Sedimentary Characteristics of the Hyperpycnal Flow in the Modern Yellow River Delta

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Based on the analysis of 3,372 sediment samples and 108 km stratigraphy profiles from the modern Yellow River delta, the results show that fine granule sediments is primary, clay silt and silt is its main sediment types. It mainly consists of two parts: saltation load and suspension load, leaking of bed load. With the decreasing of turbulence intensity seaward, it could be divided into two different hydrodynamic sedimentary environment, one is a strong hydrodynamic conditions represented by sedimentary of river bed and river mouth bar, the other one is represented by prodelta and lateral margin sediments, it is a week hydrodynamic sedimentary condition. Hyperpycnal flow belongs to the category of gravity flow and the modern Yellow river delta is a gravity flow controlled sedimentary system. Hyperpycnal flow deposits of modern Yellow River delta is an elliptic sedimentary body which typically characterized by thin on both sides with thick in the middle and the long axis parallel to the coastline.

[Key words: Modern Yellow River Delta; Hyperpycnal Flow; Gravity Flow; Sedimentary Characteristics ]

Introduction

Rivers represent the major link between continents and oceans within the global geochemical cycle and are major pathways for the delivery of terrestrial materials to the oceans$^{1,2}$. In 1855, the Yellow River bursted in Tongwaxiang of Lanyang, Henan province and then seized the channel of Daqing River flowing into Bohai Sea eventually. Since then, during
the last 150 years, the Yellow River has created a modern Yellow River Delta in the southwest of Bohai Sea Gulf\(^3\) with area of nearly 6000 km\(^2\) (Fig. 1a). From the eighties of last century, the modern Yellow River delta research has made great progress. With the development and construction of Yellow River delta, research priorities gradually changed from the initial sedimentary tectonics\(^4,5\), the tail changes\(^6-8\) to the sediment diffusion\(^9,10\), shoreline erosion and engineering geological environment\(^11-16\). However, only a few detailed researches are about deposition procession of single lobe and depositional features of estuarial hyperpycnal flow. Diaokou lobe was a natural formed and completed sub-delta lobe from 1964 to 1976 when the Yellow River entered into Bohai Sea through Diaokou river stream. It has a significant theoretical meaning for understanding the evolution of modern Yellow River delta and the special sedimentation of Yellow River hyperpycnal flow.

**Materials and Methods**

The Yellow River is famous for its high sediment content and different sources of water and sediment with up to 1.08 billion tons sediment deposit into the sea every year, which makes it well known in the world\(^17\). Water and sediment of Yellow River into the sea shows significant seasonal variation. The non-flood season is from November to next June. Water and sediment content is transported to the Bohai Sea which is only accounted for less than 20\% of the annual content, while the flood season, lasting from July to October every year, is strongly influenced by the East Asian monsoon. Middle reaches of the Yellow River rains heavily which is caused by great increase in the flow capacity. Incoming water and sediment content accounts for more than 80\% of the total amount of one year. Flood season is the
time when the burst of the lower reaches of Yellow River mainly occurs$^{18}$. 

The water depth of the reception basin of Bohai is relatively shallow, a huge amount of sediments are transported and filled up at the mouth, which causes the constantly seaward extension of the river course$^{19,20}$. While the estuarial base level of erosion continues to grow, the river channel increases year by year, and the slope of the river course becomes lower and lower. When the river course cannot meet the requirements as to function as flooding discharge and drain sands, the flow will break through the constraint of the natural or artificial embankment through the lowlands of the delta to find a new path to the sea, which results in the swinging of Yellow River lobes$^{21}$. Diaokou channel, which locating in the middle part of Yellow River delta, south coast of Bohai Sea, is the newly abandoned channel of Yellow River. Water flow began on January 1st 1964 and intercepted in May 1976 (Fig.1b), with total developing period of 12 years and 4 months. It has experienced overflow, joining, separation and diversion, a complex evolutionary history, which is also the whole history of modern Yellow River Delta’s natural evolution$^{22}$. 

