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Human Impact on Coastal Landform and Sedimentation – The Yellow River Example[1])

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ABSTRACT: Man is an important geological agent. This paper documents a unique case of the dominating role of man in coastal evolution and hydrological changes in North Jiangsu province. Owing to human breaching of dikes on the Lower Yellow River in 1128, a large anthropogenic delta – the Abandoned Yellow River Delta was formed. Its rapid growth and quick decay over a period of 400 years further illustrates the overwhelming influence of human activity in triggering coastal changes. Man's diversion of the Yellow River to Jiangsu has also resulted in a dramatic change of the drainage pattern and hydrology of North Jiangsu. The Huai-He, a major river in central China, was changed from an independent river draining into the sea in the 11th century, to a tributary of the Yangtze river since the 17th century. At the same time, Hongze lake was enlarged from a small lake to one of the largest fresh water lakes in the country.

It is well known that man is a geological agent and that man's activity has a profound impact on coastal landforms and sedimentation (Walker 1984; Ren 1989). This paper will document an interesting case of major impact on a coastal landform and on a sedimentation process that resulted from human direct intervention.

The Yellow River is noted for its extremely heavy annual sediment load (1.6 billion tons at Sanmexia) and for the frequent changes of its lower course over the last 5,000 years. Some of the major changes of the river's lower course are due to man's activity. The most remarkable is the breaching of dikes at Ligudu, Henan province in 1128 when the river was diverted southward through Jiangsu province to the Yellow Sea. The breaching was an entirely man-made attempt to block the northern nomadic cavalry from invading southern China. As a result, for 726 years (1128–1854), the Yellow River, instead of flowing northward into the Bohai Sea, has flowed southward to the Yellow Sea, and flooded an extensive area of North Anhui and Jiangsu province (Tan 1982) (Fig 1). This human diversion has had far-reaching effect on the coastal morphology of Jiangsu province and on the hydrology of North Anhui and Jiangsu provinces. The first and most important effect is the formation of a major anthropogenic delta – the Abandoned Yellow River Delta. Located on the coast of North Jiangsu, the abandoned delta has an area of 7,160 km^2 (Fig 2). Its growth and abandonment is closely related to the history of the Lower Yellow River. Since the breaching of the dike in 1128 for military reasons, the river flowed southward to North Jiangsu and North Anhui. But between 1128–1546 AD, for over 400 years, the river's course was not definite. It bifurcated in a number of distributaries and wandered over the wide plain between SW Shandong and SW Henan, from the Si He in the E to the Ying He in the W, over a distance of 250 km; the greater part of the sediment carried by the river was deposited on the plain. However a part of the discharge of the Yellow River still escaped to the Bohai Sea. For example, Tan (1955) documented that in 1194, the lower Yellow River bifurcated into two distributaries: one running northeastward to the Bohai Sea and the other flowing southward through the Si He to the Huai He. The former carried about 20–30 % of the total flow of the Yellow River. Therefore in the early years after the river's diversion, the growth of the delta was extremely slow. It was only since 1578, when the northeastward flow was cut off by dike building and when solid dikes were built along the river between Xuzhou and Huaiyin confining the flow in a fixed course to the Yellow Sea,

