# Grain size characteristics and sedimentary environment of surface sediments in East Juyan Lake

Yaokang Lian[1,2], Xiangsheng Chang [1], Guotao Dong [1,*], Zihao Chen [1], Lei Lu [3], Jing Wang [1], Ruiqi Guo [4]

[1]Heihe Water Resources and Ecological Protection Research Center, 730030 Lanzhou, China
[2]Heihe Ejina Water Resources and Ecological Protection Research Center, 735400 Alashan, China
[3]College of Earth and Environmental Sciences, Lanzhou University, 730030 Lanzhou, China
[4]Luanjingtan Yellow River High-lift Irrigation Development Center, 750312 Alax, China

**Abstract.** East Juyan Lake is the tail lake of Heihe River. It not only plays an important role in maintaining the local ecological environment, but also has certain significance for the protection of East Juyan Lake wetland. In this paper, the grain size analysis of 72 surface sediment samples collected from East Juyan Lake was carried out. The results show that the average particle size of the sediments is between 3.76φ ~ 7.31φ, with an average value of 6.43φ. The types are mainly clay and silt, mostly sandy clayey silt and sandy clayey silt. The particle size is mainly characterized by the distribution of fine in the south and coarse in the north, coarse in the near shore and fine in the far shore, which is obviously affected by hydrodynamic conditions and source supply. The separation is poor, and the material source is diverse, which affects the uniformity of particle size. There are three types of sedimentary environment in the East Juyan Lake. The first type is located in the lakeside area, the second has general hydrodynamic conditions because the water depth is between the first type of sedimentary area and the third type of sedimentary area. The third has the deepest water depth, weak hydrodynamic conditions and the finest average particle size in the three areas.

## 1 Introduction

Lake sediments preserve a wealth of information regarding environmental evolution and human activities, serving as valuable archives for studying environmental change[1]. Their grain-size characteristics also contain abundant sedimentary information[2]and are widely used as environmental proxy indicators in lacustrine research, reflecting material sources, hydrodynamic conditions, and the impacts of human activities on lakes[3]. Studying the spatial distribution of grain size in surface sediments of lakes helps elucidate modern sedimentation processes and their responses to regional climate change and human activities within the basin[4].

Since 1875, grain-size analysis has been applied to investigate modern fluvial sedimentation processes and sedimentary environments[5]. During the 1950s and 1960s, many scholars utilized grain-size data from known depositional settings to interpret the characteristics of lake sediments[6]. In recent years, research has been conducted in various lakes including lakes in the Badain Jaran Desert[3], Lugu Lake, Chenghai Lake and Xingyun Lake [7], Zhanghe Reservoir[8], Qilu Lake[9], and Qingtu Lake[10].

East Juyan Lake (EJL) is located in Ejina Banner, Inner Mongolia Autonomous Region. As a terminal lake of the Heihe River—an inland river in an arid region—it plays a key role in maintaining regional ecological security, ensuring water supply, and mitigating desertification[11]. Investigating the characteristics of surface sediments and the sedimentary environment of East Juyan Lake can enhance our understanding of terminal lakes in arid zones; however, studies focusing on grain-size characteristics in this area remain limited. For instance, Jin H et al.[12] used vertical profile data to analyze environmental evolution over the past 1500 years, and Dong Z et al.[13] collected data from 13 sampling sites to analyze grain-size parameters such as particle size composition, mean grain size, sorting coefficient, skewness, and kurtosis in surface and subsurface sediments of the Ejina Basin. Nevertheless, studies specifically addressing the spatial grain-size characteristics of surface sediments in East Juyan Lake have not yet been reported.

This study aims to analyze the grain-size characteristics of sediments in East Juyan Lake, the terminal lake of the Heihe River, and to investigate the sedimentary types, material sources, and hydrodynamic conditions of the lake.

## 2 Data and Methods

### 2.1 Study Area

EJL (101°11′55″–101°19′40″ E, 42°15′20″–42°20′20″ N) is situated at the terminal reach of the Heihe River, the second largest inland river in China. The region

* Corresponding author: dongguotao@hky.yrcc.gov.cn

experiences a continental desert climate, characterized by hot and rainy summers, cold and windy winters, and extreme aridity. Based on meteorological records from Ejina Banner spanning 1961 to 2011, the mean annual air temperature is 8.9 °C, with an extreme maximum of 40.6 °C and an extreme minimum of −35.3 °C. The maximum daily temperature range can reach 34 °C. Located at the desert margin and within a prevailing wind corridor, the lake basin receives only ~40 mm of precipitation annually, while potential evaporation exceeds 3,700 mm. Surface-water inflow is therefore the primary water source, and evaporation accounts for the bulk of water loss[14]. When the lake surface area is 43.1 km², the maximum water depth is 3.09 m.