This research aim is to understand the deposition structure of the Diaokou Lobe and the deposition mechanism of the hyperpycnal flow of the Yellow River, ten geological core drillings were placed on the subaerial delta within the Diaokou Lobe area, among which there are four 10m-drillings, five 20m-drillings, one 30m-drilling, all are qualified for whole coring sampling; the 108 km stratigraphy profiles are derived from the subaqueous delta. Sedimentation environment is determined by sedimentary facies which are divided by the parameters using the MSCL system (i.e. multi-sensor core logger) produced by GEOTEK
corp., England, and analyzed with ITRAX coring scanner. The device used in grain size test is the Malvern2000 laser grain size analyzer, which belongs to Institute of Marine Geology of Qingdao. Its measurement range is from 0.02 to 2000 µm with resolution of 0.01 Φ, repeatability error is less than 3%, achieve particle size analysis of 3,372 samples, $^{14}$C radiometric age dating were taken in some samples. All data obtained are informative and reliable.

**Basic grain characteristics of the modern Yellow River Delta**

Based on the analysis of the grain size testing results of 3,372 samples, it is clear to conclude that the sediments of Yellow River Delta is mainly fine grain, silt and clay silt, and the proportion separately are 15.4 %, 67.8 % and 16.8 %, with 43.7 % coarse silt and 24.1 % fine silt, the median particle diameter $Md$ is 3.37~7.86 Φ and the mean grain size A.K.A. $Mz$ is 4.62~6.81 Φ. Therefore, the sediment of the Yellow River Delta is characterized by fine-grained material, and the sediments are mainly composed by silt, especially coarse silt.

Standard deviation of the Yellow River Delta sediments is $δi=0.76~2.88$, the degree of separation is from medium to very poor; the chart of the grain size parameters sorting shows that the poor sorting degree of sediment accounts for 86.95% of total, the very poor accounts for 11.12 % of total, the medium accounts for only 1.93% of total, so the sorting of Yellow River Delta sediments is poor. Skewness $Ski = -0.36 ~ 0.61$, ranges from very negative bias to the extremely positively skewed, in which the proportion of the extremely positively skewed, positively skewed, nearly symmetrical, negatively skewed and very negative are 53.32 %, 39.50 %, 6.97 %, 0.15 % and 0.06 %, indicating that the Yellow River Delta
sediments is mainly extremely positively skewed and positively skewed. Kurtosis $K_g=0.75-2.21$, ranges from flat to very sharp, the proportion of flat, medium-sharp, sharp and very sharp are 6.58 %, 43.90 %, 26.54 % and 22.98 %, indicating that the kurtosis of the Yellow River Delta sediment is relatively sharp, and a small amount of high mud content sediment kurtosis is flat (Fig.2).

Typical grain characteristics of the modern Yellow River Delta

The cumulative probability curve of the sediment shows that the modern Yellow River Delta is mainly consisted of saltation load and suspended load, lacking of bed load generally. Depositional environment can be mainly divided into two categories according to the probability curve and the particle size distribution characteristics of the different sediments. The first class sediment is coarse, mainly with silt, which represents a strong hydrodynamic environment. Compared to the cumulative probability curve of other sediments, the characteristics of this type of sediment grain size separately indicate the riverbed facies, river mouth bar facies, sidebank facies and distal bar facies; the second class sediments are mainly with fine grained sediments, high clay content, representing weak hydrodynamic environment, respectively indicating flood plain facies, delta lateral margin facies, prodelta and shallow sea facies (Fig.3).

The first class sediments: the characteristic curve of particle size distribution (Fig.4) shows that a narrow peak, very positively skewed and a long thin tail are the main features. Its peak range is narrow, the peak interval ranges of the grain-size of the river bed, mouth bar, point bars and distal bar are 2.0–5.0 Φ, 2.5–6.0 Φ, 3.0–6.5 Φ and 3.0–7.0 Φ. Particle size
peaks are 3.0 Φ, 4.0 Φ, 4.5 Φ and 4.5 Φ, indicating that sediments of this class are mainly composed of very fine sand and coarse silt, which belongs to coarse particle material of single source. Sediment particles, in the order of riverbed, river mouth bar, sidebank, distal bar, tapers off.