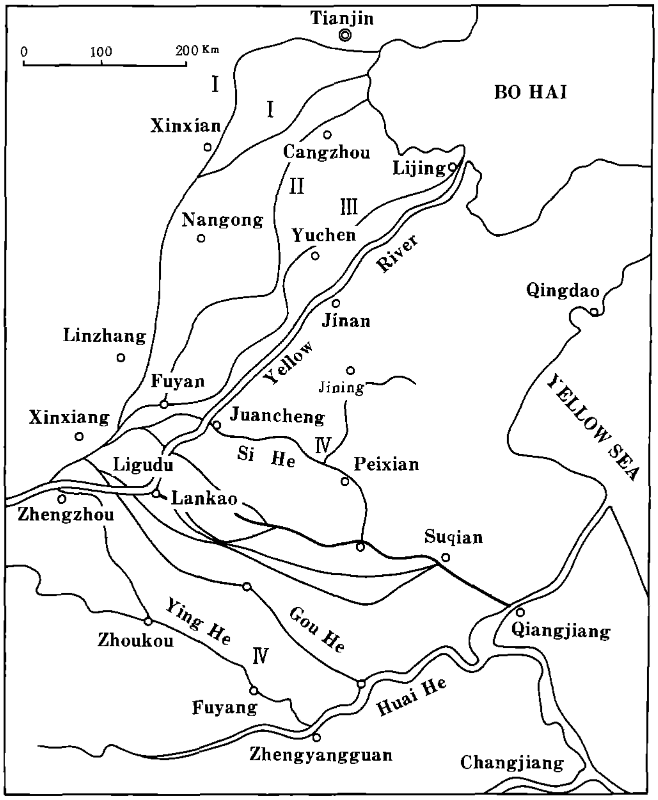

Fig 1 Changes of the course of the Yellow River during the last 5,000 years
I. 3400 – 602 BC
II. 602 BC – 11 AD
III. 11 AD – 1048
IV. 1128 – 1854
(modified after Tan 1982)

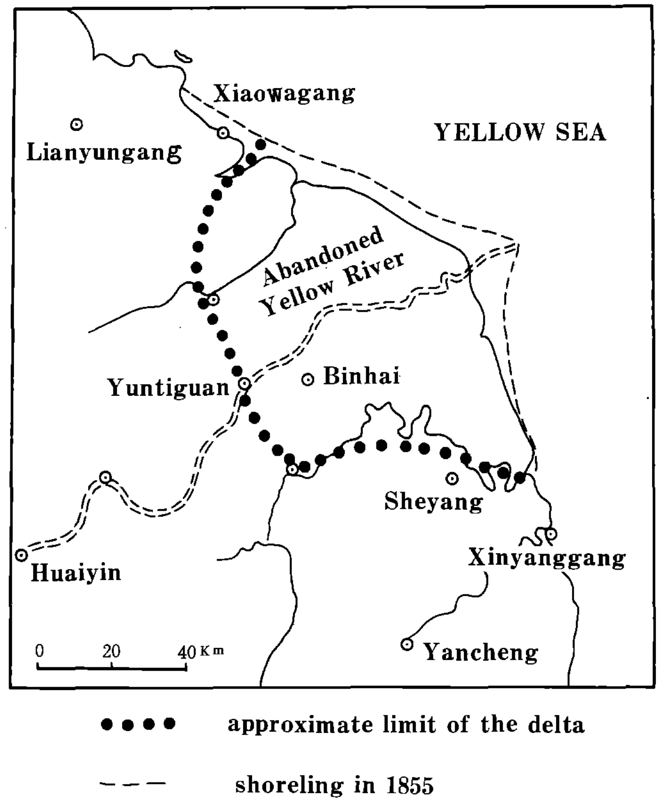

Fig 2 Abandoned Yellow River Delta

that rapid delta building began. Between 1128 and 1855, the river mouth extended into the sea 88 km, of which 73 km represents the last 280 years between 1578 and 1855. The prolongation was very rapid immediately after dike construction, being 1540 m/yr between 1578 and 1591 but gradually slowing down, averaging 200 m/yr between 1591–1855 (Fig 3) (Tab 1).

With prolongation of the river mouth, a wide deltaic plain was formed. The rate of land building was very slow at first; only 1670 km^2 of land was formed between 1128 and 1494, averaging 3.2 km^2/yr. But the rate rapidly rose to 15.5 km^2/yr between 1494 and 1855 during which time 5490 km^2 of new land was added. This is the Abandoned Yellow River Delta. With its apex at Yuntianquan, it extends like a fan to the sea from Lianyungang on the N to Sheyanghe on the S (Fig 2).

