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NEW METHOD FOR CALCULATING ROCK PARTICLE SIZE COMPOSITION PARAMETERS

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The application of the conventional arithmetic mean method to calculation of the rock particle size composition parameters is limited to the normal type of distribution and may result in high error of calculated parameters. In view of this, a new method to calculate the rock particle size composition parameters is proposed in this paper. The method was called "a weighted mean method." A detailed theoretical basis for the new method is presented, and the calculation formula expressions are derived. The calculation process is demonstrated with an example. In order to verify the accuracy of the new method, the calculation results are compared with those of the conventional arithmetic mean method. It was shown that the new method can be applied to calculate rock particle size composition parameters in cases where the granulometric parameter distribution is unknown or differs from normal distribution. The results show that the proposed method is more accurate and widely applicable.
Keywords: *rock particle size composition parameters; arithmetic mean method; weighted mean method.*

Rock particle size composition denotes the diameters of the particles constituting the rock. It reflects the solid rock matrix and has an effect on classification and evaluation of reservoirs [1-2]. The particle size composition is quantitatively derived by mean size composition, standard deviation, skewness, and sorting coefficient parameters [3-4]. The mean size composition represents the mean value of particle diameters and can

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be used to determine the approximate range of particle sizes. The standard deviation is used to classify the sorting grade. The skewness is used to describe distribution asymmetry. The rock particle size composition is comprehensively described by three parameters: mean size composition, standard deviation and skewness [5-8].

Particle size composition is usually calculated by arithmetic mean methods. The particle size distribution is represented by a curve. For normal or approximately normal distribution, the arithmetic mean method is used to calculate the diameters for characteristic points selected on the curve. The method has some limitations. First, the particle size distribution may be uncertain or diverse and differ from normal distribution, so the arithmetic mean method is not applicable. Second, the characteristic point values depend on the subjective judgment of the operator who selects them from the curve, which may result in large errors. If the characteristic point value cannot be directly obtained from the curve, the curve needs to be mathematically fitted [9-10], which may increase the error. The increased number of characteristic points helps to improve the accuracy of calculations, but this also requires a larger amount of calculations and more reliable formulas. The arithmetic mean method is the one with the lowest accuracy when compared with other mean methods (e.g. arithmetic mean, weighted mean, geometric mean, and harmonic mean) [1-3,11-14]. For these reasons, it is necessary to find a new accurate and applicable method for calculating the rock particle size composition parameters.

2. INTRODUCTION OF THE NEW METHOD

2.1 Theoretical basis

2.2.1.Theoretical basis of the new method

According to geological statistics theory, the rock particle size composition distribution is an empirical distribution of the geological particle mixture formed during diagenesis and catagenesis. The particle size composition parameters can be calculated by statistical numerical characteristics [1]. The theoretical basis for numerical characteristics, such as mean value and variance of random variables, is well developed. For a discrete random variable X, for instance, the distribution can be expressed by formula (1), and the series $\sum_{k=1}^{\infty} x_k p_k$ are absolutely convergent. Given that $f(x)$ is the probability density of the random variable X, and the integral $\int_{-\infty}^{\infty} xf(x)d_x$ is absolutely convergent, then the mathematical expectation (or mean) $E(X)$ can be expressed by formula (2), as follows:

Table 1

Rock Sample	Depth, (m)	Layer	Lithologic features	Porosity, (%)	Permeability, (mD)	Density. (g/cm^3)
S1	3744.59	He 1	Grayish-white medium sandstone	0.163	1.174	2.392
S2	3909.12	Tai 2	Light grey gravel sandstone	0.049	0.012	2.839

