitation is difficult due to low permeability and poor sorting. To improve the efficiency of exploitation, thorough research about tight gas reservoir and particle size analysis are required. Analysis about type, pore structure and particle size of sandstone in the tight reservoir can be used as a reference for exploitation of the tight gas reservoir. Sulige gas field, located in northwest of Yishan Slope of E'erduosi Basin, contains six reservoirs, including Benxi Formation, Taiyuan Formation, Shanxi Formation, Lower Shihezi Formation, Upper Shihezi Formation and Shiqianfeng Formation. It has been found that He 8 Member of Lower Shihezi Formation and Shan 1 Member of Shanxi Formation were the main reservoir. As a tight gas field, its gas is featured by low permeability. Casting thin sections and electron microscope scanning were conducted to study the lithology and pore of the tight formation, to get the difference from the common formations. Therefore, study about reservoir of Sugeli gas field is of great significance, it can be used as a theoretical basis for study about percolation mechanism of tight reservoir and a guiding basis for actual exploitation.

II. LITERATURE REVIEW

On types of tight sandstone samples, a number of studies have been conducted by experts and scholars at home and abroad. Casting thin sections and electron microscope scanning are generally used, for example, tight sandstone reservoir of Shanxi Formation was featured by tight reservoir, fine sandstone granularity, and highest content of fine sandstone, secondary content of hone and medium sandstone, and lowest content of siltstone content and coarse sandstone[1]. In "Study about Characteristics of Tight Sandstone Reservoir in Sha 2 and 3 Member of Renqiu Fault Zone in Raoyang Sag", feldspathic rock, debris sandstone and lithic feldspar sandstone were found to be the main types of reservoir stratum in Shahejie Fm of Renqiu fault zone[2]. In "Study about Characteristics of Tight Sandstone Reservoir in Upper Paleozoic Erathem of Bahannao Region in Northern E'erduosi", it was found that sandstone grade of the region is quite complete[3]. In "Study about Characteristics of Tight Sandstone Reservoir in Sha 3 Member of Shuangtaizi Tectonic Zone and its Surrounding Area", sedimentation exerted a relatively great influence on lithology of sandstone reservoir [4-5].

Domestic and international studies mostly lay emphasis on theory of concrete section, and sorting coefficient calculation that is generally used fail to meet the requirement. Therefore, in this research, particle size of tight sandstone in He 8 Member of Sulige gas field was analyzed, and standard deviation was employed. It was proved that sorting coefficients obtained with the new method were more accurate and representative.

Contents of the rest part of this paper: Literature Review in the second part summarized the deficiencies and specifically stated key problems in this paper; the third part is about the types of sandstone and pore in the reservoir; the fourth part contains particle size distribution chart of tight sandstone, and calculation of the sorting coefficient; the fifth part is the conclusions.

III. METHODOLOGY

3.1 Sandstone types in the reservoir

The study area of He 8 Member is a reservoir composed of alluvial fan, fluvial facies, braided river delta and other types of sand bodies. The types of rock include mudstone, siltstone, packsand and medium sandstone, coarse sandstone and coarse gravel sandstone, among which coarse gravel sandstone, coarse sandstone and medium sandstone, about 30m in thickness, are dominant [6]. There are also many types of sedimentary tectonics in the study area, including ripple bedding, parallel bedding, cross bedding, graded bedding, scouring side and mud cracks, etc. [7]. Fig.1 shows sandstone types and detrital composition of He 8 Member.

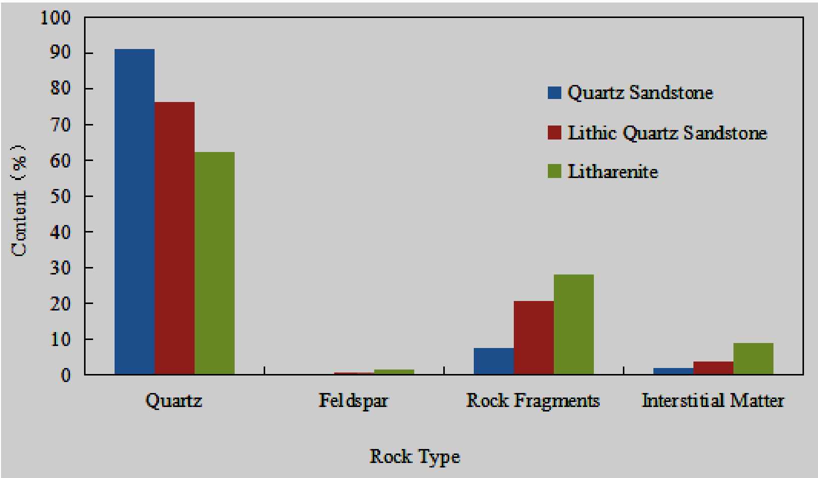

Figure 1. He 8 member sandstone style and clastic constituents content histograms

