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Comparative Analysis of Grain Size Measurement Techniques in Sedimentology

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Abstract: Grain size represents a crucial structural attribute of sediments and serves as the foundation for their classification and nomenclature. Currently, the predominant methods for grain size analysis and testing include the laser diffraction method, sieve analysis, image analysis, and sedimentation method. Each technique relies on distinct characteristics of the grains, leading to variations in measurement outcomes for the same sample. These methods present limitations in terms of accuracy or detection range. Specifically, the laser diffraction method covers a range from 0.00005 mm to 3.5 mm, sieve analysis spans from 0.1 mm to 1000 mm, image analysis from 0.1 mm to 20 mm, and the sedimentation method ranges from 0.00005 mm to 0.1 mm. Furthermore, each method is applicable to different types of samples: the laser diffraction, sieve analysis, and sedimentation methods are appropriate for samples with moderate or lower degrees of cementation, while the image analysis method is more versatile. Consequently, selecting an appropriate measurement technique based on the sample's characteristics or the specific measurement requirements is essential.

Keywords: Grain size analysis; Sedimentology; Depositional environment.

1. Introduction

Granularity is an important structural feature of sediments and the basis of its classification and naming. Granularity data is also widely used to judge the sedimentary environment and analyze the sediment transport process. The traditional grain size analysis and testing methods are sedimentation method, sieve analysis method and flake grain size image analysis method [1-4]. After the 1970s, some scholars proposed to use the principle of optical diffraction to test the grain size of the Grains, and the laser method was born [5, 6]. At present, the laser method has been widely used in recent years [2-4, 7, 8] due to its advantages of fast analysis speed, good reproducibility, and high accuracy. However, due to different measuring methods, different principles, different operability, different application scopes and different measuring instruments, various methods can measure different results on the same sample [2-4, 8-11]. In order to reasonably use and compare the granularity data tested by different methods, this article outlines the principles, advantages, disadvantages, and scope of application of each method.

2. Laser Method

The working principle of laser grain size analyzer is based on the interaction between light and Grains. In the beam, spherical Grains of a certain diameter scatter light forward at a certain angle, which is close to the diffraction angle produced by a pore equal to the diameter of the Grain. When the monochromatic beam passes through the suspended Grain flow, the diffracted light generated by the Grains is collected on the detector through the convex lens (Figure 1), and the scattered light intensity at different diffraction angles is recorded. At the same time, the light that does not diffract is focused on the center of the detector through the convex lens, and does not affect the light that diffracts. Therefore, a stable diffraction spectrum is generated when the Grain flow passes through the laser beam. The intensity I (θ) of the diffracted light has the following relationship with the grain size [3, 12, 13]:

$$I(\theta) = \frac{1}{\theta}\int_0^\infty R^2 n(R) J_1^2(\theta K R)dR \tag{1}$$

θis the scattering angle, R is the Grain radius, I (θ) is the light intensity scattered by the angle θ, n (R) is the grain size distribution function of the Grain, K = 2π / λ, λ is the wavelength of the laser, J1 Bayesian function of type 1. According to the measured I (θ), the grain size distribution n (R) can be obtained by inversion of equation (1).

The laser method has the advantages of fast analysis speed (1 to 2 minutes / piece), high accuracy, and small errors caused by human factors. However, the laser method has limitations on the degree of sample cementation and grain size range. The laser method is mainly suitable for samples with moderate or lower cementation degree. The samples are de-cemented and processed repeatedly with a rubber hammer until the samples are completely dispersed before they can be measured [1, 7]. The applicable range of the grain size of the laser method is divided into wet method and dry method. The detection range of wet method is 0.05 ~ 900μm, suitable for mudstone, siltstone, fine sandstone, medium sandstone and some coarse sandstone samples; the detection range of dry method is 4 ~ 3500μm, suitable for siltstone, fine sandstone, medium sandstone, Coarse sandstone and some fine conglomerate samples, but the grain size below 4μm cannot be detected [8]. If you encounter a sample that exceeds the detection range, the joint measurement method is generally used, such as the dry and wet combined method, the laser screening combined method, etc. The sample is separated with a standard sieve. After weighing, the sample on the sieve is used for dry method or screening method, and finally integrated Data [1].

The results of different laser grain size analyzers on the same sample will also be different, and sometimes there will be a large gap [2]. This is mainly caused by differences in instrument hardware and software, such as the wavelength of the laser light source, lens position and size, etc. [2]. In actual work, the same instrument should be used for measurement as much as possible.

