Assessment for the Coastal Sedimentary Environment in the Pearl River Delta (PRD) Region, China by Using 14C Dating

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Abstract. Since late Quaternary, the intense change of coastal sedimentary environment in the Pearl River Delta (PRD) region has resulted in accumulating the thick sedimentary layers with the different causes and properties which were influenced by the fluctuation of sea levels, the change of ancient climate and human activities. Based on the interpretation of high resolution of these sediments, such as the period, sedimentary facies and discontinuous faces, we can infer the evolution of the ancient climate of regional Quaternary environment in the background of global change to know more details about the formation of the PRD. Taking the Xilin Hill fault as the example, we explained the reason of the PRD formation, inferred its interactions with local/regional climate and sea-level changes, and analyzed the evolution of the PRD formation and its controlling factors of the coastal sedimentary environment by using 14C dating technology. It is noted that the neo-tectonic movement and the fault activities played a critical role in controlling coastal geological environment. This is helpful to further investigate the evolution of the PRD coastal sedimentary environment, the history of inversion region, and the sedimentary facies model of the interaction between land and sea. More investigations will be conducted in the near future.

Introduction

Pearl River Delta (PRD) is a dynamically evolving landform that occurs at the mouth of Pearl River systems where the sediments are deposited as they are moving to South China Sea (SCS). There are a lot of controlling factors accounting for the formation of the PRD, including sea level changes, fluvial processes, and human activities etc [1].

The PRD Quaternary environment is an important topic in response to global climate change, as it has a complicated environment, in which the PRD is located in the special position of the transition of land-sea, sensitive to the climate change and sea level rising [2].

A number of previous studies investigated the PRD region and made a great achievement, including the deposition, new tectonic movement, fault activities, sea level changes and ancient environment evolution. For example, the relationship between several activities of the fracture structure and river terraces by the causes of the block tectonic geomorphology in the PRD was proposed and discussed in the early 1980’s [1,3,4,5]. Later on, the amplitude and rate of fault block tectonic movement was reported by applying the results of the dating of Quaternary sediment chronology since Quaternary period [6]. However, it was addressed to analyze the characteristics of the fault block tectonic movement and the dynamic tectonic stress field since Late Tertiary [7]. In addition, the crustal stability of several districts in the PRD region was analyzed by using geochemical testing results [8,9].

In a word, the Quaternary geology of the PRD region is of great significance. In regard to the causes of the formation and development of the PRD since late Quaternary, it is still being an academic controversy. Someone believe that the development of the PRD was mainly influenced by rising sea level, or caused by Lushan glacial and post-glacial climate changes. In
comparison, the others stand for that the climate fluctuation didn’t change too much during Lushan glacial and post-glacial, as the amplitude of fluctuation is only several meters to ten meters since 30 ka B.P. (B.P. means before present where ‘‘present’’ represents 1950) in the north of South China Sea (SCS). However, a number of SCS transgressions since post-glacial period had provided the necessary condition for the development of the PRD [10,11,12].

In this paper, we first analyze the reason of the PRD formation and its controlling factors integrated the results of the deposition, fracture and fault-block, then discuss the effects on the PRD coastal sedimentary environment.

Study Area

The Pearl River Delta (PRD) is located at 21°20'-23°30’N and 112°40'-114°50’E, in Guangdong province, China, which was formed in the last 9000 years [13]. As it is shown in Figure 1, two alluvial deltas, separated by the core branch of the Pearl River. The North River and the West River flow into the South China Sea and Pearl River in the west, while the East River only flows into the Pearl River proper in the east. The length of the Pearl River is 2214 km, and the draining system of the Pearl River covers about 425,700 km² [13]. But the area of the receiving basin is 9750 km² [14].

![Figure 1. The study area of the PRD region (courtesy of google map as the background of the PRD region).](image)

As the deposition rate of the delta estuary and coastal waters was relatively high, a great of geological information was recorded in deep layer sediments. The sedimentary information is important of analyzing the reason of the PRD formation and controlling factors integrated the results of the deposition, fracture and fault-block, and discussing the effects on the PRD coastal sedimentary environment.

Methodology

Stratigraphic and sedimentary analyses and carbon dating are applied in the PRD investigation. By interpreting high resolution of sediments, the detailed information, such as the periods, sedimentary conditions, sedimentary facies, discontinuous faces and sequential relationships between the strata can be obtained [2,6].

14C dating is a common means for chronological divisions. The dating principle is that after the carbonaceous materials died, the carbon in the body could stop exchange with the outside world. Then the content of 14C is reduced by the rate of decay. Compared the residual content of radiocarbon 14 of samples with that of present similar samples, we could deduce the epoch from the time after exchanging 14C. As the half-life period of 14C is 5568 years, it will be reduced by about 1,000 times after 10 half-life periods [2,6,15]. So the modern radioactive detector almost cannot
work. Considering on these conditions, the 14C dating method is suitable for carbonaceous materials dating back to 300 to 50,000 years. As the precision is about 1-2%, the older the sample, the greater error is [16].

Results and Discussion

Neo-tectonic Movements

To a certain extent, tectonic movements affect the distribution of sediments, which is the result of the tectonic movements. According to the speculation, it was caused by the up-burst of upper mantle with a high density. As a result, the neo-tectonic movement has inherited the tectonic framework since Yanshanian Movement. Several borders of the PRD region are controlled by NE tectonic movements. On the other hand, the activity of NW tectonic movements dominated the trend of sedimentary geomorphology. Tectonic lines of the above two groups jointly manipulated the pattern of tectonic geomorphology in that the direction of NW is as the long axis and the direction of NE is as the short axis [6,17].