Table 2

Particle size composition parameters	Formulas
Mean size ϕ_m	$\phi_m = \frac{\phi_5 + \phi_{15} + \phi 2_5 ... + \phi_{85} + \phi_{95}}{10}$ or $\phi_m = \frac{\phi_{15} + \phi_{50} + \phi_{84}}{10}$ or $\phi_m = \frac{\phi_{15} + \phi_{50} + \phi_{75}}{3}$
Standard deviation σ	$\sigma = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$
Skewness *Sk*	$Sk = \frac{\phi_{84} + \phi_{16} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_{95} + \phi_5 - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$

$$P(X = x_k) = p_k; \quad k = 1,2,3... \tag{1}$$

$$E = \sum x_k p_k \tag{2}$$

2.2.2 Application of the new method to calculate size composition parameters

The above formulas were then applied for calculations based on the theoretical basis and mathematical statistic methods.

The mean value is a position characteristic parameter. It can be used to describe the mean position of the experimental data. For particle size composition, its mean value represents the mean position of the particle size distribution and can be calculated by using the weighted mean method:

$$\phi_m = \frac{\sum_{i=1}^{n} \phi_i \Delta f_i}{\sum_{i=1}^{n} \Delta f_i} \tag{3}$$

where ϕ_i is the calibration of the rock particle diameter ϕ; Δf_i is the percentage of the interval weight; and *n* is the number of samples (intervals).

The standard deviation is a scattering characteristic parameter and can be used to describe the degree of scattering around the mean value. For particle size distribution, the standard deviation is used to describe the sorting degree of particle size values. It is also called the sorting coefficient of size composition:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (\phi_i - \phi_m)^2 \Delta f_i}{\sum_{i=1}^{n} \Delta f_i}} \tag{4}$$

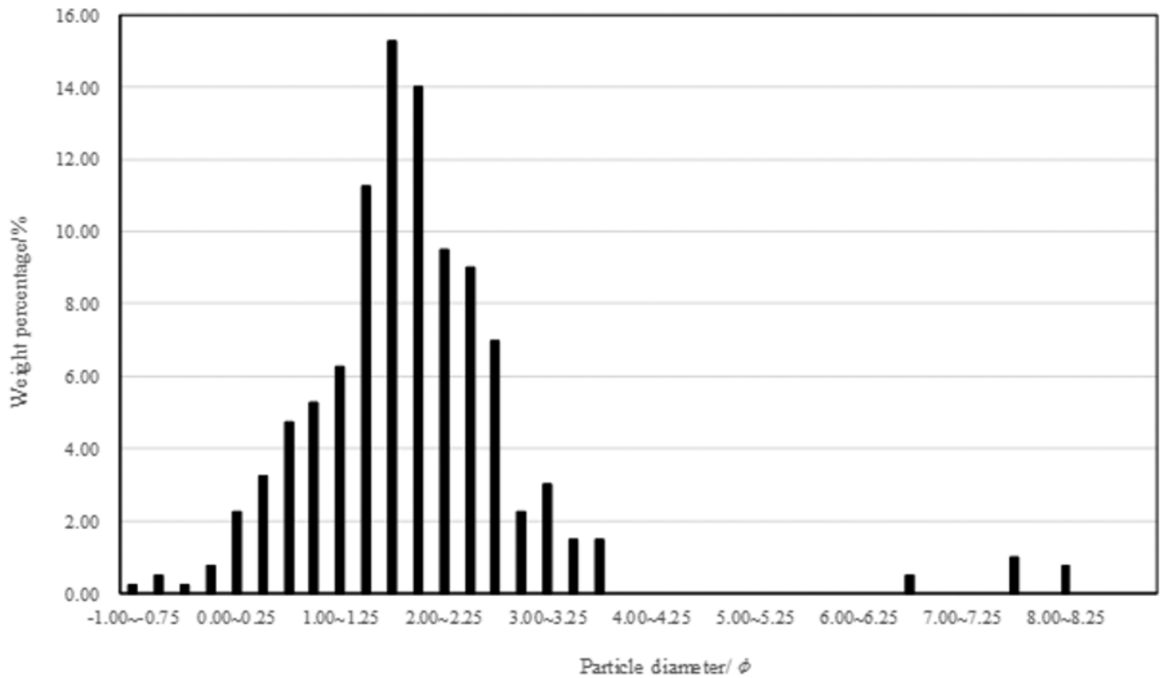

Fig. 1. The curve of the particle size composition distribution of rock S1.

