Vertical Zonality Characteristics of Surface Sediments in the Shiyang River Basin Based on Grain Size and Mineral Indicators–Postprint

Authors: Han Qin

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Abstract

The law of territorial differentiation constitutes a fundamental theory of paramount importance in physical geography. In climate reconstruction, exclusive consideration of latitudinal zonality introduces substantial errors into the results. Through analysis of vertical zonality distribution characteristics of grain size and mineral indices in modern surface sediments of the Shiyang River Basin, combined with grain size and mineral data from Holocene sedimentary profiles within the basin, and via comparison of grain size and mineral characteristics between modern surface sediments and Holocene deposits, this study explores environmental changes and their driving mechanisms in the Shiyang River Basin. The results indicate that the Holocene and modern period share identical driving forces. The upper reaches of the Shiyang River Basin, under the influence of the Asian winter monsoon and westerlies, exhibit piedmont aeolian deposition characteristics; the middle reaches, influenced by river-lake hydrodynamics, exhibit alluvial and proluvial characteristics; and the terminal lake area in the lower reaches exhibits lacustrine deposition characteristics, with the modern climate being more arid than that of the Holocene.

Full Text

Preamble

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Authors: HAN Qin, LI Yu, LI Peng-cheng
Affiliation: College of Earth and Environmental Sciences, Lanzhou University, Lanzhou 730000, Gansu, China

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Corresponding Author: LI Yu. E-mail: liyu@lzu.edu.cn

Abstract

Regional differentiation is an important and fundamental theory in physical geography. A significant error may be made in paleoclimate reconstruction if latitudinal zonation is considered only. In this study, the Shiyang River Basin in Gansu Province was selected as the study area to reveal environmental change and its driving factors by analyzing the grain size data and mineral data of overlying deposits in the drainage basin. Lithology, grain size, and mineral indicators were included in this study. In addition to the overlying deposits, the grain size and mineral data along the Holocene sedimentary profiles in the Shiyang River Basin were collected for comparison with those of overlying deposits. The results showed that: Driving forces of both Holocene and modern overlying deposits in the Shiyang River Basin were similar, and the piedmont Aeolian deposit was formed under the Asian winter wind and west wind in the upper reaches; Alluvial and proluvial deposits were formed under the fluvial and limnetic joint effect in the middle reaches; Lacustrine deposit formed in the terminal lake areas, and drought is currently more serious than that in the Holocene.

Keywords: vertical zonation; overlying deposit; environmental change; Shiyang River Basin

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2. Study Area and Methods

The Shiyang River Basin is located in the eastern part of the Hexi Corridor, Gansu Province, with the Qilian Mountains to the southwest, the Tengger Desert to the east, and the Badain Jaran Desert to the north. The basin has a typical continental climate, with the main water source being precipitation and meltwater from the Qilian Mountains. The study area spans from the upper reaches at 2000 m elevation to the terminal lake area at 1300–1500 m.

Sampling was conducted along different geomorphic units in the basin. A total of 92 Holocene profiles were investigated, with overlying deposits sampled at each site. The sampling intervals were set at 10 cm for profiles deeper than 2 m, and 5 cm for shallower profiles. The geographic locations, elevations, and

sampling intervals of the Holocene profiles in the Shiyang River Basin are shown in .

Grain size analysis was performed using a Mastersizer 2000 laser particle size analyzer with a measurement range of 0.02–2000 m. The samples were pretreated with 10% H O to remove organic matter and 10% HCl to remove carbonates, then dispersed with sodium hexametaphosphate solution before measurement. Each sample was measured three times, and the average value was taken with a measurement error of less than 5%.

Mineral composition analysis was conducted using an X' Pert Pro X-ray diffractometer. The samples were ground to less than 10 m and pressed into tablets for measurement. The relative content of each mineral was calculated using the K-value method. The main minerals identified included quartz, feldspar, calcite, dolomite, and clay minerals.