It is acknowledged that in the tectonic uplift areas, the higher landform is, the older stratum is. However, in the tectonic subsidence areas, the lower the sedimentary layer is, the older the stratum is, and each new layer is laid down horizontally over older ones in a process [6,17,18] as shown in Figure 2.

![Figure 2. Ages-sketch map of sediments in the uplifting and subsidence areas.](image)

It is no doubt that the upper cycle of two sedimentary cycles in PRD belongs to Holocene, and the lower one is dating back to late Pleistocene [19]. In addition, the tectonic movement has of great significant in the development of PRD. The delta was cut into a series of fault-blocks by the basement faults which developed or reactivated during Quaternary. As a result, the evolution process of PRD was mainly controlled by the faults since a lot of evidences have been found from the distribution of Quaternary sediments, drill holes and geologic profiles [7,20]. In a word, during the PRD formation and evolution, neo-tectonic movements not only influenced its sediments, but also controlled the river channel changes.

A Case Study of Neo-tectonic Movements at Xilin Hill

The bottom of Xilin Hill is underlying with the granites, but the top is covered by the residues of red soil and Quaternary sedimentary soil. Meanwhile, the Quaternary is distributed in the slope of the southeast of Xilin Hill, in which the middle layer of soil layer deposition is greater than 3.5 m. Among them, the fourth layer was dating back to about 40,000 years. According to the preliminary study, the strata can be divided into three parts from old to new as layer A, B, C and D as below:

Layer A: The grayish white sands are filled with the lower part of the layer. It goes up to the gray and black clay.
Layer B: The grayish sand and brownish clay.
Layer C: This layer is covered with poor bedded light orange coarse sands and fine gravels.
Layer D: the fourth layer is modern sediments, dating back to back to about 40,000 years.
Here, the late Quaternary pedestal terrace at Xilin Hill shown as in Figure 3 can be summarized and described as: 1-clay layer; 2-sand layer; 3-sand and gravel layer; 4-gravel layer; 5-vermiculated laterite weathering crust; 6-granites of late Yanshanian period; 7-faults.

The fault of Xinlin Hill is within the range of maximum value of gravity anomaly in the PRD. The fracture dislocation and fault movement caused by the fault are connected by the deep faults. In general, there were two times of transgressions in PRD since Pleistocene. The important information mentioned above provides the basis for studying the formation of the PRD. In addition, it plays an important role in civil engineering construction, urban planning, and geo-hazard prevention in the further study.

The PRD Sedimentary Environment

The sedimentary facies are a comprehensive reflection of the sediments and their sedimentary environment. The sedimentary environment not only controls the texture, structure and compositions of sediments, but also affects the distribution and combination of fossils of plants. Thus, the study of sedimentary facies is the foundation of recovering the sedimentary environment, and is also an important base for stratigraphic divisions. The sequence of the PRD sedimentary facies is divided into four major environments [11], namely, I delta plain; II delta front; III tidal estuary; IV shallow-sea shelf (in Figure 4).

As shown in Figure 4, the PRD sedimentary environment can be summarized and described as below:

**I delta plain** is the part of land, which is the district between the trend line of dry seasons and modern shore line.
II delta front is usually formed as a result of the interaction of sea and river, including estuary dam, natural levee, front slope, distributary gulf and shallow ford.

III tidal estuary is mainly influenced by the tidal action. The related depositions are tidal channel, tidal dam, tidal shallow ford, lower tidal plat and upper tidal plain.

IV shallow-sea shelf is distributed in the 30 meters depth of estuary, which riches in organisms of shallow sea and mollusks. In addition, the content of organic matter is very high.

Conclusions

In this paper, we present the late Quaternary neo-tectonic movement in the Pearl River Delta (PRD) region of China and its effects on the coastal sedimentary environment. By the example of the Xilin Hill fault, we gave the reason of the PRD formation, inferred its interactions with local/regional climate and sea-level changes, and discussed the evolution of the PRD formation and its controlling factors of the coastal sedimentary environment [7, 11]. Therefore, some conclusions can be summarized as below:

1) According to the analysis of sedimentary facies and carbon dating, the PRD evolution process since Late Pleistocene (about 40 ka B.P.) into can be divided into three stages called as pre-deltaic (40-32.5 ka B.P.), paleo-deltaic (32.5-7.5 ka B.P.) and neo-deltaic (7.5 ka B.P. to present).

2) Quaternary sedimentary layers of the PRD region in the vertical stacking sequence is such a positive sequence that the lower is coarse-grain, while the upper is middle-fine grain.

3) Based on the study of the modern sedimentary environment, the Pearl River runoff and estuarine current interact to promote the formation and development of the delta.

4) Due to the different activities of the fault zones since Quaternary, the intensity of the seven faults is different from each other. The activity of South China Sea fault is the greatest, while Xijiang fault, Beijiang fault and estuary fault are posterior and also weak [7].

5) The neo-tectonic movement plays a significant role during the evolution of the PRD. It not only controlled the changes of river channels, but also influenced the sediments of delta. The two stages of gravel stratum with fluvial facies are represented the location of the ancient valley before the two transgressions. However, the difference of distribution of gravel stratum with fluvial facies could reflect that the changes of river channels between the first transgression and the second one as a result of the fault activities.

6) The Xinlin Hill fault revealed many important and basic issues in the changes of late Quaternary environments, neo-tectonics and fault activities [7].

7) There are several controlling factors for the PRD formation, including sedimentary evolution, the Quaternary ice-age, sea level changes and human activities.

In the near future, more investigations will be conducted for the further study of the late Quaternary neo-tectonic movement in the PRD region of China and assess its effects on the coastal sedimentary environment.

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