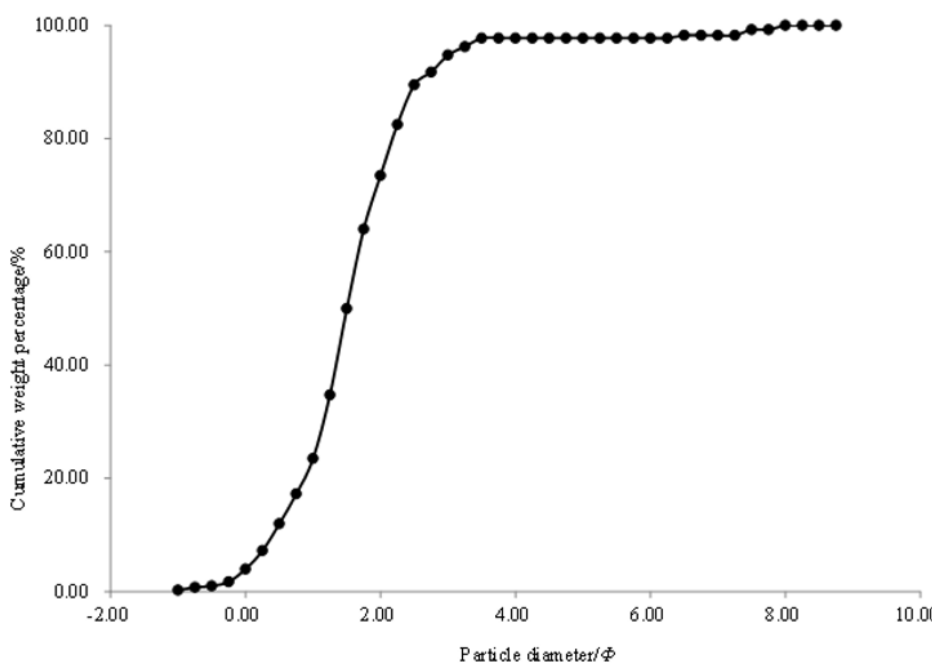

Fig. 2. The curve of the cumulative particle size composition distribution of rock S1.

Skewness is a distribution characteristic parameter that is used to describe the asymmetry of distribution. For particle size composition distribution, skewness means that the distribution is shifted towards coarse particles or fine particles:

