International Conference on Estuaries and Coasts
November 9-11, 2003, Hangzhou, China

STUDY ON RECENT DYNAMIC EVOLVEMENT OF TIAOZINI SANDBANKS ALONG COASTAL ZONE IN JIANGSU PROVINCE, CHINA

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Abstract: The Radiating Sandbanks of Jiangsu coast are famous for the special cause of formation, complex geology and geomorphology conditions and peculiar hydrodynamic status. The Tiaozini Sandbanks located in the center of Radiating Sandbanks is chosen as the study area in this paper. We use Remote Sensing images of the study area from 1973 to 2000 to analyze its dynamic evolvement. The study results are: (1) Bare area of Tiaozini Sandbanks in low tide becomes larger in recent years. Through developing sandbar and joining up little sandbanks with the main sandbank, the Tiaozini Sandbanks expand to three directions to north, east and south. (2) Different tidal flat takes on different stability: Erfenshui tidal ridge is the most stable and the central tidal flat besides Xidagang Tidal Creek is changeful. (3) Sandbank tidal creek systems have complex shift characters. First, the main tidal creek systems have different shift range and velocity. Second, the different parts of a single tidal creek system also have different shift range and velocity. Third, the near shore tidal creek systems have periodicity and the tidal creek systems located in the east area of Xidagang Creek are stable relatively. Last, tidal creek shift has two forms: sudden and gradual changes, excited by sudden events and normal change of hydrodynamics respectively.

Key words: Tiaozini Sandbanks, Tidal Creek System, Dynamic Evolvement

1. INTRODUCTION

There are a series of underwater radiating sand ridges along the center coast of Jiangsu. The troughs alternate with ridges and distribute about 200km from south to north and 140km from east to west where the water deep is between 0m and 25m. The Radiating Sandbanks have complicated and special hydrodynamics, geology and geomorphology conditions. We still used the simply chart surveyed by west countries at the beginning of this century even in the 50s'. Institute of Oceanology Chinese Academy of Sciences researched this area roughly in the 60s'. Until the coastal zone and tidal flat resource integrated investigation from 1980 to 1984, we achieved a lot of the first materials about the hydrology, landform, sediment, mud transportation and so on. We distinctly found the special panorama of the Radiating Sandbanks in the south Yellow Sea from this investigation (Ren, 1986). On this basis, scholars of different academia discuss the hydrology status, geomorphology characters, formation mechanism, development process, and sediment source and so on (Chen, 1991; Geng, 1988, 1983; Huang, 1998, 2002; Li, 1981; Ren, 1983; Wan, 1985; You, 1998; Zhang, 1984, 1986, 1991). From their views, we find that the dynamic evolvement of the Radiating Sandbanks is the research focus all along. This paper synthetically applies Remote Sensing analysis and geomorphology investigation to studying the dynamic development rules of the Tiaozini Sandbank.

2. STUDY AREA

Tiaozini Sandbanks along the Jiangsu coast locate in the center of the Radiating Sandbanks. It separates the mainland tidal flat by one tidal creek 200-300m breadth (Fig. 1). The whole sandbank is 40km from north to south and 40km from west to east. The tide of this sea area is very complex. Divided by Erfenshui tidal ridge in the center of the Tiaozini Sandbank, the north area is controlled by eddy tidal system of South Yellow Sea and the south is controlled by progress tidal system of the East China Sea. The tidal current of the two tidal systems encounters at this tidal ridge.

There are four tidal creek systems that are linked from south to north and parallel in east and west. They are Shishenggang1-Xiaodengzhuanggang Tidal Creek, Shishenggang3-Henggang Tidal Creek, Xidagang Tidal Creek and Gaonigang Tidal Creek respectively.

Because Tiaozini Sandbanks locate in the inner area of the Radiating Sandbanks and is protected by the outer sandbanks, the wave of Tiaozini Sandbanks sea area is very weak. But, the tidal creek system will shift in a large range from July to September every year because the typhoon often happens in autumn and the wind power is very violence. It will scour tidal flat hardly and make some tidal flats instability.