He 8 Member is a mixture of double provenance, Archaeozoic quartz poor sandstone in eastern side of E'erduosi Basin [8]. According to the study about types of sandstone samples in He 8 Member, lithic quartz sandstone is the main type, accounting for 70.85%, lithic sandstone and quartz sandstone 9.41% and 19.74% respectively. Quartz is the main type of sandstone in He 8 Member, feldspar content is almost zero. In sedimentary process, feldspar content decreases with weathering, and in diagenetic process, a lot of feldspar dissolute and transform into other types of clay minerals. Quartz in the study area is composed of quartz, flint, and quartzite; rock debris is mainly composed of eruptive rock, schist, phyllite eruption, and metamorphic sandstone, etc.; interstitial materials mainly include kaolinite, hydromica, ferrocalcite and siliceous contents (ferrocalcite is the combination of calcite precipitation formed by feldspar dissolution and clay minerals in strata).

3.2 Pore types in the reservoir

According to casting thin sections and electron microscope scanning, interparticle pore, interparticle dissolution pore, feldspar dissolution pore, lithic dissolution pore, zeolite dissolution pore, intracrystalline pore, shrinkage pore and micro cracks are the main pore types of He 8 Member. Fig.2 shows the distribution of pore types, in which lithic dissolution pore makes up the highest percentage.

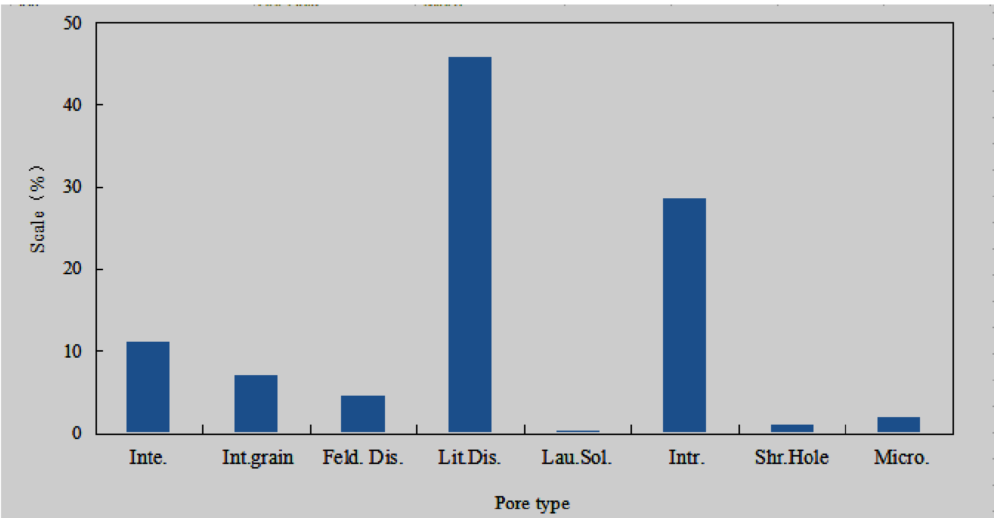

Figure 2. He 8 member pore types distribution histograms

Generally, compaction, cementation and dissolution, etc. contribute to the process of stratum formation. For a tight reservoir, throat makes increasing contribution to effective reservoir space, the greater the content of small throat and the smaller the throat radius, the greater the percolating resistance and the worse the connectivity of pore throats[9].

Clastic particles mostly contact by concave-convex and stylolites. Compaction is one of the most important diagenesis of sediments, which refers to the burden pressure of the overlying thickening sediments after sediment deposition, and is irreversible. With the formation pressure rise, plastic minerals in the reservoir become matrix in very small particles and fill in the original primary pores of the reservoir, so that the number of primary pores decrease and permeability become smaller. This effect is more apparent for small rock particles [10].

Cementation refers to the process of cementing dispersed sediment through the precipitated minerals. Interstitial materials in reservoir of the study area contain siliceous composition. Siliceous cement is given priority to quartz regrowth, from level 2 to level 4. Its growth will block some primary and secondary interparticle pores and result slow growth of interparticle dissolution pore and less pores, thus affecting permeability of the formation.