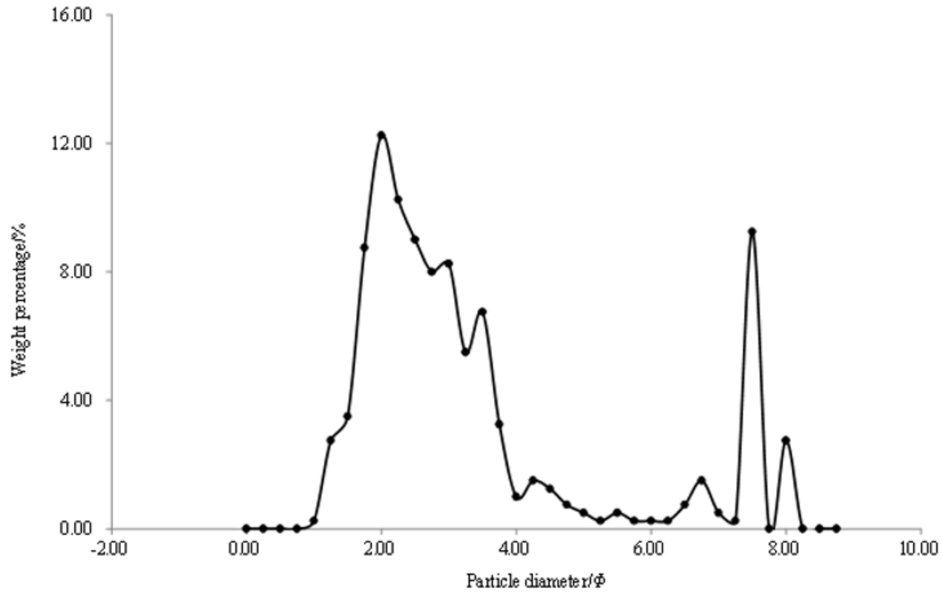

Fig. 3. The curve of the particle size composition distribution of rock S2.

$$Sk = \frac{\sum_{i=1}^{n} \left(\phi_i - \phi_m\right)^2 \Delta f_i}{\sigma^3 \sum_{i=1}^{n} \Delta f_i} \quad (5)$$

2.2 Calculation example

The new method can be used to calculate the rock particle size composition parameters without considering the distribution pattern or the curve type. Instead, the calculation is directly based on the experimentally measured particle size composition data. Here, the new method is applied to calculate the particle size composition parameters for a sample rock S1 from the Daniudi Gas Field Sinopec. First of all, the experimentally measured data are used to evaluate the percentage of the cumulative particle weight of the rock sample; then the interval weight percentage Δf_i and the product of the particle diameter and the interval weight percentage $\Phi_i \Delta f_i$ are calculated. Then, the sum of the interval weight percentages and the sum of the products of the particle diameter and the interval weight percentage are calculated. The mean particle size is the quotient of the two sums, which is 1.729. Likewise, the standard deviation and the skewness are determined as 1.070 and 0.752, respectively.

2.3 Accuracy verification

The accuracy of the new method should be verified before it is used to calculate the particle size composition parameters in practical applications. The particle size composition distribution of the rock sample S1, calculated in the above section, is shown in Fig.1. It can be seen that the distribution type is approximately normal. Hence, the arithmetic mean method is used for comparison. The arithmetic mean method requires one to draw the curve of the cumulative size composition for S1 (Fig. 2). The characteristic

Table 3

Particle size composition parameters	Result by the weighted mean method	Result by the arithmetic mean method
Mean size ϕ_m	1.729	1.723
Standard deviation σ	1.070	0.990
Skewness *Sk*	0.752	0.750

points (Φ_5, Φ_{16}, Φ_{50}, Φ_{84} and Φ_{95}) are selected from the curve to calculate the mean value; then the standard deviation and the skewness of S1 are calculated by the formulas in Table 2. The calculated values are 1.723, 0.990, and 0.750, respectively.

Formulas of the Arithmetic Mean MethodIt can be seen from the comparison between the new method and the arithmetic mean method (Table 3) that the calculation results are close, which suggests that both methods can be used to calculate the rock particle size composition parameters when the distribution is close to normal. This verifies the accuracy of the new method.

3. APPLICATIONS OF THE NEW METHOD

As was shown in Section 2, the new method proposed in this study has a solid theoretical basis, strict formula derivation, and reliable accuracy, and is widely applicable. The method was applied to rock sample S2 from the Daniudi Gas Field Sinopec. The parameters are presented in Table 1. As shown in Fig. 3, the particle size distribution differs from normal or approximately normal distribution. In this case the arithmetic mean method is no longer applicable, and the new method is used to calculate the S2 composition parameters. TheThe calculated values of the mean size, the standard deviation, and the skewness are 3.371, 1.904, and 1.344, respectively.

4. CONCLUSIONS

1. The arithmetic mean method is limited to strict conditions and may result in large errors when applied to calculate the rock particle size parameters.

2. The weighted mean method requires no consideration of the type of distribution; it is widely applicable and more accurate when used to calculate the rock particle size parameters.

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