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The sedimentary environmental evolution of Lubei Plain since last glacial period

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Abstract: *Since the last ice age, the global environment has gradually changed to a modern height. With the end of the ice age, the temperature has warmed and the sea level has gradually risen. The information of environmental change is recorded in sediments. Therefore, by analyzing the physical and chemical characteristics of sediments, we can reconstruct the paleoclimate change and understand the law of paleoenvironment change since the last glacial period. This study takes the HM borehole located in the northern Shandong plain as the research object. By analyzing the grain size and geochemical characteristics of sediments, this paper analyzes the evolution characteristics of the sedimentary environment in the northern Shandong Plain since the last glacial period and draws the following conclusions: the northern Shandong Plain has shown the characteristics of strong-weak alternating change of sedimentary power due to the influence of transgression regression events since the last glacial period; the analysis of geochemical characteristics shows that the sedimentary environment in the study area is deeply affected by climate change, reflecting the characteristics of climate cold warm alternation.*

Keywords: *last glacial age; Sedimentary environment; Geochemical characteristics; northern Shandong Plain*

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I. Introduction

The study of environmental changes in geological history can provide methods and references for predicting future global environmental changes. Therefore, fully understanding the laws of environmental changes since the last glacial period is of great significance for grasping the environmental changes in the Cenozoic, especially since the Quaternary [1]. Since the last glacial period of the Quaternary, the sedimentary sequence in coastal areas is closely related to sea level rise, and is also affected by tectonic movement, inheritance of geological environment and other aspects[2]. Since the last glacial period, the sedimentary environment of the northern Shandong Plain has undergone complex changes. Under the background of global climate change, there have been frequent alternations between glacial and interglacial periods, cold periods and warm periods. The formation and transformation of the system play an important role. The sedimentary records of the northern Shandong Plain contain rich information on climate change and sea-land interaction, and it is one of the important areas to study the evolution of the paleoenvironment. At present, many achievements have been made in the research on the geological landforms and Holocene transgression in the coastal zone of the northern Shandong Plain[3]. Research on environmental evolution is still lacking.

Grain size analysis is one of the basic contents of sedimentology research. The variation of sediment grain size is the most important sedimentary feature in the strata. At the same time, the grain size test experiment has strong operability and fast speed, and the variation law of sediment grain size is common, which is the research area. The primary object of the stratum can provide a good way for the analysis of the evolution of the regional depositional environment[4]; the content changes of the main elements in the sediments often reflect the content ratio of the mineral components in the deposition process, and can also reflect the degree of weathering of the sediments[5]. Therefore, through the analysis of grain size and geochemical characteristics, the changes of sedimentary environment can be systematically analyzed.

Based on the core data of the HM borehole in Huimin County, Shandong Province, this paper clarifies the evolution of the sedimentary environment of the northern Shandong Plain by analyzing the variation of the grain size and element content of the drilled sediments with depth. Provide scientific evidence.

II. Study area

Huimin County is located in the central part of Binzhou City, with geographic coordinates ranging from 37°6′N to 37°35N and 117°17′E to 117°49′E. km, with a total area of 1357km2. The study area belongs to the Yellow River alluvial plain in the northwest of Shandong Province. The terrain is high in the southwest and low in the northeast, and the plain area is vast. The terrain is high in the south and low in the north, and the plain area is vast. From the perspective of climatic conditions, the study area has a temperate continental monsoon

climate, with an annual average precipitation of 593.1 mm and an annual average temperature of 12.4 °C. Huimin County belongs to the Lower Depression of the North China Land Platform in terms of geological structure. Due to the migration and flooding of the Yellow River in history, a large amount of sediment is deposited and filled, and the geological structure is loose, which provides good geological conditions for storing groundwater; The river and the Tumasa River traverse the east and west, providing good conditions for agricultural development; the crops are mainly wheat and corn, and the vegetable and forest fruit industries are flourishing.

III. Analysis of sedimentary dynamics since the Last Glacial Age

In general, the average particle size of HM pore sediments is 27.64 μm, the particle size varies in the range of 109.4~4.71 μm, the sorting coefficient is 2.98, and the sorting is poor; the skewness is -0.59, which is extremely positive; the kurtosis is 0.76, which belongs to moderate kurtosis. The average content of sand, silt and clay accounted for 22%, 64.8% and 13.2%, respectively, and the particle size component was dominated by silt (Table 1).