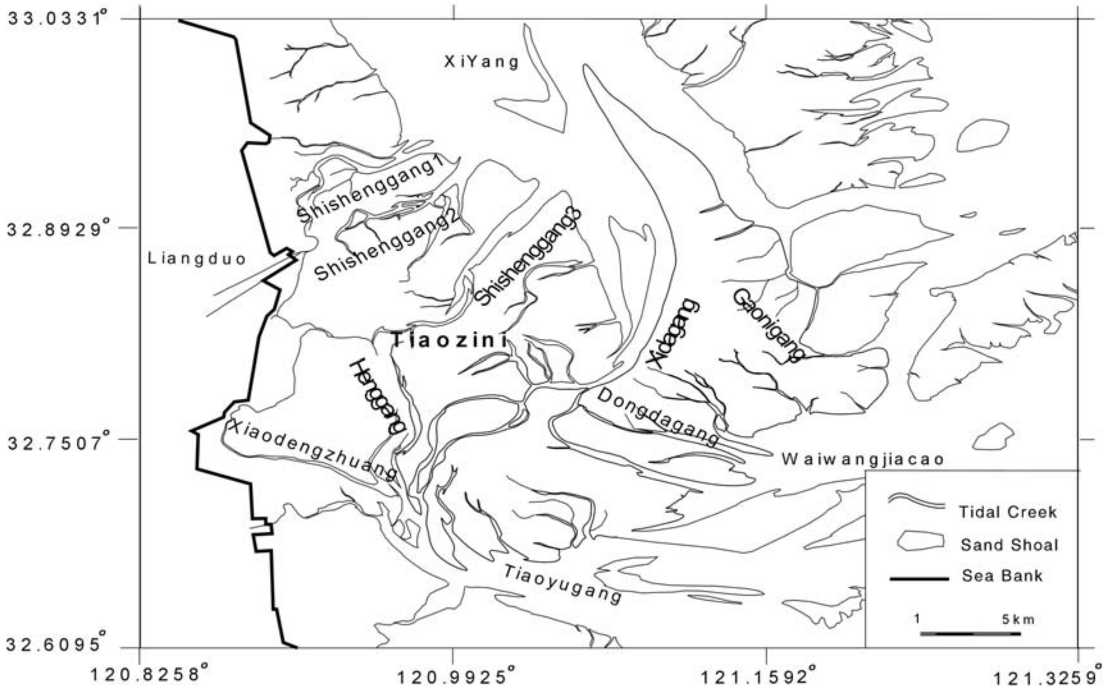

Fig. 1 Topography sketch map of the Tiaozini Sandbanks of Jiangsu coast

3. STUDY METHODS

We aimed at Tiaozini Sandbanks of Jiangsu coast. We chose fourteen remote sensing images of MSS and TM from 1973 to 2000 and the chart of 1963 and 1979 of the Radiating Sandbanks area. We detailed the configuration of Tiaozini Sandbanks and the positions of the main tidal creek systems in different periods. We used MapInfo of GIS digitizing images and charts.

We must resolved two key problems when using images in different time and from different origins in the course of studying the development progress of Tiaozini Sandbanks. The first is the matching of these images accurately. We matched images and checked precision through using 42 field position datum. This field spots were usually the crossing points of the roads, the crossing points of the roads and the ditches, the corners of the manmade ditches, the crossing points of the roads and the banks, river gates and so on. When choosing these spots, we made a certain distance among them in order to improve precision.

The whole land area is 22km from west to east and 60km from south to north. The second is the tidal height revision of the images in different time. We chose the 1979 chart as standard number and drew a lot graphs of the inserted values of the water level. We compared the Tiaozini Sandbanks in different periods with them showed in 1979 chart. So, we achieved the area change and movement trend of the sandbank.