Cumulative probability curve of the sediments shows that the sediment of first class mainly consists of saltation load and suspended load, the saltation load segments generally steeper and its dip angle can reach 60 ~ 68 °, which represents its well sorting, concentrated particle size, narrow kurtosis and the cumulative probability can reach 70~93 %; suspended load line is relatively flat, the dip angle is 11 ~ 18 °, the cumulative probability is 7~30 %. The point of intersection by saltation load and suspended load is the thin section in the chart which means the suspended coarsest particles. Value of thin section Φ is increasingly getting larger in the order of the riverbed, river mouth bar, side bank, distal bar, ranging from 4.1 to 5.7 Φ. Compared with other Φ value of the thin section of fluvial deposits (2.75~3.50 Φ), this value is larger. By comparison with modern Yellow River and the Mississippi River Delta sediments, the cumulative probability curve of the modern Yellow River Delta is very similar to the main river of the tributaries of the Mississippi River Delta bed and the modern riverbed sediments, but the Φ value of its thin section is generally too large, compared to the probability curve of the Mississippi delta sediments. Meanwhile, mouth bar facies of the modern Yellow River delta lacks of traction load bed line and the thin section Φ value is too large.

This type of sediment cumulative probability curve is similar; with saltation load line almost parallel especially, reflecting its similar depositional hydrodynamics environment of
saltation load. The cumulative probability of suspended load shows that the cumulative probability of suspended sediment of sidebank and river mouth bar respectively accounts for about 18% and 15%, while it can reach to about 25% at the environment of the channel and distal bar. Due to the weaker energy of river, it no longer has sufficient capacity to carry the original sediment, so sediment deposition occurs. Large particles, in saltation load firstly stop than depositing down, with the further decreasing of the energy, the saltation load gradually stops moving in the order of the magnitude of size and weight. Relatively larger particles of suspended load will gradually transformed into the saltation load then deposit on the river bed. Large flow velocity of the Yellow River course and the high sandiness makes the fluid viscosity larger. Coarse particulate matter in suspended state is difficult to settle, so more suspended load accumulate on the riverbed. However, when the river reaches the estuary, its channel is suddenly widened and jacked by the sea water, the hydrodynamic force becomes weak, in addition, hydrodynamic conditions of the marginal bank is also relatively weak, so some of the coarse particles transform from suspended sediment into saltation load; distal bar is easier to be transported in suspended condition than deposition, due to its fine particulate matter. Therefore in every facies the sediments probability curve of the Yellow River Delta are similar, but there are also differences, which are mainly reflected in facies that the sediments are transported by the intensity-different turbulence or caused by the differences between main sediments.

The second class of sediments: particle size distribution characteristic curve (Fig.5) shows that this type of sediment featured by relatively wider kurtosis and positive bias. Peak scope are located at 4.0 ~ 9.0 Φ, particle size peak is between 6.5 ~ 7.0 Φ. The peak range of
shallow marine facies are very different from the delta lateral margin samples, individual samples appear bimodal, while the probability cumulative curve of individual samples of shallow water and flood plain appears very small amount of saltation load segment. Shallow water sedimentary facies is mainly derived from storm resuspension deposition and bioturbation, delta lateral margin can also be subjected to long-distance transporting of storm resuspension deposition and coarse particulate matter deposition during the flood, and flood plains sedimentary facies are mainly caused by coarse particles deposition at the bottom of low-lying land and plant roots. Sediment cumulative probability curve shows that this type of sediment takes high clay content, the probability curve is only a flat line, its inclination is generally about 45°. This is mainly because such a depositional environment is far from estuary and weak hydrodynamic conditions, while coarse particles in the sediments deposited in the process of long-distance transporting.

