Seasonal variation characteristics of tidal sedimentation of the middle tidal flat —
A case study of tidal flat in Dafeng, Jiangsu Province, China

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Annual field observations and sample collection of each spring-neap tidal cycle sediments had been done on middle tidal flat of Dafeng coast, Jiangsu province. Grain-size and pollen analysis had been examined. Variation trends of sedimentary particle size are basically same on different landforms on middle tidal flat, but particle size has obvious seasonal difference. Upper of the middle tidal flat is relative higher, the sedimentary particles are smaller. As there is no vegetation cover in the middle tidal flat, the seasonal variation of sporopollen characteristics has significant differences with high tidal flat in the aspects of pollen species, number of individuals or the ratio of Artemisia/Chenopodiaceae.

Keywords: Middle tidal flat, Tidal sedimentation, Seasonal variation, Muddy tidal flat

Introduction
The rhythmite of the tidal sedimentation is the carrier of the tidal cyclical variation. It is great significant to study the tidal sedimentary rate and sedimentary environment. The existing research reveal well different time-scale tidal cycles, such as flood and ebb cycle1, spring-neap cycle2-4, and even longer tidal cycle5. In these different time-scales of sedimentary cycles, the seasonal variation rules is necessary to identify sedimentary records of events occurred in summer or winter half year. So it arises wide concern. Li et al. analyzed the characteristics and the causes of seasonal tidal variation in Da Mutu, Xiang Mountain, Zhe Jiang Province6. Yang Shilun analyzed seasonal erosion and deposition cycle exiting widely on tidal flat in Yangtze River delta7. Wang Jian made the seasonal discrimination research about deposition of salt artemisia muddy tidal flat near Doulonggang in Dafeng, Jiang Su Province8. Yang et al. revealed seasonal sediment on open tidal flat in the southwest coast of South Korea9. These studies already have made firm foundation to further reveal the seasonal characteristics of tidal sedimentation. To analyze the seasonal sedimentary difference of micro-landscapes on tidal flat, different parts of the middle tidal flat in research area were selected and modern sedimentary observation and analysis about spring-neap tidal cycle in a whole year were carried out in this paper.

This research site locates in the coast of Dafeng, Jiangsu province. It is typical silt-muddy tidal flat on the inner edge of Jiangsu radial sand. It is belonged half open sea coast, influenced by the north of abandoned Yellow River estuary and the south of the Yangtze river estuary, resulting to a great deal of sand. Beach surface is flat and wide, and average slope for 0.05%, average width for 8-10 km, some beach’ width is less than 5 km due to reclamation. The tides belonged to the meso tidal range coast is irregular half day tide and coast rotation flow. The tidal range is average 3.68 m. Annual average wind speed is offshore for 4-5 m/s, sea for 5-7 m/s, and the primary wind directions are NNE and NEE. Waves popularly are north and the frequency that wave height is less than lm is for 85%10. Owing to larger tidal range and high content of sand sediment, sedimentary rate is very high, thus it is an ideal area for researching modern tidal sediment.

Observation site is on the silt-muddy coast in the north of ChuanDongGang lockport 10 km in Dafeng city. Sample collection sites were at A(33°06'50"N, 120° 51'12"E), B(33°07'01", 120° 51'39"E) (Fig. 1). Site A is on sand-muddy tidal flat, and B on silt and fine sand flat. Site A and B are 800 meters apart.
Materials and Methods
Members of the research group observed and sampled at Site A and B from May 5, 2007 to Oct. 14, 2008.

The specific sampling methods are as follows. Setting respectively two pieces homemade sediment-boards (50 cm × 40 cm) in each observation site and making the surface sedimentation boards and beach keep on the same plane (Fig. 2) ensured to collect surface sedimentary and columnar samples every half month. We observed 33 times totally each half month and collected samples as much as possible at two or three days after each spring tide as well lunar the forth (or the fifth) and nineteenth (or twentieth), then put collected samples into bags to seal and numbered the bags according to sampling date and site then took the samples regularly observed to make particle size and pollen analysis in environment evolution and ecology construction laboratory of Nanjing normal university.

We selected sedimentary samples of 24 spring-neap tidal cycles at site A and B from Sept., 2007 to Aug., 2008 to determine particle size. Then analyze each month pollen of sedimentary samples at site A, determined 39 kinds of genus of pollen totally. We analyzed the variation of tidal sediment in one year.

Result and Discussion
Particle size variation of sediment
The analysis to particle size of samples collected from site A and B shows that the sedimentary particle size variation has obvious seasonal difference (Figs 3 and 4). Figure 3 shows the median particle size variation of surficial sediment samples collected every half month. Figure 4 shows the variation of average particle size value of sediment collected two times in the same month.

From Figure 3 and Figure 4, we can know that the trend of particle variation is same, but the sediment is finer at site A than B. This is because site A is near shore, elevation relatively high, the tidal power weak, the capacity of the carrying sand weak, only fine sand could be brought to relatively high place to settle. Sediment particle is coarse at the two sites from August to October and from January to February. In other months sediment particle is fine relatively. Because the research area in late summer and early autumn are affected by typhoons, which cooperates with tide to make waves of tide high (Fig. 5), increasing the capacity of carrying sediment, coarsening sediment particle.

