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Application of Gravel Roundness Quantitative Description in Conglomerates Reservoirs

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In this paper, we focus on the quantitative roundness characteristics of drilling cores in conglomerates reservoir from the Triassic Baikouquan Formation in the Circum–Mahu Sag, northern Junggar Basin, Xinjiang Province in Northwestern China. Based on de–flat roundness measuring method, we try to use quantitative roundness analysis to distinguish different sedimentary microfacies of core images. As a result, two types of channels deposits gathering coarse-grained sediments are exampled. It reveals that ephemeral channels get a higher roundness value by 0.436–0.811, dominated by sub-rounded shape. Intermittent channels get a smaller roundness value by 0.387–0.678. Meanwhile, roundness variation of gravel in intermittent channel is lower than that of ephemeral channel. There's good gravel roundness and diversified roundness type in the braided channel deposition developed in fan delta plain. The reason of worse roundness in intermittent channels might be the mix of hard-to-wear source rock gravels after in-lake.

1. Introduction

As one of the very important parameters for describing granular shape of clastic rocks, roundness is used for representing the rounding degree for original edge and corner of clastic particles (Blott and Pye, 2008; Tao et al., 2015). Calculation formula for roundness has already been proposed by some scholars like Wentworth and Krumbein in the early and medium term of the 20th century, in order to calculate the roundness value of gravel grain (Wentworth, 1919; Wadell, 1932). Restricted by complicated measurement procedures and test conditions, however, qualitative description was mostly adopted by research, resulting in the quite low progress. Quantitative research on roundness was started in the latest 10 years by some scholars in China, and the methods included fractal dimension method and Fourier roundness method (Cheng et al., 2012).
Sedimentation process and hydrodynamic mechanism for clastic particles are studied by observing the law of variation at vertical direction of roundness (Gui et al., 2016). Transport distance of sediments by different origin rocks are researched by observing the variation on the plane (Li et al., 2014). Previous research on roundness of gravels were mostly focused on formation environment of gravel (Machado et al., 2016), track the sediment provenance and have inversion of transport and sedimentation process of sediments (Qian et al., 2014; Yousef et al., 2016), identify sedimentary cycle by combining the deposition parameters such as separation and particle size and use this trend to judge the tectonic activity (Liu et al., 2102). However, there were few research on the combination of roundness and sedimentary microfacies. Transport mechanism of sediment may vary in different sedimentary microfacies, but the gravel roundness may be the reflect of particles transport and wearing process, sediment provenance and depositional environment. Therefore, it is necessary for the quantitative research on the particles roundness characteristics.
In this paper, we put forward a new idea for calculating roundness and apply it in sedimentary microfacies. It is an interdisciplinary research on sedimentology. De-flat roundness calculation method is used. It is featured by easy acquisition of basic parameters, precise calculation process and easy realization of roundness quantification. More details of this method will be introduced in Section 2. After that, we calculate the roundness of five sedimentary microfacies from fan-delta deposit at Baikouquan Formation of Circum-Mahu Sag, which are debris flow, intermittent braided channel, ephemeral braided channel, submerged distributary

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channels and submerged debris flows. It provides quantitative sedimentological cognition to the sedimentary mechanism of conglomerates.

2. Geological Background

Mahu Sag, located at northwestern margin of Junggar Basin (Figure 1), reaches Shiyingtan bulge and Yingxi sag and connects Zhongguai bulge at the south. Mahu Sag is provided with sufficient sediment provenances from Zaire Mountain and Halaalate Mountain at the northwest wedge. Proximal coarse fan delta group is formed at the western belt of sag along with the continuous tectonic uplift and steep slope and terrain (Zhang et al., 2015). The major target strata researched by author refers to the Baikouquan Formation (T_1b) at Lower Triassic Series. The strata thickness is approximately 144-181 m, having sandy conglomerates as major sediment. As an advantage, the clastic particles have large particle size, which is higher than 2 mm mostly, making it easy for observing the morphological characteristics of gravel grains through naked eyes, and launching quantitative measurement to roundness of gravel grains.