Table 1Descriptive statistics of HM borehole sediment particle size

	Average particle size/μm	Sorting	Skewness	Kurtosis	Sand	Silt	Clay
Max	109.40	7.06	0.37	2.14	80.7%	89.2%	41.0%
Min	4.71	2.25	-0.59	0.76	0.4%	15.9%	3.3%
Average	27.64	2.98	-0.25	1.18	22.0%	64.8%	13.2%

The particle size of sediments can better reflect the dynamic characteristics of the sedimentary environment. In the depth range of 20.00m~17.00m, the sediment particles at this stage are relatively large, and the particle size components are mainly sand with larger particles, with an average particle size of 66.34 μm, which indicates that a strong change in sedimentary dynamics has been experienced at this time. Dating infers that this period was during the Yumu sub-glacial period. The rise in temperature caused the sea level to rise, resulting in transgression-regression events, and the depositional dynamics were strong; The average particle size is 15.66μm, the sand content in the particle size component decreases rapidly, the clay content increases, and silt is still the main component. The level drops, and the dynamics of the depositional environment is weak; within the range of 11.45m to 10.28m, the particle size of the sediment increases again, the average particle size reaches 64.55μm, and the sand content increases, indicating that the dynamics of the depositional environment is enhanced at this stage, and the large particles can be transported. According to the dating data, it can be inferred that the sedimentary environment at this stage was affected by the Kenli transgression event in the post-glacial period; within the range of 10.28 m to 0 m, the sand content in the sediment composition decreased, the grain size composition was dominated by silt, and the clay content increased. The decrease of the average particle size indicates that with the receding sea water, the land is exposed, the sea level is basically the same as that of modern times, and the dynamics of the sedimentary environment decreases.

IV. Geochemical characteristics of the northern Shandong Plain

4.1 Distribution characteristics of major elements

The main elements in the HM borehole in the northern Shandong Plain mainly include SiO_2, CaO, Na_2O, Al_2O_3, TFe_2O_3, K_2O, MgO, MnO and TiO_2, and the sum of the content of the nine oxides is greater than 87%. Among them, the average content of SiO2 is the highest, which is 57.9%, followed by Al_2O_3, CaO and TFe_2O_3, with the average content of 11.6%, 6.8% and 4.1%, respectively. The contents of K_2O, MgO, Na_2O, TiO_2 and MnO were all low, and the average contents of these five major elements were 2.4%, 2.1%, 1.8%, 0.56% and 0.08%, respectively (Table 2).

Table 2 Descriptive statistics of major elements in the North Shandong Plain

	Max/%	Min/%	Average/%	SD	CV
SiO_2	27.3	70.8	57.9	7.79	0.13
CaO	1.0	11.5	6.8	2.51	0.37
Na_2O	1.0	2.5	1.8	0.36	0.20
Al_2O_3	8.3	15.1	11.6	1.76	0.15
TFe_2O_3	2.1	6.6	4.1	1.22	0.30
K_2O	1.7	3.1	2.4	0.28	0.12
MgO	1.0	3.3	2.1	0.62	0.29
MnO	0.03	0.15	0.08	0.03	0.38

TiO_2	0.3	0.7	0.6	0.08	0.15

The content of SiO_2 showed a decreasing trend in the range of 20 m-15 m, and the change range was larger in the stage of 15 m-4 m, and showed a trend of first stable and then decreasing at 4 m-0 m. It is considered that SiO2 is the main element of modern Yellow River estuary sediments, and its content is positively correlated with particle size; it shows that the variation of SiO_2 content with depth in northern Shandong Plain may be related to particle size. The changing trends of Al_2O_3, TFe_2O_3, CaO, K_2O, MgO and MnO are basically the same, and they are all opposite to those of SiO_2. The contents of Na_2O and TiO_2 are relatively low, and there is no obvious change rule.

4.2 Principal Element Factor Analysis

The factor analysis results of 9 major elements in the sediments of the northern Shandong Plain are shown in Table 3. The cumulative contribution rate of the three factors is 96.0%, which can represent the information contained in the sediment major element data in the northern Shandong Plain. The variance contribution rates of the three factors are 39.4%, 39.3% and 17.3%, respectively.