Tab 1 Evolution of the abandoned Yellow River mouth

Date	Prolongation (km)	Rate of prolongation (m/yr)
1128–1578	15	33
1578–1591	20	1540
1591–1855	53	200

(After Go, S. C. 1984)

It may be pointed out that this delta was essentially formed by man's action, being initiated by the breaching of dike in 1128 and later accelerated by dike building and confinement of the flow since 1578.

After the Yellow River entered the Bohai Sea again in 1855, the coastal zone near the abandoned delta became sediment starved and the coast immediately changed from a prograding one to a receding one. About 160 km of the coast suffered form recession. In the early years after the abandonment, coastal recession was very rapid. Near the abandoned Yellow River mouth, the rate of recession was about 1 km/yr which is probably the largest rate of coastal erosion documented in the world but it quickly decreased. Comparison of 1923 and 1969 maps shows that the coast at the river mouth receded 80 m/yr and that recently (1982–1983), the rate of recession was about 15 m/yr. The coast north and south of the river

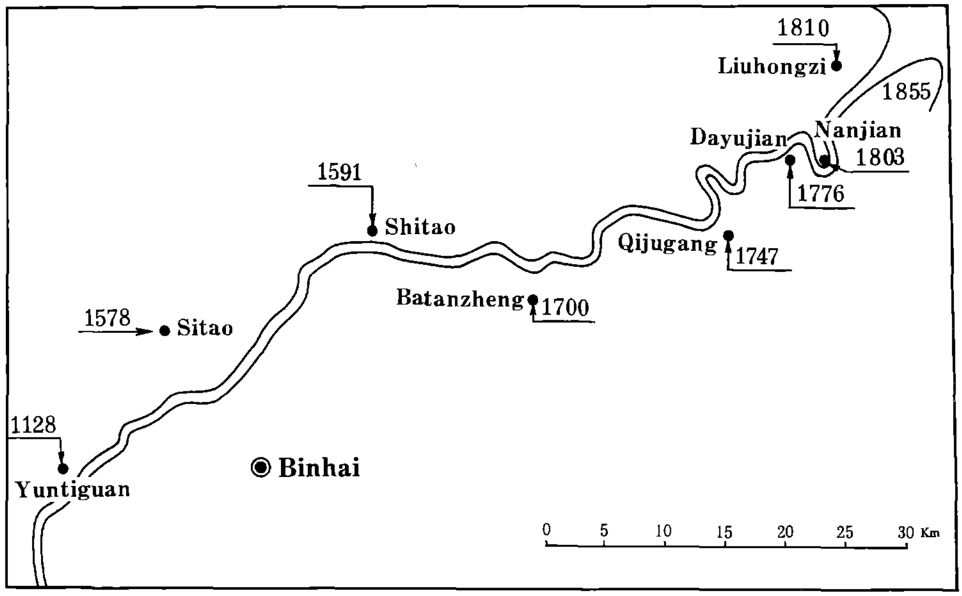

Fig 3
Prolongation of the abandoned Yellow River mouth, 1128–1855

mouth also retreated at a rate of 20–30 m/yr in the last 20 years. The current rate of recession is about 10–15 m/yr on those coasts that do not have strong sea dikes. Thus, the former coastal land in 1855 is now at a water depth of 3–4 m. For example, Kaishan Island, a part of the mainland in 1855, has now become an island in the sea, 7.6 km from the mainland coast. It is estimated that the coastal recession between Shaoxanghe Kou in the N and Dalaba Kou in the S has resulted in the loss of about 1400 km^2 of land since 1855 (Zhang 1984, 1988).

Together with the recession of the coast, a dramatic readjustment of the shore profile has also been taking place. The most profound change is a steeping and lowering of the upper part of shore profile by erosion and a coarsening of the sediment of the tidal flat by winnowing. Here, wave action has replaced tidal currents as the most important agent in shaping the profile. The resulting profile of receding tidal flat is characterized by its steep gradient (about 4‰, in contrast to 0.15–0.2‰ for a prograding tidal flat). Its sediments (coarse silt and very fine sand), coarsen from the sea to the land in contrast to a prograding mud flat where sediments (chiefly fine silt) become progressively finer landward. Thus, the typical profile of receding mud flat is concave upward, similar to that of sandy beach, whereas a prograding mud flat usually has a convex upward profile. The former indicates the dominant role of waves while the latter reflects that tidal current is the chief agent in shaping the profile (Fig 4). With recession of the coast, miniature cheniers are formed here and there, about 10–60 m wide and 0.2–1.6 m high (Ren 1985).