## 2.2 Sampling and Analytical Procedures

Surficial bottom-sediment samples were collected with a Peterson grab sampler in July 2019 at 72 sites (Fig. 1). All samples were immediately placed in polyethylene bags, transported to the laboratory on ice, and stored at 4 °C prior to analysis. Particle-size distributions were determined with a Malvern Mastersizer 2000 laser diffraction analyser (measurement range 0.02–2,000 µm); analytical details follow Zhang T et al.[7].

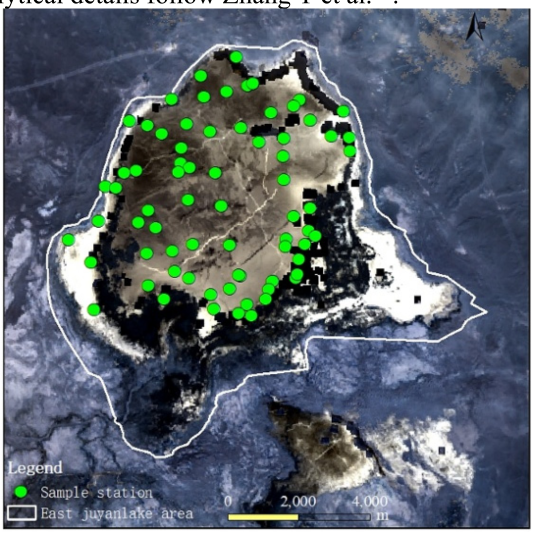


**Fig. 1.** Schematic diagram of EJL sampling point (background: Landsat Image in 2020)

## 2.3 Data Processing

Sediment classification and nomenclature follow the gravel-free Folk ternary diagram[15]. Grain-size data obtained from the laser particle size analyzer were converted to the dimensionless φ scale using the formula:

$$\varphi = -\log_2(x / x_0) \qquad (1)$$

where x is the grain size in µm and $x_0$ is the reference size (1 mm). Grain-size parameters were calculated using the Folk–Ward graphical method[16]. MATLAB was employed to interpolate φ values corresponding to cumulative percentiles of 5%, 16%, 25%, 50%, 75%, 84%, and 95%, from which the final parameter values were derived[17].

# 3 Results and Discussion

## 3.1 Grain-size composition and spatial distribution of surface sediments

Following the Udden–Wentworth grain-size scale[18], three sediment end-members were identified: clay (<4 µm), silt (4–64 µm), and sand (>64 µm). The spatial distribution of each fraction is shown in Figure 2.

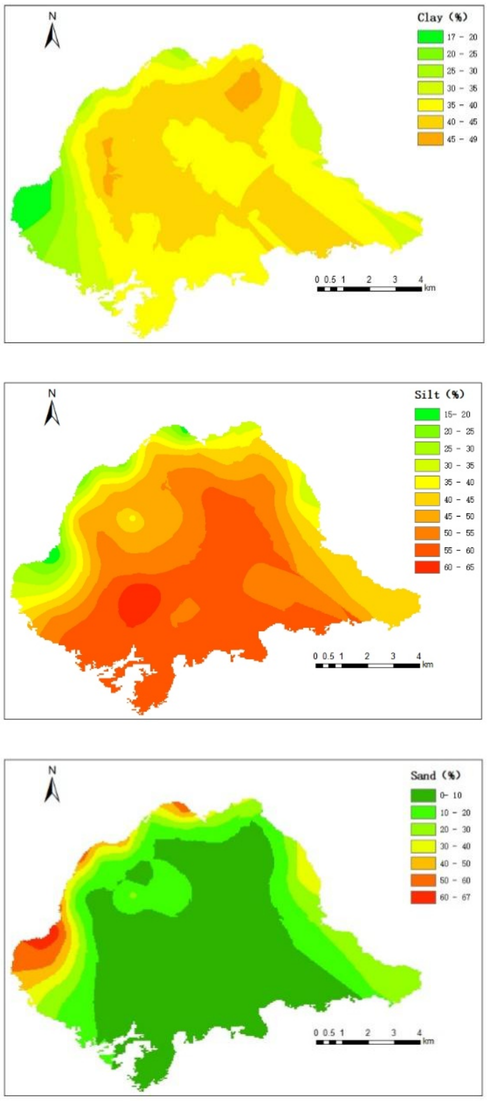


**Fig. 2.** distribution of grain size components in surface sediments of EJL

Clay content ranges from 2.31% to 58.51%, with most lake areas containing 30–50%. Clay abundance generally decreases from the lake center toward the shore, with relatively low values in the western and northern parts of the lake.