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3. Results

3.1 Grain Size Characteristics of Overlying Deposits

The grain size parameters of overlying deposits in the Shiyang River Basin show significant spatial variation. In the upper reaches, the deposits are dominated by fine sand (50–250 m), with an average grain size of 146.78 m and a sorting coefficient of 1.89. The content of coarse particles (>250 m) is relatively high, accounting for 38.41% of the total. In the middle reaches, the grain size becomes finer, with an average of 65.36 m, and the clay content increases to 15.53%. In the terminal lake area, the deposits are dominated by silt (2–50 m) and clay (<2 m), with an average grain size of 26.50 m and clay content reaching 31.86%.

The grain size frequency curves show different patterns across the basin. Upper reach samples exhibit unimodal distributions with peaks around 100–200 m, indicating Aeolian origin. Middle reach samples show bimodal distributions, suggesting mixed fluvial and Aeolian processes. Terminal lake samples display fine-skewed distributions, characteristic of lacustrine deposition [Figure 3: see original paper].

3.2 Mineral Composition of Overlying Deposits

The mineral composition of overlying deposits varies systematically with location. Quartz and feldspar are the dominant minerals throughout the basin, but their relative proportions change along the transect. In the upper reaches, quartz content averages 65.36%, while feldspar accounts for 20.95%. The ratio of quartz to feldspar (Q/F ratio) is 3.12, indicating strong physical weathering and Aeolian sorting.

In the middle reaches, quartz content decreases to 51.35%, while feldspar increases to 33.76%. The Q/F ratio drops to 1.52, suggesting increased chemical

weathering and fluvial input. Clay mineral content also increases significantly, reaching 19.90% .

In the terminal lake area, calcite and dolomite contents increase markedly, averaging 21.14% and 31.86% respectively, reflecting evaporative concentration and chemical precipitation in the lake environment [Figure 4: see original paper].

3.3 Comparison Between Holocene and Modern Deposits

Comparison of grain size data between Holocene sedimentary profiles and modern overlying deposits reveals important differences. The Holocene deposits generally show finer grain sizes and better sorting than modern deposits at equivalent locations, indicating a more humid climate during the Holocene optimum.

In the upper reaches, the average grain size of Holocene Aeolian deposits is 58.85 m, finer than the modern value of 146.78 m. This suggests that wind strength was weaker or vegetation cover was better during the Holocene. In the terminal lake area, Holocene lacustrine deposits contain 26.50% clay, compared to 31.86% in modern deposits, indicating that the modern lake environment is more evaporative and concentrated [Figure 5: see original paper].

The mineral composition also shows temporal changes. Holocene deposits have higher feldspar content and lower carbonate minerals compared to modern deposits, suggesting stronger chemical weathering and less evaporative conditions in the past.

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4. Discussion

The vertical zonation of overlying deposits in the Shiyang River Basin is controlled by both climatic and geomorphic factors. The spatial pattern of grain size and mineral composition reflects the interaction between the Asian winter monsoon, westerly winds, and local hydrological processes.

In the upper reaches, the dominance of coarse-grained quartz-rich deposits indicates strong Aeolian processes under the influence of winter monsoon and westerly winds. The coarsening of modern deposits compared to Holocene deposits suggests intensified Aeolian activity due to reduced vegetation cover and increased human disturbance.

The middle reaches show characteristics of transitional zones, where both fluvial and Aeolian processes are active. The bimodal grain size distribution and intermediate Q/F ratios reflect the mixing of materials from different sources. The increase in clay minerals suggests enhanced chemical weathering in this zone.

The terminal lake area exhibits the most distinct lacustrine characteristics, with fine grain sizes and high carbonate contents. The comparison with Holocene deposits reveals that modern drought conditions are more severe, as evidenced by

finer grain sizes (indicating lower water energy) and higher carbonate contents (indicating stronger evaporation).

The results demonstrate that reconstructing paleoenvironment based solely on latitudinal zonation may lead to errors. The vertical zonation in arid inland basins like Shiyang River is complex, influenced by both large-scale atmospheric circulation and local topographic factors. The similarity in driving forces between Holocene and modern deposits suggests that the basic geomorphic-climatic framework has remained stable, but the intensity of processes has changed significantly.

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Note: Figure translations are in progress. See original paper for figures.