The result of the components of sediment samples also shows that the content of fine sand and very fine
Fig. 3—Median particle size variation of tidal sediment every half month from Sep., 2007 to Aug., 2008

Fig. 4—The variation of average value of median particle size from Sep., 2007 to Aug., 2008

Fig. 5—The variation of wave height from Sep., 2007 to Aug., 2008

Fig. 5—The variation of wave height from Sep., 2007 to Aug., 2008
sand in late summer, early autumn and late winter is higher, the fine silt and mud in late autumn, early winter, late spring and early summer is higher. In terms of sedimentary dynamic, the different carrying way of the sediment could make particle size different. The fine particles of tidal sediment on the flat at the observation sites are formed primarily from suspended sand in the water sinking under the action of tidal current. And the coarse particles may be formed from fine sand and silt under the control of waves or strong tidal current. So particle size was coarse in late summer, early autumn and late winter.

**The sporopollen characteristics of the sediment**

Figures 6 and 7 show sporopollen content and seasonal variation of site A. And the variation of individual percentage content is as follows:

In autumn (Number A11, A13, A15): The average percentage content of woody pollen is 54.3% as the highest of the year. The average percentage content of herb pollen is 25.6% as the lowest of the year. The average percentage content of fern pollen is 25.6% as the lowest of the year. Fern's is 20%. It is pine which has the highest content of pollen among the woody plants and the average content of its pollen is 17.1%. The peak value (17.5%) of pollen content of ulmus occurs in this season, while ulmus flower in spring. Probably, that is because of the transport and re-depositon process related to water.

In winter (No. A17, A19, A21): The average contents of woody plant pollen, herb pollen and fern pollen are individually 54.1%, 27.7%, 18.2%. The content of pine pollen is the highest among all kinds of woody plant pollens, and its average content is 32% and its highest value (41.1%) appears in this season. In winter when plants wither and wilt, the sporopollen content should be lower, but Pinus has the peak value. That is because pine pollen with the balloon can float in the water or the atmosphere for a long time, spread long distances.

In spring (No. A23, A25, A27): The average contents of woody plant pollen, herbaceous pollen and fern pollen are individually 45.4%, 35.4%, 19.2%. The content of pine pollen is the highest among all kinds of woody plant pollens, and its average content is 31.7%. In this season, the percentage of herb pollen is highest of the year, and the peak value of chenopodium appears in this season. At the same time, Pinus has subpeak (40%).

In summer (No. A29, A31, A33): The average contents of woody pollen, herb pollen and fern pollen are 50%, 26%, 24% respectively. The content of pine pollen is the highest among all kinds of woody plant pollens, and its average content is 34.5%. And the average content of fern pollen is the highest of the year.

Figure 7 also shows the other features of sporopollen composition, as following:

1. The total number of sporopollen species is highest in June and October, up to 31. And the minimum occurs in September, only to 16.
2. In the percentage of species, the woody plant is higher from May to August, from October to December, reaching 45-48%; and the minimum occurs in March, only to 34.6%. The content of
herb pollen keeps higher level in April and May, reaching about 40%; the content of Fern is highest in March, up to 26.9% and lowest in May, only to 13.0%.

(3) The ratio of Artemisia/Chenopodiaceae is lowest in autumn with an average of 0.08, the highest value reaching 1.00 occurs in January of winter.

(4) Pine pollen dominance (percentage of pine pollen in woody plant pollen) is higher in spring and summer, reaching 62.6-77.4%, and it is lowest in the autumn, only to 17.1-41.8%.

It is easy to explain that herb pollen has more species and higher content between April and June when they flower. While the woody plant pollen...
percentage is lowest in spring and highest in autumn and winter. We believe that this area is located in the middle tidal flat with no woody plants, so pollen percentage is low in spring. And the peak value of woody plant pollen percentage occurs in autumn and winter, because of re-carrying woody plant pollen. Fir and hemlock is most typical. Fir and hemlock flowering in spring are in high altitude area. Their pollens are re-carried by water current. So the highest level of woody plant pollen percentage in the middle tidal flat occurs in autumn and winter. All of these show the specificity of middle tidal flat. Table 1 summarizes the differences in the characteristics of pollen between this research on middle tidal flat and previous on high tidal flat.

We can see from Table 1, the percentage of sporopollen species and individual number, the total number of species, the percentage of Chenopodipollis in middle tidal flat is very different from that in high tidal flat. Probably, the reason of this phenomenon is that the middle tidal flat with no vegetation has strong tidal power, sediment particles are coarse, pollen and other fine-grained sediment is not easy to save.

Conclusion

Field observations of the spring-neap cycle deposition on Dafeng coast of middle tidal flat for 12 months and the analysis of the grain-size and sporopollen of the samples in lab, we can draw two important conclusions as follows:

1) The grain-size of sediments have the same trend in generally in one year between sand-muddy flat and silt-sand flat on middle tidal flat, while the sediment on sand-muddy flat which is higher is significantly smaller than that on silt-sand flat which is lower. Both the summer typhoon and winter cold wave make the sediment become coarser.

2) Because of no vegetation on middle tidal flat, the seasonal variation of the pollen characteristics is obviously different from high tidal flat, such as the sporopollen species, number of individuals, the ratio of Artemisia/Chenopodiaceae, and some other indicators. On middle tidal flat, the total number of pollen species is higher in late autumn and early winter. The sporopollen individual number of woody plants is minimum in late winter and early spring. The sporopollen individual number of herb plants is higher in winter and spring than in summer and autumn, fers’ is lowest in January. And Artemisia/Chenopodiaceae ratio is lowest in the autumn.

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Reference

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