Silt content varies from 4.96% to 70.63%, showing a general south-to-north decreasing trend. Low silt contents are observed along the western, northern, and northeastern shorelines. At the southern lake entrance, where river inflow occurs, reduced flow velocity leads to the deposition of fine-grained sediments, primarily silty or clayey particles.

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Sand content ranges from 0% to 92.73%, but is generally <10% across most of the lake. Higher sand contents are concentrated along the western, northern, and northeastern shores. This distribution pattern is inversely related to those of clay and silt. High sand content is attributed to coarse-grained material along the western shoreline, which is heavily influenced by human activity. As lake surface area fluctuates with inflow, coarse sand may advance into the lake basin during low-water periods, leading to abrupt changes in sand composition. In contrast, low sand content in the southern part of the lake is associated with fine-grained sediment input from the inflowing river.

According to the Folk ternary classification (Fig. 3), the 72 surface sediment samples are dominated by clay and silt, primarily classified as sandy clayey silt and silty clay.

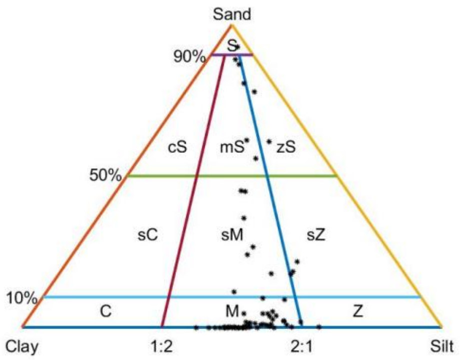


**Fig. 3.** folk triangle classification of surface sediments in the EJL

### 3.2 Variation characteristics of grain size parameters of surface sediments

The grain size parameters analyzed primarily include mean grain size (MZ), sorting coefficient (SD), skewness (SK), and kurtosis (Ku). The mean grain size (MZ) of surface sediments in the study area ranges from 3.76 φ to 7.31 φ(Fig.4), with an average of 6.43 φ. Coarse particles are predominantly concentrated in the west bank. The spatial distribution of surface sediment grain size is generally characterized by finer grains in the south and coarser grains in the north, as well as coarser grains nearshore and finer grains offshore. In other words, sediment grain size coarsens progressively from the river entrance toward the north and from the lake center toward the shore, a pattern evidently influenced by hydrodynamic conditions and sediment supply. Toward the lakeside areas, as water depth decreases, sedimentary dynamics and sediment transport capacity increase.

The sorting coefficient (SD) ranges from 1.2 to 2.4(Fig.4), averaging 1.61. Higher values indicate poorer sorting and greater particle size heterogeneity. According to the widely used classification scheme for grain-size parameters [19] the sediments are classified as poorly sorted. This suggests complex hydrodynamic conditions in the lacustrine sedimentary environment and diverse sediment sources, both contributing to the non-uniform grain-size distribution.

Skewness reflects the symmetry of the frequency curve, with a normal distribution having a skewness of 0. The skewness values of the sediments range from −0.2 to 0.5(Fig.4), averaging −0.01, indicating nearly symmetrical distribution in the lake area. Grain-size composition analysis reveals a bimodal distribution, with peaks around 2.5 φ and 8 φ. In lakeside areas, skewness values are mostly greater than 0, suggesting a tendency toward coarser particles, whereas in other areas, values are mostly below 0, indicating a dominance of finer particles. The bimodal distribution implies multiple sediment sources or different depositional dynamics[20], which also explains the poor sorting observed.