4. STUDY RESULTS

4.1 AREA CHANGE OF THE TIAOZINI SANDBANK

The development history of Tiaozini Sandbank was short. It still was shallow area in 1904 chart made by English and it changed little in 1947 chart made by Japanese. But there were some small sandbanks in the Sand Ridges Distribution Map made in 50s' and Lvsi Fisheries Map made in 1957 by China. These small sandbanks integrated with each other in the 60s' and formed Tiaozini Sandbanks, which was the second large sandbank of the Radiating Sandbanks. Recently, Tiaozini Sandbanks becomes larger and larger (Table 1) and had became the largest one from 1988.

Table 1 Appearance area of Tiaozini Sandbanks (According to remote sensing images, km^2)

Time	Tidal Height (cm)	Paohuiji Sandbank	Xiaotiaozini Sandbank	Gaoni Sandbank	Total Area (km^2)
1973	140	273.54	151.90	34.13	459.57
1978	—	302.82	89.22	97.07	489.11
1979	114	234.96	181.28	76.81	493.05
1980	113	265.36	166.15	66.87	498.38
1984	153	210.81	165.52	48.83	425.16
1985	127	296	92	122	510
1988	137	195.37	160.25	147.99	503.61
1995	—	195.70	266.06	27.96	489.72
1997	137	236.27	306.4	31.49	574.16
1998	—	390.89	193.10	28.67	612.66
1999	152	395.44	194.07	25.90	615.41
2000	162	429.57	188.57	22.85	640.99

Contrasting the images in different images with the 1979 chart (Table 2), we found that the area of Tiaozini Sandbanks raised at the annual rate of 10 km^2 from 1980. The area was 16.4 km^2 in 1973 which was smaller than that in 1979. The area was 41 km^2 in 1973, which was larger than that in 1979. The area was 100 km^2 in 1997, which was larger than that in 1988 at the tidal height of 137cm. The area was 190 km^2 in 1999, which was larger than that in 1984 at the tidal height of 152 cm or 153 cm. So we knew the raise scope was very large. But, there was an exception in this rising course. The sandbank area was 12.5 km^2 in 1984, which was smaller than that in 1979. The reason was that the remote sensing image in 1984 was made in August 4 when was storm activity period. In this season, the storm tide would scour tidal flat.

Table 2 Appearance area comparison of Tiaozini Sandbanks

year	The 1970's	The 1980's			The 1990's		
	1973	1980	1984	1988	1997	1999	2000
Tidal Height (cm)	140	113	153	137	137	152	162
Area of images (km^2)	541.1	612.2	536.1	617.2	713.6	731	754.2
Area of 1979 chart (km^2)	557.5	571.1	548.6	558.8	558.8	548.9	542.3
Area subtraction (km^2)	-16.4	41.1	-12.5	58.4	154.8	182.1	211.9

4.2 CHANGE TREND OF TIAOZINI SANDBANKS

Through contrasting images, we found that three parts' area of Tiaozini Sandbanks became larger and larger. First, Neiwangjiacao Tidal Creek shift to the south and sand spit (we called it Nanjianzi) that located from south to north developed at the mouth of Neiwangjiacao Tidal Creek. Bird-foot branches of the sand spit had formed in 2000 image. So we knew Tiaozini Sandbanks was extending to the south. Second, Gaoni Sandbank located in the east of Tiaozini Sandbanks was extending to the East and would locate between Dongsha Sandbank and Zhugensha Sandbank. It was mainly because the small sandbanks scattering the east area of Tiaozini Sandbanks were moving to the main sandbank. The Jiangjiawu Sandbanks that located in the north of Gaoni Sandbanks was close to it year after year and only a narrow tidal creek separated them in images. Third, the north area of Tiaozini Sandbanks extended to the XiYang Tidal Channel. We found that the change form of the area was the advance and retreat of the Beijianzi sand spit.

The sediment of the sandbanks came from three origins. First origin came from the coastal tidal flat at the north and south of the Tiaozini Sandbank. Second origin came from the digging of tidal channels, such as Xiyang Tidal Channel, Huangshayang Tidal Channel, Xiaomiaohong Tidal Channel etc. Third origin came from the scatter small sandbanks that would connect with the main sandbank in the future.