Near Xiaowagang, a survey was conducted every week between the end of 1980 and 1981. The result shows that the surface of mud flat was lowered 16 cm a year. In some parts of the receding coast, cheniers were destroyed by local farmers and, as a consequence, erosion and recession were accelerated. For example, near Dalaba Kou, cheniers were totally taken away in the spring of 1986. By November, 1986, the surface of the tidal flat was lowered 20 cm and an erosion bluff was formed on the seaward side of the chenier which retreated 50 m during the same period.

The shift of the Lower Yellow River southward to the Yellow Sea has also had a profound influence on the evolution of the coastal plain of Jiangsu province. Near the abandoned delta, the direction of coastal current is toward the S (from oceanographic data and drifting bottle tests) so that the coast S of the delta is profoundly affected. On the Jiangsu coastal plain, there are six chenier ridges, of which on the outer (seaward) side four ridges have ^{14}C dates of 5600–7000 BP, 4600 BP, 3310–3880 BP and 850 BP, respectively. They run

Tab 2 Clay mineral assemblages in river bed sediments of major rivers in China

	Yellow River	Abandoned Yellow River	Yangtze
M	23 %	24 %	6 %
I	59 %	58 %	68 %
C	9 %	8 %	11 %
K	8 %	9 %	14 %

(After Zhu, F. G. 1988)