The typical sediments probability curve of the modern Yellow River Delta shows that all of the various types of sediment probability curves have a upper arch, although depositional environments are different, the thin section shows a transition state but not typical segments intersect of two lines, which reflects the strong turbulence effect inside the fluid, gravitational differentiation is more effective for heavier particles deposit during sediment sinking, while the lighter particles are still left in the turbulence, so that it has the characteristics of the steep thick end segment and good sorting and gradually turning flattened at the smaller end. Probability curve of river and river mouth bar are very similar, both of the probability curves show a two-stage. There is a bit of transition between the saltation load and suspended load. Thin section is respectively 4.1 Φ and 4.7 Φ, which indicates a trend of gradually weakning
of the hydrodynamic force, after the Yellow River high sandiness fluid flooding at the slope off the estuary dam and in the river course; the lessened water dynamics shows increasingly an obvious characteristic of gravity flow, so that the shape of the probability curve is almost a symmetrical arc, which is one of the typical characteristics of the gravity flow deposition. In other words, the high content of sandiness fluid of Yellow River has part of the characteristics of traction current due to the large flow velocity on river way and its close position to the river mouth bar. When its flow velocity reduces, the high sediment content fluid flow along the slope becomes under its own gravity force and transforms into gravity flow. With the increase of transport distance, turbidity current mixes with the overlying water to reduce its density and flow velocity, it makes the carried suspended solids sink and reduce its density, the gravity flow begins to transform to the traction current with the reduction of density. The critical value of this change is closely related to sediment content of fluid and flow velocity, but different depositional environment probability curves show that all the Yellow River fluids have gravity flow properties, and they just have differences in strength due to different depositional environments.

In order to study the sedimentary characteristics of high sediment content flow in the Yellow River in detail, we have obtained nearly 2000 samples and used C-M diagram to analyze(Fig. 6). C-M diagram of the modern Yellow River delta sediments indicates that the sediments of Yellow River Delta clearly appear the characteristics of gravity flow deposits (Fig.6), its morphology distribution is very similar to the QR segment of rivers, also it is a long strip parallel to the C-M line, but it is away from the C-M base line gradually accompanied by the C and M value decrease, which indicates that the main transport pattern
of the Yellow River Delta sediment is graded suspension and transits to uniformity suspension with the increases of transportation distance.

Because of large density and fast flow speed of the gravity flow, the Cs value of the gravity flow is generally bigger than normal river graded suspension. As to the normal traction current Yangtze River Delta sediments, the Cs and Cu values of QR section are about $400 \, \mu m$ (1.3 $\Phi$) and $200\mu m$ (2.3 $\Phi$), while the Yellow River Delta sediments Cs is $250 \, \mu m$ which is far less than the ordinary river, and its largest sorting index Im is 3.6 $\Phi$ (80 $\mu m$), which is larger than the Im value of ordinary turbidity currents (all the turbidity current Im values are less than 1 $\Phi$), and smaller than the ordinary mudslides Im value (the mudflow Im value can up to 6 $\Phi$). Therefore, the C-M diagram of the Yellow River Delta sediments has characteristics of gravity flow, but has great differences with ordinary turbidites and mud flows; it should belong to a special fluid between turbidity currents and mudflows. This is mainly due to the fine sediment particles of Yellow River itself; sediment content is high, and the formation of high sediments content flow changed with the hydrodynamic conditions and turbulence intensity. This is one of the particularities of Yellow River fluid which is different from other fluids. Fine sand grain and high sediment content flow make sediment in suspension transport state. Upper reaches beam velocity is high due to large river channels beam gradient, sediment and hydrodynamic conditions did not reach equilibrium, after enter into the estuary part, river way gradient decreases with the addition effect of sea jacking makes river flow speed decrease, and sediment subside rapidly.

In order to study the change law of the fluid at Yellow River estuary section during its flowing into the sea, the sediments of different depositional environments were obtained from
25 to 30 samples for C-M diagram depositional environment; in accordance with the different sedimentary facies of Yellow River Delta corresponding to the location of the C-M diagram (Fig.6), the riverbed deposition, the river mouth bar deposition and point bar sediment are mainly graded suspension, the deposition transition to uniform suspension from distal bar, delta lateral margin and the prodelta (including flood plains), individual prodelta and flood plains even the sidebank deposits have the characteristics of still water suspension deposition. C-M diagram location of the various sedimentary facies are consistent with the results shown by the cumulative probability curve, which demonstrates turbulence intensity of hydrodynamic force weaken gradually along the direction of the river water into the sea.