4.3 SHIFT CHARACTERS OF THE TIDAL CREEK SYSTEM IN THE TIAOZINI SANDBANKS

Tidal creek system of the sandbanks was the most active factor and was very easy to change. From above analysis, we got their shift characters.

(1) The tidal creek often had different shift range and speed. Xidagang Tidal Creek that was the most active one of all the sandbank tidal creeks had the largest shift range (maximum is 9.55km/a) and speed. Sishenggang Tidal Creek, Neiwangjiachao Tidal Creek and Xiaodengzhuanggang Tidal Creek were in the middle. Their shift range was often little than 4km/a. Dongdagang Tidal Creek and Gaonigang Tidal Creek were the smallest one whose shift range were often little than 1.5km/a. When the tidal creek systems were in unsteady adjustive period, their shift speed and range would attain maximum. Whereas they often moved little, when they were in steady period.

(2) A certain part of one tidal creek also had different shift range. The shift range of the gate part of the Sishenggang Tidal Creek, Neiwangjiacao Tidal Creek and Xiaodengzhuanggang Tidal Creek was very large. But the center part and the end part were very small. The shift range of the whole part of Xidagang Tidal Creek was very large. It was because the bank geomorphology development of the tidal creek system would control the shift status of the tidal creek. If there were jetties or river gates beside the tidal creek, their shift range would be very small. Otherwise, their shift range would be large relatively.

(3) The coastal tidal creek systems in the west of the Xidagang Tidal Creek had a certain periodicity. But the sandbank tidal creek systems in the east were stabile relatively. The period from development to disappear of Sishenggang Tidal Creek was about 16 years. The Sishengang Tidal Creek adjusted in 1984 and had three stream roads. It also adjusted in 2000 and had two stream roads. The tidal creek distribution in this two years was very similar. The period from development to disappear of the Neiwangjiachao Tidal Creek was about 15 years. The period of Xiaodengzhuanggang Tidal Creek was about 15 years too. Otherwise, the shift of the Dongdagang Tidal Creek and Gaonigang Tidal Creek had not periodicity. They continually withdrew from developing in some way.

(4) The shift types of the tidal creek were break change and gradual change respectively. Break change correlated to some special happened events such as super storm tide that would cause the readjust of the tidal creek systems. From comparing the image in 1996 with the

image in 1997, we found that the plane distribution of the Xidagang Tidal Creek in this two years was opposite (Fig. 2). This phenomenon was not fit to the normal evolvement and maybe affected by the typhoon (Number 11) in 1997. Gradual change correlated to the normal change of the sediment and water. The shift types behaved extending, shifting to one side etc.