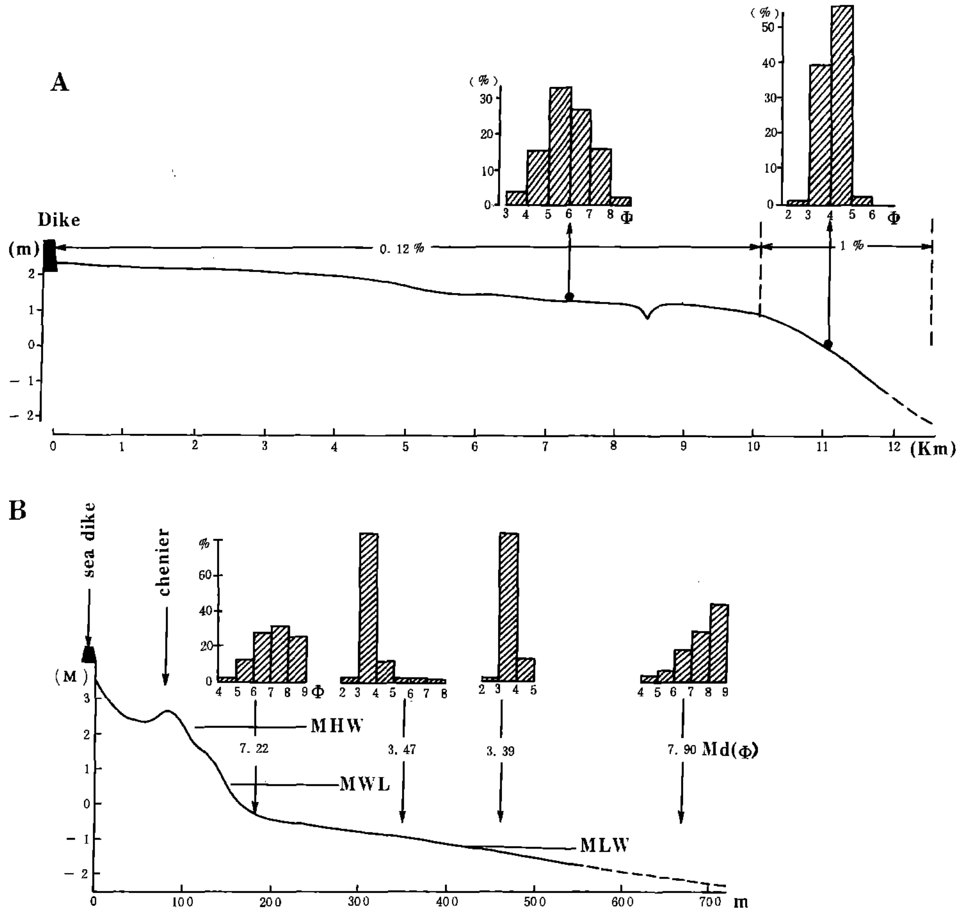

Fig 4
Profile of tidal mud flat in Jiangsu province
A) Prograding flat (Xinyangang)
B) Receding flat (Xiaowagang)

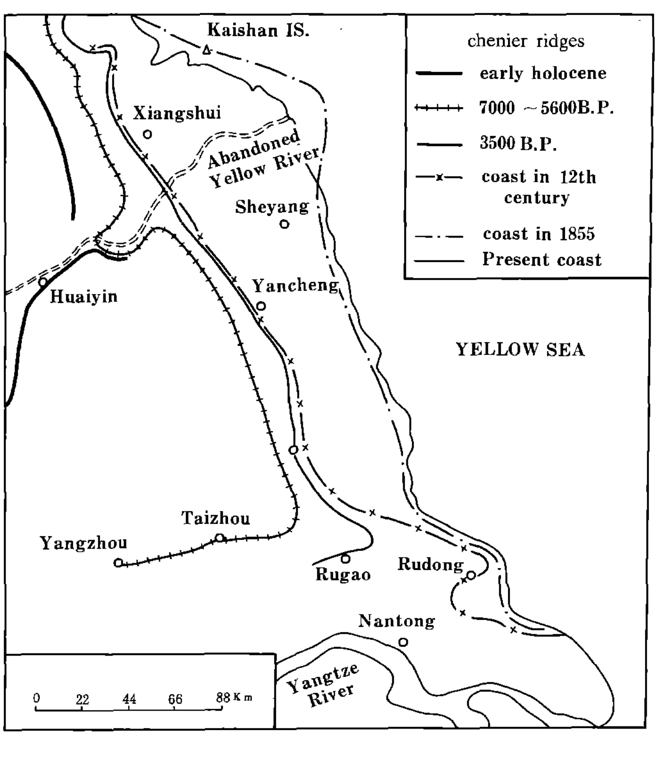

Fig 5 Chenier ridges and coastal evolution of North Jiangsu (modified after Guo 1984)

parallel to each other, separated only by a very short distance. The outermost chenier approximately marks the coastline in the 11th century when Fan's Sea Wall (similar to the Roman Sea Wall in NE England) was built (1023–1027 AD). From the map (Fig 5), it can be seen that before the shift of the lower Yellow River in 1128, the Jiangsu coast was quite stable; in about 5,000 years, the coastal plain had prograded only 5–20 km. In 1100 A D, Funing and Yancheng were located at the seaside and Lianyungang was an island. The present coastal plain E of Yangcheng, about 50 km wide, was built after 1128 by the deposition of Yellow River sediment[2] (Guo 1984). The clay mineral assemblage spectra of the coastal plain and tidal flat sediments show distinct montmorillonite and calcite peaks which bear clear witness to its loess origin (Ren 1986; Yang 1988; Zhu 1988). The boundary between the coastal plain, built chiefly of Yellow River sediment, and that formed mainly by Yangtze River sediment is near Qianggang about 32° 30'N. A recent study of clay minerals in surficial soils along the coast