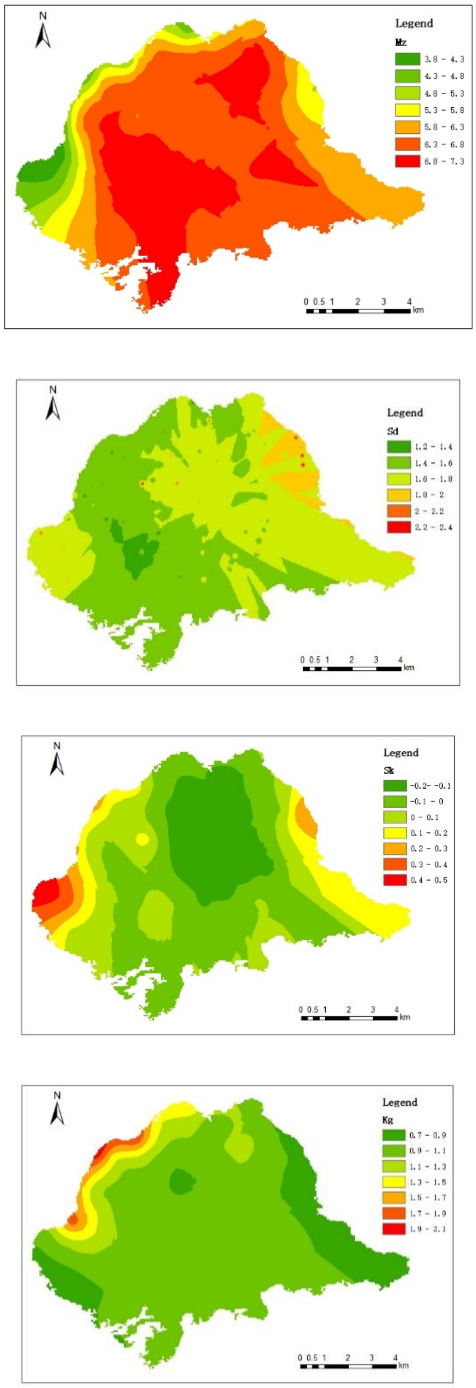

**Fig. 4.** spatial distribution of different grain size parameters of surface sediments in the EJL

### 3.3 Division of sedimentary environment

As a mathematical analytical method, cluster analysis has been widely applied in studies of sedimentary environments. Since most clustering methods require classification variables to be independent of each other, it is essential to select variables that effectively reflect class characteristics when performing cluster analysis[21]. In this study, variables were first classified using R-type cluster analysis, followed by sample classification through Q-type cluster analysis.

Seven commonly used grain-size parameters—mean grain size, sorting coefficient, skewness, kurtosis, and the contents of sand, silt, and clay—were selected for R-type cluster analysis. The results are presented in Figure 5. As shown in the figure, mean grain size, clay content, and silt content form the first group; skewness, sand content, and sorting coefficient constitute the second group; and kurtosis alone makes up the third group. Accordingly, mean grain size, sorting coefficient, and kurtosis were adopted as the grain-size characteristic indices for distinguishing sedimentary environments in this study.

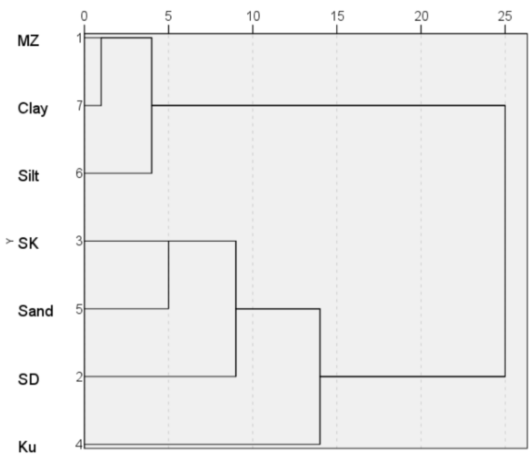


**Fig. 5.** R-type cluster analysis pedigree of seven commonly used grain size parameters of sediments

The results of Q-type cluster analysis are shown in Figure 6. The sedimentary environment in the East Juyan Lake can be divided into three types. The first type is mainly distributed along the lakeside zone from the west to the north of the East Juyan Lake, with a mean grain size of 2.47 φ. Compared with the second and third types, this area has the coarsest grains and the highest sand content (85.32%). Corresponding sediment types include sand, silty sand, and clayey silty sand. Sorting is poor (1.55), and skewness is positive (0.25). The grain-size distribution curve shows a distinct unimodal symmetric normal distribution in the coarse fraction (0–4 φ), indicating a relatively single sediment source[22], which aligns with the high-energy tidal and wave actions characteristic of lakeside areas. The fine fraction, however, exhibits multi-peak asymmetry.