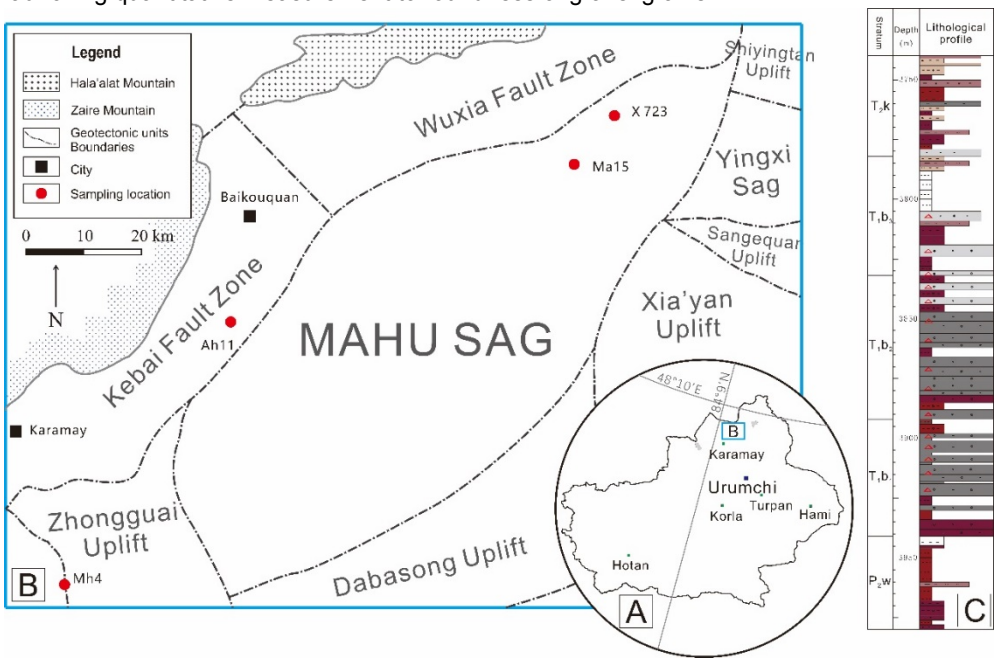

Figure 1: Location of the Study area.

A: Research area locates in northern Xinjiang, China. B: Detailed map with sample location in the Circum-Mahu Sag and surrounding geotectonic units. C: Lithostratigraphy of the study area (modified from reference (Zhang et al., 2016)).

3. Measurement and Calculation Method

3.1 Background and principle for calculation method of de-flat roundness

According to E.P. Cox (1927), it is incapable to measure the roundness of small particles by using the calculation formula for roundness of inscribed circle proposed by Wentworth (1919). It is suggested to reflect the roundness through size and perimeter of particle, as the percentage roundness system (Yang, 2010). The physical significance refers to the ratio of the area of particle and the area of perfect circle. The calculation formula of percentage roundness is:

$$Rp=4\pi A/P^2$$

Where, Rp means percentage roundness of particle; A means particle area; P means particle's perimeter.
Percentage roundness is indeed the deviation degree from particle to perfect circle. Generally, the aspect ratio (the ratio of short axis and long axis of particle) is used to represent the variation degree of particles in sedimentation process (Plink-Björklund, 2015). However, the particle with different aspect ratio may have the same roundness, which violates the significance of rounding degree. So, it is necessary to get rid of the influences from aspect ratio on calculation result.

As an improved method based on percentage roundness, de-flat roundness method can get rid of the calculation error of percentage roundness due to aspect ratio of particle. This method is indeed a process of calculating the percentage roundness of target particles after image treatment to to-be-measured particles. Principle of de-flat roundness method (as shown in Figure 2): first of all, acquire the original image of particle, convert it into binary image and then extract the grain contour and convex hull to calculate the minimum exterior rectangle of convex hull. After this, calibrate four parameters, modify and calculate the length-to-width ratio of gravel contour to convert the minimum bounding rectangle into square, that is to say, gravel contour is provided with de-flatting and shape normalization. Finally, calculate the percentage roundness of target particle in order to improve the scientificity of representing rounding degree through percentage roundness.