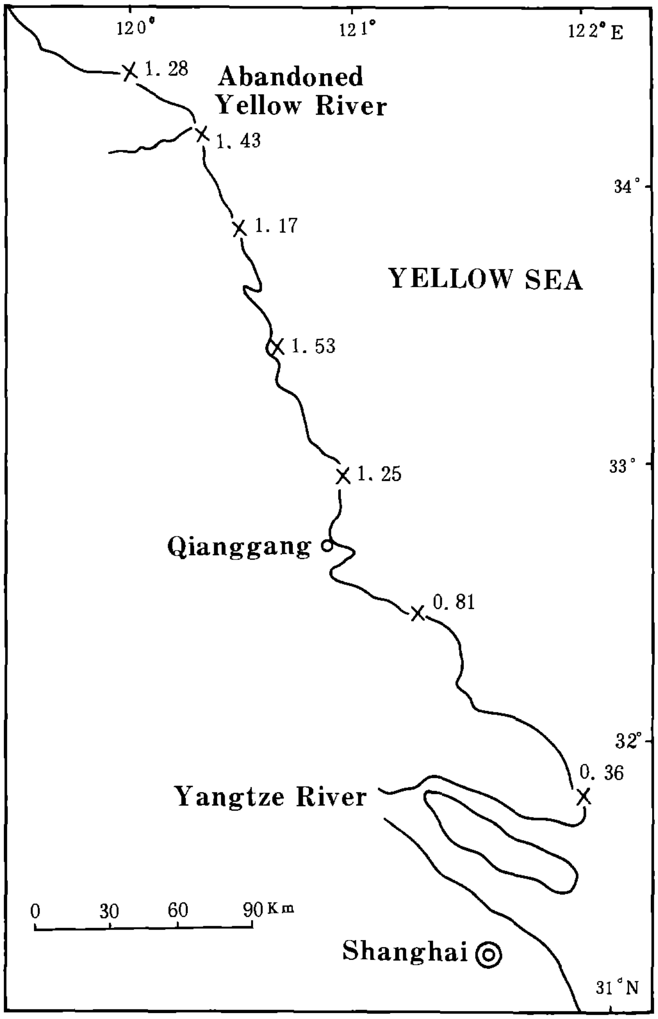

Fig 6 m/c+k ratio in sediments of the coast of Jiangsu province (data from Chen 1983)

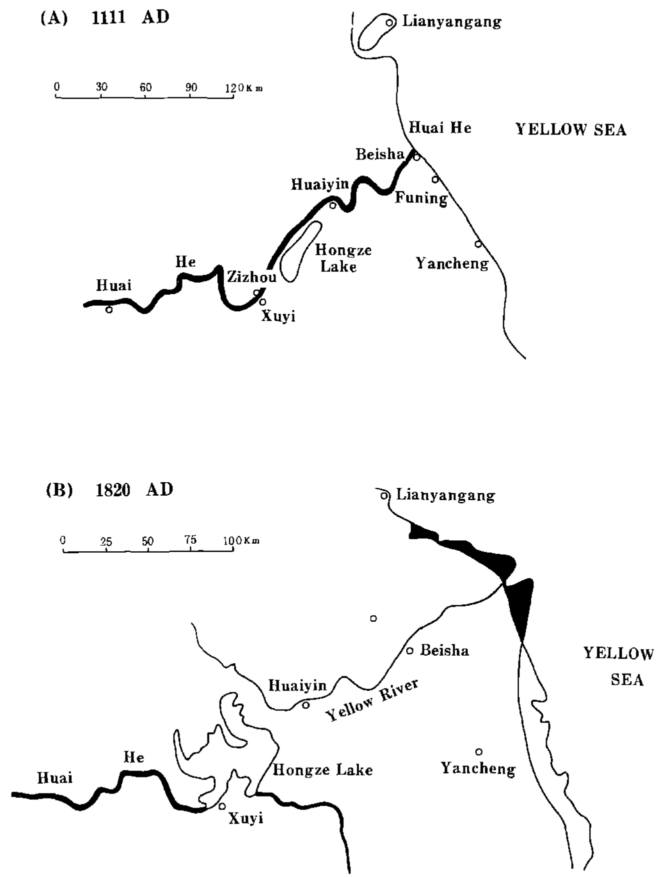

Fig 7 The Huai He and Hongze Lake in
A) 1111 AD
B) 1820 AD
(modified after the Historical Atlas of China, Cartographic Publishing House, Beijing 1982–1988)

shows that the ratio montmorillonite/chlorite + kaolinite is > 1 N of Qianggang and < 1 S of Qianggang. In the former, montmorillonite predominates over chlorite and kaolinite whereas in the latter, the reverse is the case (Fig 6) (Chen 1983) (Tab 2).