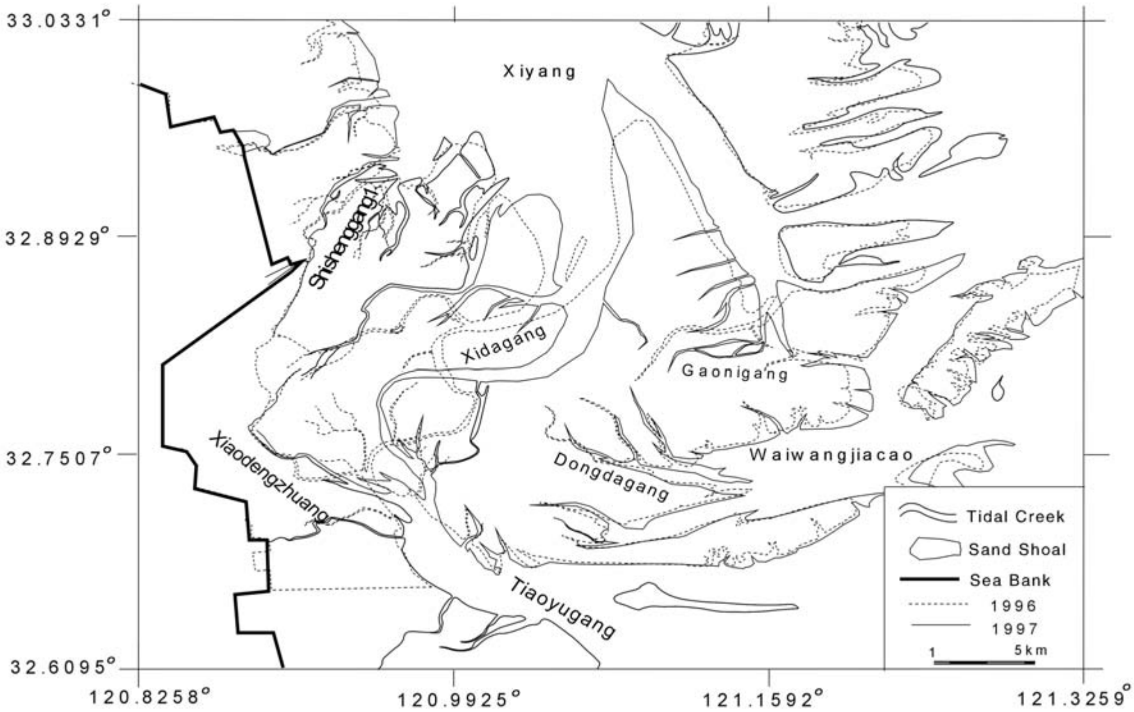

Fig. 2 Compare the changes of the Xidagang tidal creek in 1996 with that in 1997

4.4 STABILITY DISTRICT OF THE TIAOZINI SANDBANK

Every part of the Tiaozini Sandbanks had different stability. We could estimate the stability through stability coefficient R (Zhang, 1992).

$$R = 1 - P = 1 - K\sum \frac{(L_1 + L_2)\times l}{(S_1 + S_2)(t_2 - t_1)}$$

L_2 and L_1 (km) is the tidal creek length at the time t_2 and t_1. S_2 and S_1 (km^2) is the sandbank area at the time t_2 and t_1. l (km) is the shift distance from t_2 to t_1. Σ is the number sum of the tidal creeks in the sandbanks. K is the correct coefficient that is between 1.05 and 1.20. t=t_2－t_1(year). t_2 and t_1 is the time of two images. R is the stability coefficient of a certain sandbank between t_2 and t_1. R expresses the ratio of the residual area where tidal creeks didn't shift to the whole area of one sandbank tidal flat in a certain time. If R is large, sandbank tidal flat is stable. If R is small, sandbank tidal flat is unstable. P is unstability coefficient and expresses the ratio of the residual area where tidal creeks shifted to the whole area of one sandbank tidal flat in a certain time. The reciprocal of P expresses the time that the tidal creek shifts the whole sandbank tidal flat.

We district the Tiaozini Sandbanks to 7 areas and calculate their stability coefficients. We class the Tiaozini Sandbanks as different stability area through analyzing the images from 1996 to 2000 (Fig. 3).

The most stable tidal flat of the sandbanks is the Erfenshui sand ridge between the end region of Sishenggang Tidal Creek and the end region of the Xiaodengzhuanggang Tidal Creek (district II). Its annual average stability coefficient ($\overline{R}$) is 0.941. $\overline{P}$ is 0.059 and $\frac{1}{\overline{P}}$ is 16.907. This means the tidal creek need about 16 or 17 years to shift district II tidal flat.

The more stable tidal flat of the sandbank is the north and central region of the Sishenggang Tidal Creek (district I) and the both sides of the Gaonigang Tidal Creek (district VII). Its annual average stability coefficient ($\overline{R}$) is between 0.88 to 0.91. $\overline{P}$ is between 0.11 to 0.08 and $\frac{1}{\overline{P}}$ is between 8.60 to 11.60. This means the tidal creek need about 8 or 12 years to shift district VII and district I tidal flat.

The unstable tidal flat of the sandbank is the south and central region of the Xiaodengzhuanggang Tidal Creek (district III). Its annual average stability coefficient ($\overline{R}$) is 0.805. $\overline{P}$ is 0.195 and $\frac{1}{\overline{P}}$ is 5.131. This means the tidal creek need about 5 or 6 years to shift district III tidal flat.