Factor 1 is mainly composed of CaO, MnO, SiO_2 and Na_2O, of which SiO_2 and Na_2O are strong loadings. The sediments of the Yellow River are high in Ca and carbonate, and MnO is easily enriched to form carbonate. The mobility of SiO_2 is poor, so it is easy to stay in the sediment, the content of SiO_2 is high, and the content of other elements is relatively low, resulting in its negative correlation between SiO2 and other oxides. The factor loadings for K_2O, Al_2O_3, TFe_2O_3 and MgO were 0.930, 0.856, 0.740 and 0.671, respectively. K_2O and TFe_2O_3 will be adsorbed by sediments with smaller particle size due to changes in depositional environment. Usually, MgO and Al_2O_3 are strongly correlated, and Al_2O_3 is stable and easy to enrich in clay minerals. The variance contribution rate of factor 3 is the smallest, indicating that the influence on the major elements of sediments in the northern Shandong Plain is weak. TiO_2 shows a strong positive load in factor 3, and Ti is relatively stable under various environmental conditions, indicating that the material source of TiO2 may be mainly terrestrial.

Table 3 Factor loadings of major elements in the North Shandong Plain

	Factor1	Factor 2	Factor 3
SiO_2	-0.841	-0.419	-0.169
CaO	0.953	0.153	0.157
Na_2O	-0.662	-0.651	-0.247
Al_2O_3	0.330	0.856	0.382
TFe_2O_3	0.497	0.740	0.431
K_2O	0.252	0.930	0.208
MgO	0.581	0.671	0.436
MnO	0.831	0.424	0.252
TiO_2	0.220	0.370	0.901

4.3 Variation characteristics of geochemical indicators

Different chemical elements in sediments will be differentiated due to differences in activity, and weathering indicators can effectively reflect the chemical weathering degree of sediments. In this paper, two indicators, chemical alteration index (CIA) and silicon-aluminum ratio (S/A), are used to analyze Weathering degree of HM borehole sediments in the North Shandong Plain.

The larger the CIA value, the stronger the weathering degree; on the contrary, the S/A decreases with the increasing weathering degree. The CIA value of the HM borehole in the northern Shandong Plain fluctuates greatly (36.4-69.0), with an average value of 56.9, and the overall weathering degree is relatively weak. The CIA showed an increasing trend in the range of 20 m-15 m, the CIA fluctuated greatly in the stage of 15 m-4 m, and decreased in the range of 4 m-0 m. The variation law of S/A is opposite to that of CIA, indicating that the two reflect the same weathering intensity.

Both trace elements Rb and Sr are dispersed elements, but there are differences in geochemical behavior. The ionic radius of Rb is larger than that of Sr, so Rb is easily adsorbed, resulting in a small migration distance and Sr is easily taken into the solution. The Rb/Sr value can be used to reflect the depositional environmental conditions. Under the humid and hot climate, the Rb/Sr value is smaller; on the contrary, under the cold and dry depositional environment, the Rb/Sr value is larger. The Rb/Sr ratio varies from 0.2 to 0.7, and the Rb/Sr ratio shows an increasing trend in the range of 20 m to 15 m, indicating that the climate is changing to dry and cold; Occurs; 4 m ~ 0 m is relatively stable, but has a trend of changing to dry and cold.

Since the compound solubility of Ba is lower than that of Sr, Ba easily forms insoluble BaSO4 and deposits, while SrSO4 migrates farther. Therefore, Sr/Ba can indicate the salinity level, which in turn indicates the marine and terrestrial environment. In general, the Sr/Ba value in freshwater sediments is less than 1, while the Sr/Ba value in marine sediments is greater than 1. The Sr/Ba values of the HM boreholes in the northern

Shandong Plain are all less than 1, but during the deposition process, there is an obvious trend of transformation to marine or continental facies.

V. Conclusion

In this study, the northern Shandong Plain was used as the study area, and the grain size and geochemical characteristics of the HM borehole sediments were analyzed, and the following conclusions were drawn:

(1) The dynamics of the sedimentary environment in the northern Shandong Plain area since the last glacial period has shown a law of alternating strength and weakness, which is related to the sea level change caused by climate change in the region and the transgression-regression events caused by it. exhibit different deposition dynamics.

(2) The change trends of Al_2O_3, TFe_2O_3, CaO, K_2O, MgO and MnO are basically the same, but the change of SiO_2 content is opposite to that of the above 6 major elements. The content of Na_2O and TiO_2 is low, and there is no obvious change law; The analysis shows that the major elements are affected by changes in the depositional environment and have different sources; the element ratios indicate that the depositional environment of the northern Shandong Plain has been affected by climate changes since the last glacial period, reflecting the characteristics of alternating cold and warm.

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