Since the abandonment of the Yellow River in 1855, erosion of the subaerial and subaqueous delta supplies copious amounts of material to the coast S of the delta where progradation continues to the present. Regular surveys show that S of Xinyanggang, the coast prograded 136.6 m/yr between 1954 and 1986. But as the time went on, erosion of the delta gradually decreased. The construction of coastal protection works, including stonedikes, groins and offshore dikes, since the late 1970s further reduced the sediment supply from Abandoned Yellow River Delta. Thus, on the coast S of the delta, a drastic reduction of sediment supply occurred in recent years. At the same time, submarine sand ridges which shelter the coast have suffered erosion in its N part. For these reasons, the receding coast gradually encroaches southward at the expense of the prograding coast. From 1980 to 1986, the boundary between receding and prograding coasts moved southward about 20 km from Dalaba Kou to N of Xinyanggang. North of Xinyanggang the lower intertidal flat has suffered from erosion and has been lowered 1.8–11 cm in this period (Shen 1988).

The shift of the course of the lower Yellow River has also had an important effect on the morphology and hydrology of the North Anhui and North Jiangsu plains. The most remarkable variation is a change in the lower course of the Huai He, a major river in central China, and in the size of Hongze Lake (area 2,200 km^2), one of the largest fresh water lakes in China. Before 1128, the Huai He entered the sea at Beisha, N of Funing. As the sediment load of the Huai He was very small[3]), there was not much sediment supplied to the coastal zone where little progradation had occurred for a long time. On the lower Huai He, a tidal effect was felt up to Xuyi, on the S bank of the present-day Hongze Lake. This indicates that the lower Huai He was wide and deep at that time. Before the 11th century, Hongze was a village on the Huai He where the highway passed. In the early 12th century (1111), Hongze Lake was still quite small, its size only about ¼ that of the present lake (Fig 7). A dramatic change in hydrology occurred in 1546 when the Yellow River totally flowed S to the Huai He. Its huge sediment load quickly choked up the lower course of the Huai He which caused the flooding of a wide area near Hongze Lake; the lake was gradually enlarged to approximately its present size. (Fig 7)

In the late 17th century (1680) the prosperous Zizhou city SW of the lake was drowned; its ruins have been found in the present lake. This event is well documented in Chinese records and has been staged as a well-known act in the Beijing opera which attributes the drowning of the city to a lake monster. Since the outlet of the Huai He to the sea was blocked by the Yellow River, it turned southward to join the Yangtze near Yangzhou and henceforth became a tributary of the Yangtze instead of an independent major river draining to the sea (Hu 1947; Zhou 1987) (Fig 7)[4]).

From the above, it can be seen that the shift of the lower Yellow River in 1128 is a geologic and geomorphologic event of major importance. This paper illustrates the important role man has played in changing the coastal morphology and hydrology of North Jiangsu and the rapid growth and quick decay of a large delta has been triggered by human activity.

Notes

1) The project was funded by National Science Foundation of China

2) Area of the coastal plain about 7,200 km^2, estimated sediment volume 720×10^8 m^3.

3) The Huai He river, drainage basin area is 185,700 km^2, its annual flow 351×10^8 m^3, its flood peak discharge is 20,000 m^3/s (nearly the size of the Yellow River) (Bengbu station), but its sediment load is 10.6×10^6 tons and sediment concentration is 0.376 kg/m^3 (average 1960–1979), about two orders of magnitude less than those of the Yellow River.

4) The ratio of total flow of the Huai He entering the Yangtze and the sea is 73.3 % and 26.7 % respectively (average 1951–1980).

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