To some extent, the more active tidal flat is the center part of the Tiaozini Sandbanks, which belongs to the tidal flat of the Xidagang Tidal Creek where the tidal creeks often change. Through analyzing the images from 1996 to 2000, we find that this area adjust forcefully and the tidal creeks often shift because of the effect of the super storm tide. So, the tidal flat is unstable.

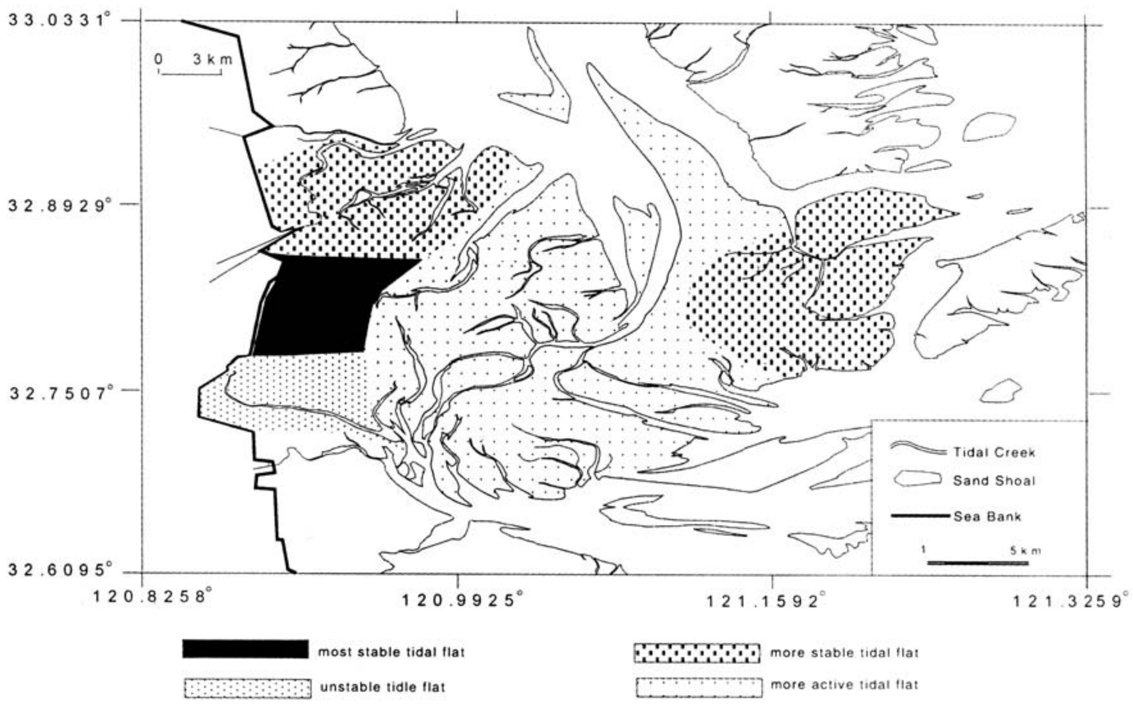

Fig. 3 Tidal flat stability of the Tiaozini Sandbank from 1996 to 2000

5. RESULTS

We can achieve these results from above analysis.

First, the emerged area of the Tiaozini Sandbank in low tide becomes more and more recent years. It enlarged from 459.57km^2 in 1973 to 640.99km^2 in 2000.

Second, the sandbank enlarged to three directions, which are north, east and north. The development form is sand bar, scatter little sandbank and so on.

Third, the tidal creek systems have complex shift characters.

Last, the different area of the sandbank has different stability. The Erfenshui tidal ridge is the most district and the center tidal flat of the both side of the Xidagang Tidal Creek is unstable.

ACKNOWLEDGEMENTS

The Science and Technical Innovation Foundation of Hohai University (Grant No. 2003410543) supported this study.

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