3. Sieve Method

Pour the disintegrated debris Grains into a set of standard sieves with different pore sizes, separate the debris Grains of different grades through a full vibrating sieve, weigh the debris Grains of each grade, and obtain the debris grain size distribution range [1].

The sieve analysis method is mainly used for sandstone and conglomerate with moderate or lower cementation degree; the disadvantage of the sieve analysis method is that the too small pore size has a large error of the sieve, so it is not suitable for analysis of silt and clay Grains, and the accuracy is relatively low [1].

Sieve analysis method and laser method can get different results when measuring the same sample [2, 3]. Studies have shown that the test results of the laser grain size analyzer are overall coarser than the results of the sieve analysis method, which is caused by different test mechanisms and different definitions of Grain diameters [3].

4. Image Method

According to the principle of stereology, the features of the feature points in the three- dimensional space can be characterized by the features of the feature points in the two- dimensional interface. The image analysis method is to take the image under the microscope into a computer, scan the two-dimensional image on the computer, and measure and edit the pixel group of the feature point to obtain the characteristic value of the two-dimensional image, thereby obtaining the broken Results of grain size distribution of clastic rocks [1, 2].

The image method is mainly applied to sandstone and coarse siltstone with moderate or above cementation degree.

Comparing the measurement results of the same sample with the image method and the laser method, it is found that the average Grain diameter measured by the laser method is finer than the image method, and the standard deviation, skewness, and kurtosis are all larger [2]. This aspect is because the image method ignores the statistics of silt and clay; on the other hand, the image method measures the area percentage of particulate matter, while the laser method measures the mass percentage [2].

5. Settlement Method

The analysis of sedimentation method is to use different free sedimentation speeds of Grains of different grain sizes in the liquid to determine the content of each level, so as to obtain the grain size distribution of fine Grains [1].

The settlement method is mainly used for the measurement of siltstone and mudstone with moderate or less cementation degree [3]. The accuracy of the settlement method is not high. In addition to the defects of the operation method itself, errors caused by human factors can also affect the reliability of the test results [3].

Compared with the measurement results of the same sample by the sedimentation method and the laser method, the content of the clay component measured by the laser grain size analyzer is lower than that by the sedimentation method [3]. This is mainly caused by the measurement range and test principle of the laser grain size analyzer [3].

6. Application Scope of Grain Size Analysis Test Method

The measurement ranges, sample cementation limits, and reproducibility of the above methods are different. See Table 1 for details. According to different samples and different measurement needs, appropriate measurement methods should be selected.

Table 1. Comparison of different analysis for grain size

Method	Measuring range	Sample cementation	Reproducibility
Laser	0.00005mm~3.5mm	Meddle and low samples	High
Sieve	0.1mm~1000mm	Meddle and low samples	High
Image	0.1mm~20mm	No limited	middle
Settlement	0.00005~0.1mm	Meddle and low samples	low

7. Conclusion

With the rapid development of computer and other technologies, grain size analysis testing methods are developing towards diversification, precision, and automation. But there are still the following problems:

(1) Different grain size analysis test methods are based on different Grain characteristics, such as the sieve analysis method to determine the pore size of the hole through which the Grains can pass; the sedimentation method to measure the sedimentation speed of the Grains; Area; the laser method measures the light transmittance of the Grains. There is no definite relationship between these characteristics, so for the same Grain, the grain size measured by different methods is not the same. At present, there is no uniform definition of the grain size of non-spherical Grains, so the accuracy of different methods is difficult to compare. The accuracy of various methods can only be reflected by the reproducibility of testing the same sample. High reproducibility means high accuracy of this method, and low reproducibility means low accuracy of this method.

(2) Various grain size analysis and testing methods have problems with accuracy or detection range. For example, the wet detection range of the laser method is 0.05 ~ 900μm, which cannot meet the demand for debris flow samples. For this kind of sample with a wide grain size range, a joint measurement method can be used, but this joint measurement method itself has errors, and it is not a Grain diameter that is measured between methods. The future grain size analysis and testing methods should be developed in the direction of broadening the measurement range.

(3) There are defects in the preparation of ancient samples. All samples that have undergone diagenesis need to be ground after removing cement. In terms of removing sample cement, there may be insufficient cleaning or cleaning transitions. In grinding samples, there may be Grain breakage transitions or Grain adhesion, which destroys the original shape of the Grains.

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