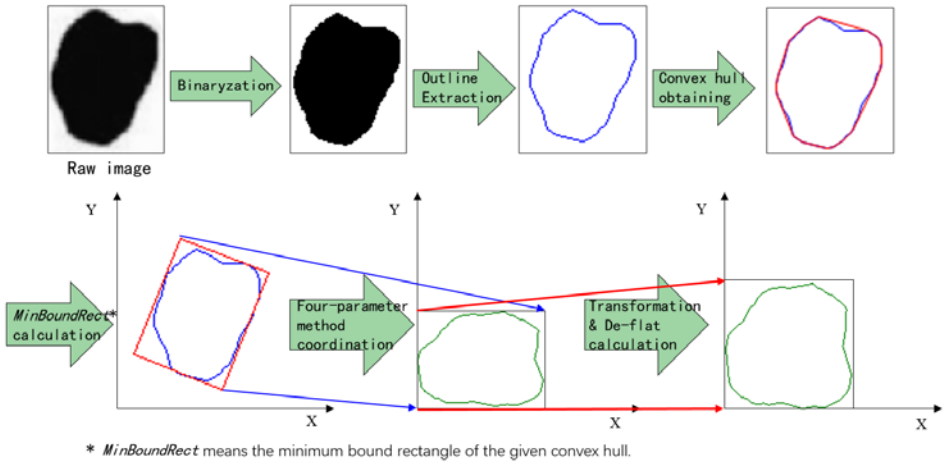

Figure 2: Basic Concept of De-Flat Roundness

3.2 Judgment standard

Classification standard to single particle by previous scholars should not be simply copied, since this test is mainly focused on the lithofacies roundness. Standard particle layout is drawn in accordance with roundness classification table by Krumbein, and this number interval can be used as reference for roundness research of Circum-Mahu Area, as shown in Figure 3.

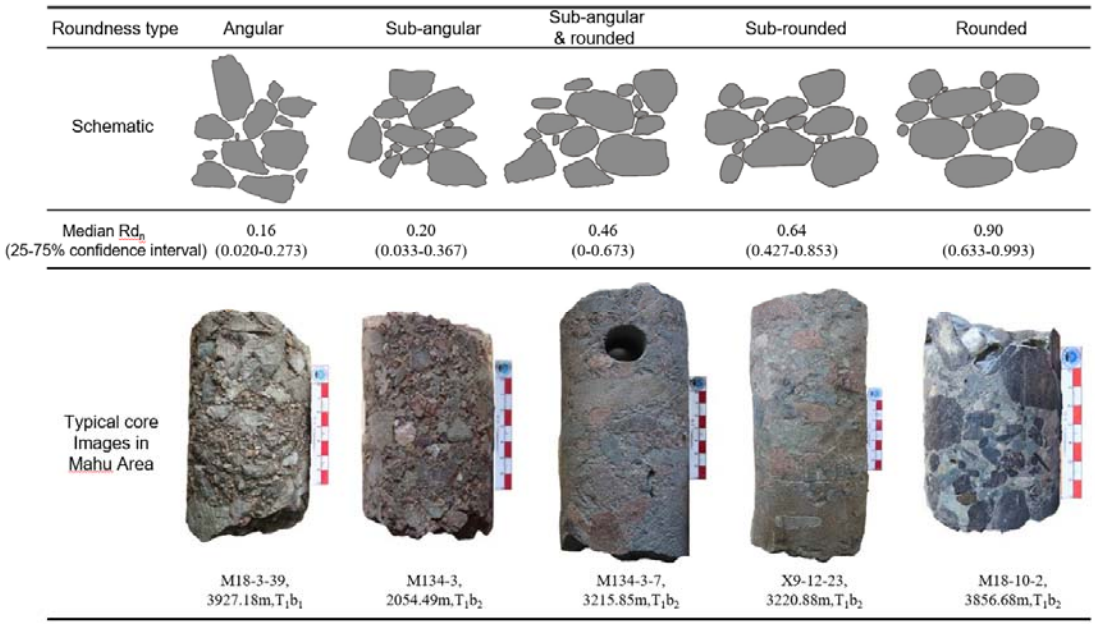

Figure 3: Quantitative Criteria of De–Flat Roundness (Rdn)

Besides, roundness variation is used as one of the standards in this research for judging the sub-angular – sub-rounded gravel collection. In case of high variation (experience value higher than 0.04), it means that the gravels of all roundness types are developed and it should be determined as sub-angular– sub-rounded shape.

4. Analysis on Roundness in Circum-Mahu Area

In accordance with the lithofacies dividing scheme and lithofacies combination relationship for sandy conglomerate of fan delta at Baikouquan Formation of Circum-Mahu Sag, the type of sedimentary facies in research area should be fan delta facies deposition.

Rounding data from a total of 55 wells were collected in this research, a total of 312 were measured accumulatively and a total of 7,607 particles were extracted. The author provided the example of sedimentary microfacies in sandy conglomerate development and 2 representatives sedimentary microfacies profiles were finally selected to introduce the roundness and change rules of variance at vertical direction, namely, intermittent braided channel, ephemeral braided channel. A total of 14 gravel facies was measured. with 516 gravels were extracted. The statistical sheet is as shown in Table 1.