**Results and Discussions**

*Framework of the hyperpycnal flow deposits of the modern Yellow River Delta*

The section A-A' is located in the middle part of the Diaokou lobe (Fig.1b), longitudinal (NNE) throughout the whole Diaokou lobe, about 28 km, it integrated representative drilling and shallow stratigraphic profile information, and presented complete stratigraphic evolution of history of Diaokou lobe of Xian country transgression from the middle of late pleistocene epoch.

According to the physical and chemical parameters of this area which is 30 m to the shallow strata sediment (Fig.7), since the middle of late Pleistocene, the Yellow River Delta has experienced twice warm climate and one cold climate\(^24\). Dating back about 36,000 to 23,000 years, the Earth’s climate was gradually warming and global sea level was high, water intrusion in the Bohai Sea, developed the second marine layer-Xian country transgression
layer. Around 20,000 years ago, the Earth entered the Last Glacial Maximum period, the climate was significantly cold, sea level dropped by over one hundred meters, the modern Yellow River delta became land again after sea water exit the Bohai Sea with some shallow lakes and rivers distributed on it, which deposited the second continental facies. Dating back 8,800 years ($^{14}$C dating), the climate became gradually warm, the sea flooded the Bohai Sea once again; the tidal flat deposits developed gradually, the first marine layer –Huanghua transgression layer began to develop with the rise of the sea. According to historical records about 4~ 2 ka B.P. Yellow River was re-injected into the Bohai Sea, the prodelta area of Yellow River delta extension to the northern sea of study areas, covering on the top of the Huanghua transgression layer. From AD 1194 to 1855, the Yellow River flowed into the sea in the northern Suzhou, the Diaokou delta lobes region sea port in the shallow water environment. In 1855 the Yellow River involution Shandong into the sea, and the modern Yellow River delta began to develop from then on, especially since 1964, after the Yellow River rechanneled Diaokou river into the sea, a massive amount of sediment carried by the Yellow River quickly accumulated in this area, the tidal flat and shallow sediments formed by the submarine delta of the Yellow River and Huanghua transgression constitute the first marine layer together. With the high swing rate of the Yellow River estuary and the rapid sediment deposition, land-based Delta developed rapidly and formed the first continental facies.$^{25}$

The prodelta deposition of the first lobe (1855 to 1889) and fourth lobes (1904 to 1929) located in the shallow water sediments, the thickness was about 3m; in 1934 the sixth lobes began to develop, from 1953 to 1960 Shenxiangou mainstream road situated at the southwest
side of the Diaokou river basin, distal bar and delta lateral margin deposition deposited here.

On the whole, the early stage delta lobes took the shape of lenticular from 1855 to 1964, seaward until a water depth of 18m, towards land until delta peak thinning wedge out gradually, the main deposition body located near ZK20-4, the most thickness is about 10m. Because the fairy ditch mainstream road southward in 1960, the sediment source of the district decline sharply, its roof sediment transformed by wave especially in shallow water area, we can see a mixture of yellow silt sediment layer. The seventh lobe (1964 to 1976) deposition basement formed.

From 1964 to 1976, the Diaokou flow path substrate was stepped, it took ZK20-4 as a turning point, the substrate was very flat at the landward side of the ZK10-4 ~ ZK20-4 length about 10km, the water depth changed a little, basically located about 5m from it, it should belong to a small bay in front of the walking river; water depth gradually increased from ZK20-4 to the sea-side, the water depth gradually increased since 5m to about 18m, the slope is 0.6‰. From 1964 to 1966, the beginning of Yellow River rechannel, the river was overflow wandering state with wide and shallow flow, a lot of sediment deposited along depressions and estuaries small gulf (ZK10-4 ~ ZK20-4), estuarine sand seats developed, while at the turning point of water depth, the relatively fine-grained material deposited here, formed complex structure sheetflood stage sedimentary bodies; after 1967, estuaries shallow bays gradually filled, the water depth of mouth outside was up to 12m deep, the slope steepened, the river was in a straight single state, the sediment sent to the open sea, and estuarine sand bar development, with the extension of the riverway, river mouth bar gradually extension seaward, covered on top of prodelta deposition, the delta front steep, usually above 2‰; in
flood period of the Yellow River, hyper sandiness fluid bottom erosion can reach deep estuary sand sheet and the top of the mouth bar, the channel deposits rapid formation, while the high sediment deposition rate of Yellow River makes the rapid riverbed rise, the flow out of the slot, formed the top flood plain deposition. Therefore, sediments are mainly deposited in rivers, estuaries sand seats, mouth bar, distal bar and prodelta from land to sea, constituting the gradually seaward evolutionary sequence of the river. Affected by delta retrogradation in 1976 after the Yellow River rechannel, from the survey data we can see that the maximum thickness of Diaokou lobe is 11.3 m (ZK30), the reality lobe subject located in the ZK30 about 5 km to the sea side, the thickness is more than 13 m, it respectively developed ternary sedimentary structures from the bottom to top up which include the prodelta deposition, delta front deposition and land-based delta plain deposition.