Dissolution refers to the combined actions of external force to surface erosion, abrasion and corrosion, etc. Dissolution pore accounts for 57% of He 8 Member, and dissolution plays an important role for the pore formation. Dissolution pores are mostly feldspar dissolution pores and lithic dissolution pores, but feldspar dissolution pore is rare in the study area, and feldspar dissolute along the cleavage crack or edge to form interparticle pore. Silica particles are often enveloped by chlorite, which prevent regrowth of quartz, while some pores survive, and chlorite can also protect some cracks in the reservoir.

IV. RESULT ANALYSIS AND DISCUSSION

4.1 Particle size distribution of tight sandstone

According to statistics about particle size composition, size distribution frequency of the core samples in different permeability were obtained, as shown in Fig.3.

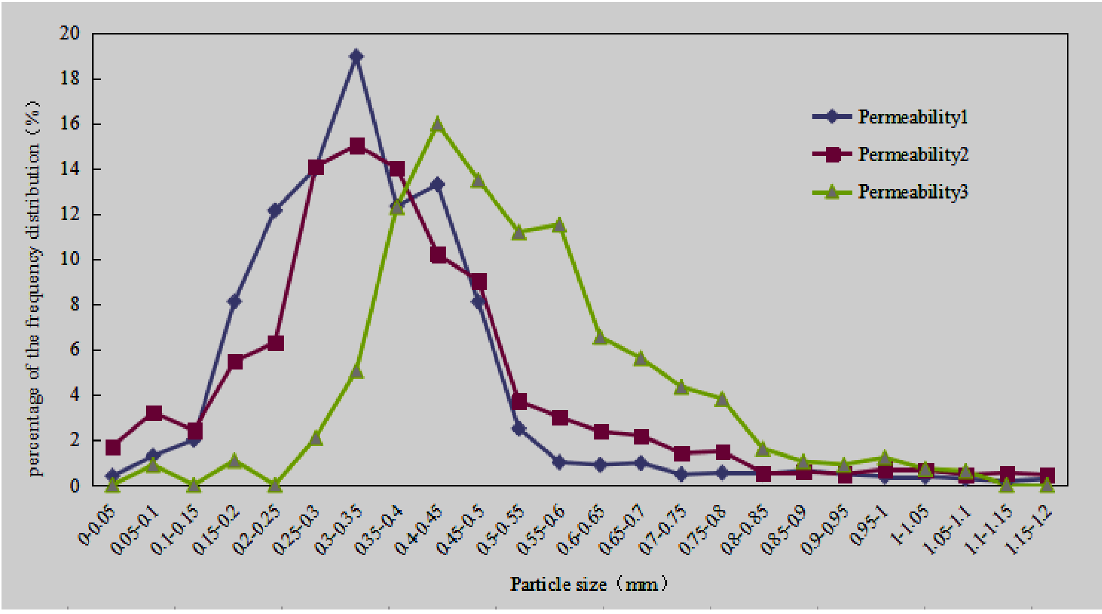

Figure 3. He 8 member grain size of sandstone frequency distribution curve

Based on particle size analysis, particle size composition frequency distribution curves of the sandstone were obtained. Change rule of particle size in different permeability was studied, and a curve of different types was selected.

Particle size composition frequency distribution curves of the sandstone are mostly similar, with a main peak structure, and sometimes an irregular form on both sides of the main peak. With the increase of permeability, main granularity peak appear in accordance with the order of high, medium and low permeability, while median size also follow this principle [11-13]. Peak of curve 1 is 18.95%, peak of curve 2 is 15.02% and peak of curve 3 is 15.98%. Among the three curves, curves 1 and 2 are of high permeability, with a very small fluctuation in left side of the peak and little fluctuation in the right side. Curve 3 shows a low permeability, size composition frequency distribution curves of the sandstone of low permeability is significantly different from that of high permeability, with different degree of fluctuations in the left and the right sides of the peak, reflecting poor separation and diversified particle size distribution.

Rock particles of tight sandstone are generally small, and reservoir is quite close to the provenance area, thus a variety of grades coexist, and concentrated coexistence of different grades result in poor separation of particles. Under the action of various sedimentary factors, particles of different grades fill each other, forming a tight arrangement [11]. In this condition, pores and throats inside rocks are blocked tiny particles, i.e. increasing specific surface of the rock, so that permeability of rock is affected and internal storage declines.

4.2 Sorting coefficient of tight sandstone

Particle size change of clastic particles is mainly affected by provenance and sedimentary facies, the closer to the provenance, the greater the particle size and the worse the results of sorting and rounding; the farther from the provenance, the smaller the particle size and the better the results of sorting and rounding. Therefore, grain size differs in different facies, for example, grain size in waterways with greater water power is greater, while that in distributary bay or lacustrine facies is relatively smaller[14]. Tight sandstone gas reservoirs currently detected in China are mostly of continental facies, which mostly exist in rivers, lakes and other continental sedimentary environment.