The second type of sedimentary area is mainly distributed in the southwest, southeast, northeast, and northern parts of the lake. The mean grain size is 5.17 φ, indicating finer sediment. Sorting is the poorest among the three areas (2.29), and skewness is negative. Kurtosis is the lowest (below 1), being flatter than that of a normal distribution. The grain-size distribution curve displays a multi-peak asymmetric pattern, with prominent double peaks around 2 φ and 8 φ. The 8φ component is consistent with the wind-suspended component ( 6φ-9φ ), which may be a wind-carrying sediment deposition[23]. The sand, silt, and clay contents in this area are 35.88%, 39.41%, and 24.72%, respectively, intermediate between the first and third sedimentary types.

The third type predominates in the East Juyan Lake area, excluding the eastern lakeside zone. The mean grain size is 7.06 φ, the finest among the three types. Sorting is the best (1.48), skewness is slightly negative (−0.07) and close to zero, and kurtosis is 1.04, near the normal-distribution value of 1. The grain-size distribution is multi-peak and asymmetric. Sand content is low, while silt and clay contents are 53.89% and 44.70%, respectively. The high clay content reflects relatively weak hydrodynamic conditions in this area.

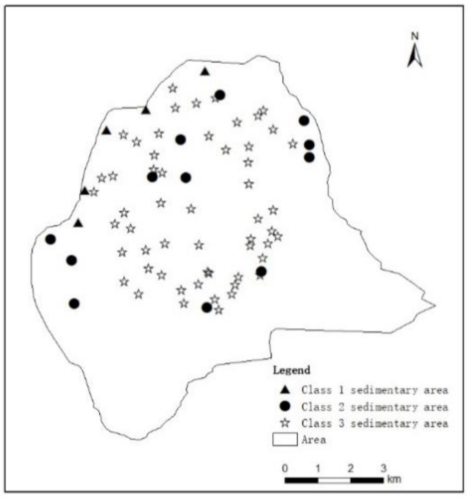


**Fig. 6.** Q-type cluster partition and sedimentary dynamic partion

In summary, the first sedimentary type exhibits clear high-energy lakeside dynamics, with coarse sand as the main sediment source. Due to intermediate water depth, the second type experiences hydrodynamic conditions between those of the first and third types. The third type is characterized by the deepest water, weakest hydrodynamics, and the finest mean grain size. Maintaining a certain water surface area in the East Juyan Lake is essential for preserving its fundamental ecological functions and has significantly improved the surrounding ecological environment. However, the lake remains vulnerable to re-desiccation during consecutive dry years[14]. Following the implementation of ecological water diversion to restore the terminal lake (East Juyan Lake), the sedimentary environment continues to exert a sustained influence. Sediment and aeolian sand transported into the lake by river flow contribute to siltation, thereby compromising aquatic ecological health and necessitating maintenance through engineering measures such as dredging[24]. The analysis of sedimentary dynamics presented in this study also provides scientific and technological support for future dredging operations in the East Juyan Lake.

## 4 Conclusions

By integrating the particle size analyzer with the MATLAB scientific computing software, we realize the automation of particle size parameter calculation. We adopt programming techniques to achieve the automatic classification of the Folk triangle, and based on the cluster analysis method and ArcGIS spatial analysis software, we realize the rapid visualization of the spatial distribution of particle size parameters and the automatic identification of sedimentary environments. The results indicate that the combined application of multiple computer technologies can be efficiently and accurately applied to the analysis of sediment grain size characteristics and the research of sedimentary environments.

The clay content in the study area ranges from 2.31% to 58.51%. In most parts of the lake, clay content falls between 30% and 50%, decreasing from the lake center toward the shore. Clay content is relatively low in the western and northern lake areas. The 72 surface sediment samples are mainly classified as clay and silt, predominantly sandy clayey silt and clayey silt.

The mean grain size (MZ) of sediments ranges from 3.76 φ to 7.31 φ, with an average of 6.43 φ. Coarse particles are mainly concentrated in the western lakeside zone. Surface sediment grain size is generally finer in the south and coarser in the north, as well as coarser nearshore and finer offshore. That is, grain size coarsens progressively from the river entrance northward and from the lake center toward the shore, reflecting clear influences of hydrodynamic conditions and sediment supply. Toward the lakeside, as water depth decreases, sedimentary dynamics and sediment transport capacity increase.

Based on mean grain size, sorting coefficient, and kurtosis, the study area is divided into three sedimentary types. The first type, located in the lakeside zone, shows distinct high-energy conditions and is dominated by coarse sand. The second type, with water depth intermediate between the first and third types, experiences moderate hydrodynamic conditions. The third type occurs in the deepest water, exhibits weak hydrodynamic conditions, and has the finest mean grain size.

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