Hyperpycnal flow deposition characteristics of Modern Yellow River Delta

The Yellow River estuary bay is an area of very shallow waters, on the conditions of very shallow water environment, hyperpycnal flow of Yellow River strongly mixed with seawater, it is no time to development a complete sedimentary sequence since the sediments will be rapidly accumulated and forms the estuary sand seats. Due to the shallow water depth and the boundary conditions, it cannot form a typical hyperpycnal flow and delta lateral margin deposition, but at turning point of water depth, relatively smaller sediment exists and settled layer of clayey silt and silty sand interactively appeared. It is because in the early period of rechanneling, the mouth position and length which extends into the sea are variable, resulting in the constantly changing of the depositional environment in the area, the hydrodynamic
conditions are extraordinarily complex, thus corresponding sedimentary facies are difficult to determine from a typical sedimentary facies standard point of view, therefore here we definite as sheetflood stage deposition. Yellow River rechanneled at Diaokou in 1964 and did not change until 1966, the Diaokou stream was mainly in the sheetflood deposition stage, underwater deposition expanded to the sea with a shape of fan-shaped, deposition was limited to the area between Tiao River and Shenxian ditch underwater delta (Fig. 8a).

At the beginning of the second stage of lobe development, the river course is straight and single, which is a typical mode of the Yellow River delta evolution. After the jet current of the Yellow River water body flowing into the sea, the flow velocity rapidly decreases in the influence of seawater jacking, sediment, especially abundant coarse particulate matter begin to deposit, fine sediment fractions cement under the effect of flocculation of sea water deposit rapidly. Estuarine sand seats and the mouth bar developed, furthermore, rapid sediment accumulation results in progradation of delta which quickly form into land. From 1966 to 1968, a single river course was gradually formed, the water depth outside the mouth increased, river mouth sand bar developed, subaqueous delta slope was relatively large, the shape of mouth bar liked a spindle which is thick in the middle and thin on both sides (Fig. 8b); From 1968 to 1972, river mouth sand bar continued to develop toward the sea. Yellow River was in a swing state from 1972 to 1974, the thin small subaqueous delta deposited in the southeast of the original Shenxian ditch area. From 1974 to 1976, a small underwater delta developed again in the northwest side of the original underwater delta (Fig. 8c). From 1964 to 1976 Diaokou lobes subaqueous delta sedimentary body scale can be express use Fig. 8d, the Diaokou lobe subaqueous delta was an oval which is wide in east-west direction and narrow in south-north
direction, its long axis direction parallels to the coastline, its main body of underwater deposition extended seaward more than 20 km, the area with maximum sediment thickness was located in the middle, the maximum sediment thickness was 13 m, the maximum deposition rate was 4.0 m/a, estuary position often changed and had seasonal characteristics of “summer deposition and winter erosion”, so the main body of Diaokou lode average deposition rate was about 1.1 m/a.