Table 1: Statistical Samples of Sedimentary Microfacies in Roundness Research

Sedimentary Subfacies	Sedimentary Microfacies	Code	Typical cored intervals	Numbers of lithofacies	Numbers of particals
Fan-delta plain	intermittent channel	IC	X#723-7	5	151
	ephemeral channel	EC	M#15-2	9	365

River can be divided into ephemeral rivers, intermittent rivers and perennial rivers on the basis of occupation rate of river. The river flow is continuous within a year for perennial rivers, has irregular drying for multiple times within a year for intermittent rivers, or basically dried within a year for ephemeral rivers; for river flow with occasional developmental seasonality, sedimentary characteristics and geomorphic features of both may have obvious difference. The braided river deposit in Baikouquan Formation mainly includes intermittent channel and ephemeral channel, of which, the features of sedimentary characteristics and quantitative rounding are introduced below.

4.1 Intermittent braided channel

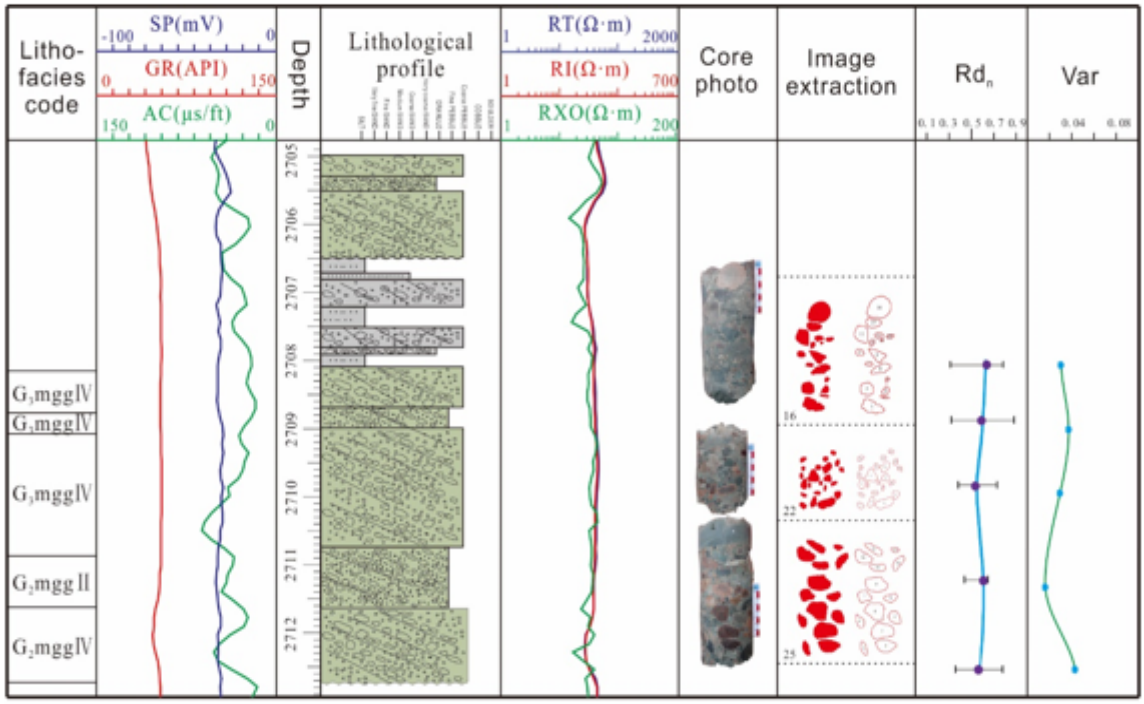

Figure 4: Typical Sedimentary Section of Intermittent Channels (Well X#723, 2708.10–2712.73m)

The thickness range for intermittent braided river at Baikouquan Formation is 1-10 m. The typical section is as shown in Figure 4. The de-flat roundness of this profile includes sub- angular – sub-rounded shape as primary shape, or corner angle as secondary shape and it has upward and good trend; the range of Rd_n is 0.387–0.678. Average roundness of variance is 0.047 and fluctuation range is low, which means, the roundness type of gravels in intermittent braid channel is concentrated.