In determining rock sorting, sorting coefficient S_o is generally used. Sorting coefficient refers to the particle diameter ratio corresponding to 25% and 75% of the cumulative curve.

$$S_o = \frac{P_{25}}{P_{75}}$$

Where, S_o - sorting coefficient; P_{25}, P_{75} – particle size diameter at 25% and 75% of the cumulative curve, mm.

DOI 10.5013/IJSSST.a.17.01.19

ISSN: 1473-804x online, 1473-8031 print

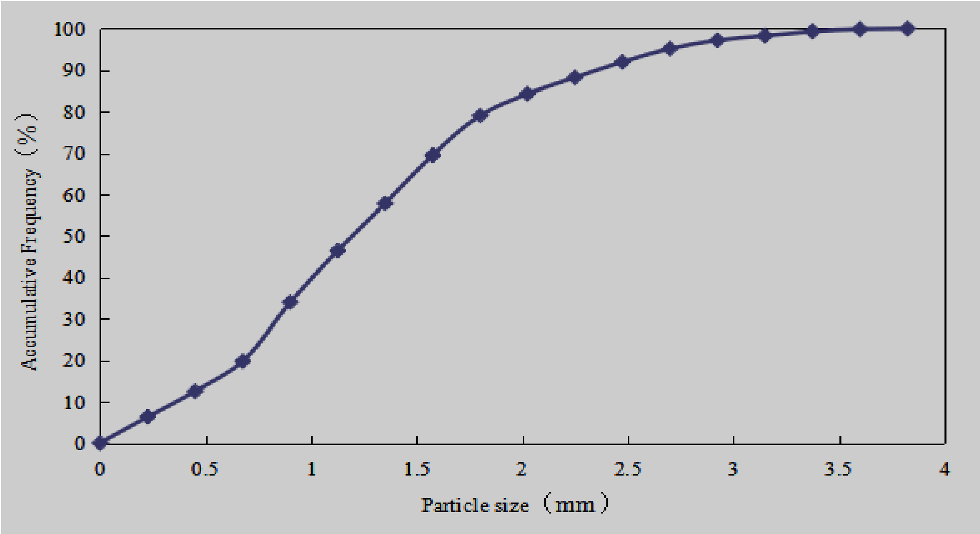

Figure 4. He 8 member granularity accumulative frequency curve

Cumulative frequency curve in Fig.4 shows a flat trend, reflecting poor sorting in this section. It can be seen that particle size in 25% and 75% are not representative, as some are greater than 75%, so that this method is not sensitive enough for tight sandstone.

Standard deviation can be calculated in studying about the particle size separation. In 1957, Falk and Ward[15] obtained the standard deviation formula by graphical method.

$$\sigma = \frac{P_{84} - P_{16}}{4} + \frac{P_{95} - P_5}{6.6}$$

Where, σ - standard deviation; P_5, P_{16}, P_{84}, P_{95} - particle size diameters corresponding to 5%, 16%, 5%, 95% on the curve.

Standard deviation formula better reflected the change in sorting of the curve tail, avoided the tail influence, and improved the applicability of standard deviation for bimodal or skewed normal distribution. It takes more rock particle size into consideration and plays a complementary role for calculating sorting coefficient of tight reservoir.

V. CONCLUSION

With the increasing importance of unconventional reservoirs, particle sizes of tight sandstone in He 8 Member were analyzed, to develop oil and gas resources fully and improve the rate of oil recovery. Results of analyzing the types pore structures and particle sizes of sandstone in the tight reservoir can be used as a reference for exploitation of the tight gas reservoir. Main conclusions: 1) Reservoir sandstone: quartz, debris and quartz debris in the study area.2) Main pore types of reservoir in the study area: interparticle pore, interparticle dissolution pore, feldspar dissolution pore, lithic dissolution pore, zeolite dissolution pore, intracrystalline pore, shrinkage pore and micro cracks. The influence of different diagenesis on stratum differs, and compaction and cementation can reduce porosity of formation, while dissolution increases porosity of formation. 3) According to fluctuations of different amplitude in both sides of peak of the particle size composition frequency distribution curve, the samples are of low permeability and poor particle sorting. 4) In studying about sorting of tight sandstone, standard deviation employed on the basis of considering the sorting coefficient can be used to correct the particle size error.

Further researches should be carried out to improve the efficiency of research in a more scientific and efficient approach, so as to improve the rate of oilfield exploitation.

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