Four months from July to October each year, the flood season begins, the Yellow River flow increases greatly due to the strongly influence of the East Asian monsoon. Incoming water and sediment account for more than 80% of the total amount. The high sediment content water of the Yellow River forms hyperpycnal flow after its flowing into the sea, when its direction is consistent with the trend direction, fluid velocity increases, erosion of bottom sediments make the higher density fluid, the suspended material is not easy to deposit and the deposition rate slows down; While on the contrary, the Yellow River water is blocked and high-density flow dissipates, sediments accumulate rapidly, and the lateral high-density flow forms on both sides of the river due to the high-density flows spilling on both sides. Meanwhile, the trend and the flow field shear front which vertically or obliquely crosses the direction of runoff makes the river mouth bar of the Yellow River Delta spindle-shaped cross the outside estuary, the leading edge gradient is comparatively large, which can be up to 3~5 ‰, the river mouth bar develop rapidly outside the entrance, causing the river bed gradient decreases rapidly, difficulty of river drainage, burst rechanneling occurs frequently, and this is one of the special deposition phenomenon of hyperpycnal fluid in the Yellow River Delta. Therefore, oval-shaped sedimentary body which is thick in the middle, thin on both
sides and long axis parallel to the shore line is the typical characteristic of the modern Yellow River Delta hyperpycnal flow deposits (Fig. 9).

Conclusions

Grain size analysis results of the Yellow River Delta samples shows that the Yellow River delta sediments are mainly fine-grained sediments, clayey silt, in which silt is the main sediment type, and poor sorting, very positively skewed and kurtosis sharply are the main sedimentary characteristics.

Depositional environment includes: river bed, river mouth bar, side bank and distal bar for the first class, representing a strong hydrodynamic condition, and the delta side of the edge, floodplains, shallow sea and the delta front for the second class represents the weak dynamic conditions. Hydrodynamic conditions gradually weakened in proper sequence of the riverbed $\rightarrow$ river mouth bar $\rightarrow$ sidebank $\rightarrow$ distal bar $\rightarrow$ delta lateral margin $\rightarrow$ prodelta $\rightarrow$ flood plain. Yellow River delta sediments are mainly composed of two parts, the saltatin load and suspended load, a general lack of bed-load, although the first class sediment cumulative probability curve is similar morphologically, there are also differences depending on the hydrodynamic conditions and sediment, this mainly reflects the difference of turbulence intensity or the main sediment even if all facies sediments are turbulence transporting. For the second class of sediments, the coarse particles composition in the sediment deposited along the long-distance removal mainly due to the distance is far away from the estuary and the weak hydrodynamic conditions. Clay as the representative of fine particulate matter deposit here after going through a long distance suspended transport.
modern Yellow River delta deposition from land to sea successively is mainly the rivers, estuarine sand seat, river mouth bar, distal bar and prodelta deposition, constituting the evolutionary sequence of gradually seaward extension of river course. Delta deposition rate is fast, river swings frequently, the vast majority of sediment accumulated near the estuary, slopes are gentler, depth are less than 18 m, and the maximum sediment thickness is greater than 13 m.

Yellow River high sediment content fluid belongs to the scope of gravity flow. Its transport pattern is mainly graded suspension assisted with homogeneous suspension, which is also mixed with a small amount of hydrostatic suspended sediments, which has the turbidite deposition characteristics. However the Yellow River sediment has its own characteristics of the fine particles and high sand content. There is a big difference between the normal traction flow and turbidite sediment, due to the high silt content, fast deposition rate. The development shape is oval-shaped with the long axis parallel to the shoreline, appears in spindle shape cross the estuary. Average deposition rate is 1.1 m/a, the maximum deposition rate can be up to 4.0 m/a.

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**Figure captions**

Fig.1. Location of the research area and cores
   a. The different period lobes distribution in the modern Yellow River Delta
   b. Study area of Diaokou lobe (1964~1976)

Fig.2. The distribution chart of grain size of the Yellow River delta

Fig.3. The Yellow River delta sediments Cumulative probability curves

Fig.4. The first kind of sediment particle size distribution characteristics

Fig.5. The second kind of sediment particle size distribution characteristics
   a. Shallow sea facies b. Delta lateral margin facies c. Prodelta facies
   d. Flood plain facies

Fig.6. Typical modern sediments C-M figure of Yellow River delta

Fig.7. A-A’ section and sedimentary complex map of Dioakou Lobe

Fig.8. 3D chart of Diaokou lobe development in modern Yellow River Delta

Fig.9. Sedimentary model of the Modern Yellow River Delta (According to Wang)