4.2 Ephemeral braided channel

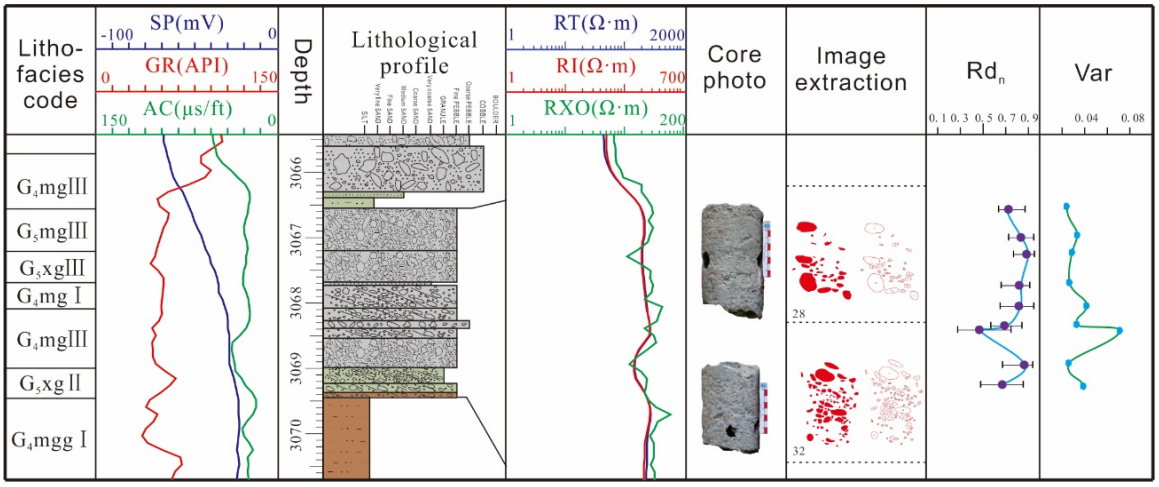

Figure 5: Typical Sedimentary Section of Ephemeral Channels (Well M15, 2708.10–2709.00 m)

Thickness of ephemeral braided channel is smaller than intermittent river, 1-4m thick in general. Typical profile for ephemeral channel deposit is shown in Figure 5. Sub- angular – sub-rounded shape is the major de-flat roundness characteristics in this section; range of Rd_n is 0.436–0.811; the values increase upwards and there's large fluctuation at the bottom. Roundness variance has large fluctuation at the bottom and decreases upwards. The average V is 0.072.

5. Discussions

By comparing the roundness characteristics and variation rules at vertical direction in Figure 4 and Figure 5, the de-flat roundness for ephemeral channel deposit gravel is better than intermittent channel, even if gravels in both braided channels mainly have sub- angular – sub-rounded shape; Meanwhile, roundness variation of gravel in intermittent channel is lower than that of ephemeral channel, which means, the roundness type of gravel in ephemeral channel is relatively concentrated. Actually, roundness is also a factor affecting the degree of abrasion. Affected by transport friction, the rounded gravels can have easier transport than angular gravels. It is presumed that, the gravels with good roundness can be easily conveyed to ephemeral channel which can become watery or dry occasionally; with high content of mud and sand in ephemeral channel, gravels are featured by high roundness and more types in the ephemeral channel which is far from the sediment provenance.

From above, the maximum de-flat roundness doesn't exist in the intermittent channel, but in the ephemeral channel. Average value of Rd_n is 0.634 (dominated by sub-rounded shape). Meanwhile, intermittent channel and ephemeral channel have high roundness variance and higher than 0.04. Therefore, there's good gravel roundness and diversified roundness type in the braided channel deposition developed in fan delta plain, which is different from the traditional geological cognition. It is generally believed that, the gravel may have higher wear degree along with the increasing distance of provenance. Based on analysis of test result, the flatting roundness is inconsistent with realities after mixing with of gravels containing great amount of non-abrasive parent rocks, since the subaqueous channel is affected by gravel of multiple sources; or, gravel roundness is low since core position of subaqueous channel deviates from the main body of channel erosion.

6. Conclusions

(1) A new thinking for calculating roundness, de-flat roundness method, is proposed in this paper.
(2) The results show that gravel roundness of Baikouquan Formation being ranked from ephemeral braided

channel to intermittent braided channel. The roundness variance shows larger intermittent braided channel than ephemeral braided channel.

(3) Roundness characteristics of distributary channel deposits in research area are caused by different factors, like transport process, mix of non-abrasive parent rocks, and so on. There's good gravel roundness and diversified roundness type in the braided channel deposition developed in fan delta plain, which may be cause by the mix of non-abrasive parent rocks.

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